The International GNSS Service (IGS): Product and Services

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FIG Working Week
18-22 May 2011
Marrakech, Morocco

"The International GNSS Service provides the highest-quality GNSS data, products, and services in support of the Earth sciences and research, PNT, the terrestrial reference frame, Earth rotation, and other applications that benefit society."

IGS is a key component of the Global Geodetic Observing System - GGOS

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WHY IGS?
Some Historical Notes

- Geodynamics, geodetic, and space agency organisations realised the potential of GPS by the late 1980’s.
- Motivating goal: *millimetre* positioning in support of science & engineering anywhere in the world.
- No single agency can, or should, assume the capital investment & recurring operations costs for the entire *global geodetic infrastructure*.
- Join with key international *partners* to form federation, facilitate cooperation, set standards… *driven by stringent science requirements*.
- Global framework for virtually all regional & national networks.
- Implement a global *civilian* GPS tracking system for geoscience, research, etc… *the gold standard*.
- Later, more products (tropospheric, ionospheric…) generated from the same rich data set.

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The IGS: IAG’s First Operational Service (1)

- Some important dates:
  - Start of 3 month Test Campaign 21 June 1992
  - IGS became an official service of the IAG in January 1994
  - Became the *International GNSS Service* March 2005
- **Key to approach**: sharing investments and operational costs by pooling the resources of many (> 200) organisations to establish an independent ground segment and generate high quality GNSS products … IGS does not own any facilities … operates on “best efforts” basis, reliability through redundancy, with all products freely available anyone, and advocates an *open data policy*.

http://igs.org

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The IGS: IAG’s First Operational Service (2)

- IAG service since 1994, and now a service of the GGOS.
- Name change GPS -> GNSS in 2005 reflects intent to generate products for all current & future GNSS.
- Highest accuracy GPS & GLONASS satellite orbits available anywhere
  - ~3-5cm 3D wrms GPS
  - ~10-15cm GLONASS
- Network of geodetic receivers produce GNSS data on a continuous basis:
  - mm-level station positions and velocities densify and define the International Terrestrial Reference Frame (ITRF)
  - ~90 stations also track GLONASS
  - ~100+ report hourly
  - Real-time test network for RT Pilot Project
- Strong links with FIG (esp. Commission 5)

IGS Organisation

- Roles and responsibilities defined in Terms of Reference, and various charters and policy documents.
- ~400 stations, strong ties to dense regional networks: EUREF, SIRGAS, AF-REF, US CORS, CMONOC, … will support APREF!
- 4 Global Data Centres; Sth. Korea, US(2), France; 6 Regional DCs, 17 Operational DCs.
- Analysis Centre Coordinator, 10 ACs, 4 Associate ACs, 17 Regional ACs.
- International Governing Board ~27 members.
- 150 Associate Members - electing body of Governing Board.
- Central Bureau - executive & daily management of IGS.

http://igs.org/organization/centers.html
IGS Tracking Network

Core Stations:
- Global Stations (ITRF 2005) 132
- VLBI Co-located 25
- SLR Co-located 37
- Doris Co-located 51

Project Stations or Experimental Capabilities:
- Timing stations 80
- Reprocessing campaign 2003-2007 467
- Tide Gauge Co-located 103
- Multi-GNSS 63
- Real-time 120

Current IGS Products:

- Precise GNSS orbits (post-processed & predicted):
  - GPS (3-5cm, 3Dwrms), predictions (<5-10cm)
  - GLONASS (~10-15cm, 3Dwrms)
- GNSS clock corrections (satellite & stn.: sub-ns)
- Earth orientation parameters (polar motion, PM rate, LOD)
- Ground positioning (sub-cm) & access to ITRF
- Consolidated input to ITRF definition/maintenance
- Ionospheric delay mapping
- Tropospheric corrections (integrated water vapour)
- Tracking data from IGS stations (RINEX files)
- Biennial IGS workshop (next mid-2012)
- Site guidelines & other documentation (e.g. workshop proceedings)

All products are available at no cost to the user
IGS products are formed by combining independent results from each of several Analysis Centres. Improvements in signals, instrumentation, network and computations have improved product consistency, e.g., for the Final GPS satellite orbit calculation it is about 2 cm.

http://acc.igs.org/

IGS Product Summary (1)
http://igs.org/components/prods.html
IGS Product Summary (2)
http://igs.org/components/prods.html

<table>
<thead>
<tr>
<th>Earth Rotation Parameters</th>
<th>Accuracy</th>
<th>Latency</th>
<th>Updates</th>
<th>Sample Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra-Rapid (predicted)</td>
<td>PM</td>
<td>-0.2ms</td>
<td>real time</td>
<td>four x daily (05, 06, 15, 21 UTC)</td>
</tr>
<tr>
<td></td>
<td>PM rate</td>
<td>-0.3mas/day</td>
<td></td>
<td>four x daily (06,06,12,18 UTC)</td>
</tr>
<tr>
<td></td>
<td>LOD</td>
<td>-0.05ms</td>
<td></td>
<td>four x daily (06,06,12,18 UTC)</td>
</tr>
<tr>
<td>Ultra-Rapid (observed half)</td>
<td>PM</td>
<td>-0.25mas/day</td>
<td>3-9 hours</td>
<td>four x daily (06,06,12,18 UTC)</td>
</tr>
<tr>
<td></td>
<td>PM rate</td>
<td>-0.05mas</td>
<td></td>
<td>four x daily (06,06,12,18 UTC)</td>
</tr>
<tr>
<td></td>
<td>LOD</td>
<td>-0.01ma</td>
<td></td>
<td>four x daily (06,06,12,18 UTC)</td>
</tr>
<tr>
<td>Rapid</td>
<td>PM</td>
<td>-0.84ms</td>
<td></td>
<td>daily (17 UTC)</td>
</tr>
<tr>
<td></td>
<td>PM rate</td>
<td>-0.2mas/day</td>
<td></td>
<td>daily (12 UTC)</td>
</tr>
<tr>
<td></td>
<td>LOD</td>
<td>-0.01ma</td>
<td></td>
<td>daily (12 UTC)</td>
</tr>
<tr>
<td>Final</td>
<td>PM</td>
<td>-0.15mas/day</td>
<td>11-17 days</td>
<td>every Wednesday</td>
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<tr>
<td></td>
<td>PM rate</td>
<td>-0.03mas</td>
<td></td>
<td>daily (12 UTC)</td>
</tr>
<tr>
<td></td>
<td>LOD</td>
<td>-0.01ma</td>
<td></td>
<td>daily (12 UTC)</td>
</tr>
</tbody>
</table>

New products are (& will be) developed, after thorough testing within Pilot Projects & WGs.

QuickTime™ and a decompressor are needed to see this picture.

Operations...
IGS Workshop 2010 Resources

- IGS Workshop was held at Newcastle, U.K. June/July 2010
- See [http://igs.org](http://igs.org) for video presentations and consolidated recommendations
  - Captures IGS state-of-the-art presentations - useful for those unable to attend, excellent reference
- Topics included:
  - FIG, IAG & IGS Relationships – Lilje gave an invited presentation
  - Combining GNSS signals
  - Network infrastructure (antenna monuments, receivers for new signals, phase centre calibrations, data flow and standards, …)
  - Real-time products
  - Re-processing data 1994-2010
  - Orbit modelling (new WG set up)
  - Loading and tides
  - Ionosphere, troposphere
- Joint session with Sea-Level experts, using GNSS for Tide Gauge Benchmark Monitoring (IGS TIGA Project)
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IGS Tracking Networks

GPS

Glonass

Glonass network needs improvement… “multi-GNSS” Pilot Project will be soon launched

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Our Changing World of GNSS!

**GPS (32)**
- L1 C/A, L2 P, L1 and L2 phase
- Modernized: L2C and L5, first launches in 2005 and 2009
- IOC 2012+ for L2C, 2015+ for L5

**GLONASS (23, 21 operational)**
- L1 C/A Code, L1 P and L2 P, L1 and L2 phase
- Full constellation of 24 satellites expected 2010+
- Switch to CDMA with GLONASS K satellite – first launch 2010

**Galileo (2)**
- Current test satellites in orbit – Glove A and B
- First launch 2009, IOC 2013+
- Full constellation of 30 satellites expected 2020

**COMPASS (8)**
- First launch 2009
- Regional coverage 2012
- Full constellation of 35 satellites expected 2020

**QZSS (1)**
- Augments GPS over Asia-Oceania region
- First launch 2010, 1 year in orbit validation
- Full constellation of 3 satellites expected 2011+

**NEW GNSSs – and modernization of GPS & GLONASS**
- require new equipment, new guidelines, new networks, new data handling and analysis to ensure full interoperability for maximum user benefit. A great opportunity for FIG & IAG/IGS collaboration.

**ICG**

- ICG established since 2006 to coordinate system providers and facilitate international use of GNSS.
- United Nations - Office of Outer Space Affairs (UNOOSA) is the Secretariat of ICG, **ICG is an affiliated UN entity**.
- IGS is an Associate Member of ICG and has highlighted the importance of AF-REF & GNSS application developments.
- IGS, FIG and IAG (as NGOs) co-chair ICG Working Group D, ‘**Interactions with National/Regional Authorities and International Organizations in Monitoring, Networks, and Reference Frames**’.
- 6th ICG meeting, Tokyo, Japan, September 2011.
IGS Real-time Pilot Project

- Strategic Plan to respond to needs of GGOS Natural Hazards theme.
- Maintain a global IGS RT receiver network, generate RT products (orbits, clocks), and investigate standards for RT data and products.
- Currently ~120 real-time stations, >35 participating organisations, 6 active Analysis Centres (NRCan, ESA, BKG, DLR, GMV, TUW).
- ESA/ESOC provides Analysis Centre Coordinator and Combination Center.
- RT service to begin 2013.
- Formats & protocols being tested.
- Targets:
  - real-time clock rms: 0.3 ns (vs 4ns for Broadcast);
  - 5-6 cm for orbits rms; and
  - 10 sec latency

http://www.rtigs.net

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RT Tracking Network 2011

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FIG Working Week 2011
Bridging the Gap between Cultures
Marrakech, Morocco, 18-22 May 2011

RT Combination Performance

![RT Combination Performance Graph]

AC Performance

<table>
<thead>
<tr>
<th>AC</th>
<th>Feb 6 2009</th>
<th>June 8 2010</th>
<th>March 9 2011</th>
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<tbody>
<tr>
<td></td>
<td>Clock RMS (ns)</td>
<td>Clock Sigma (ns)</td>
<td>Clock RMS (ns)</td>
</tr>
<tr>
<td>Comb</td>
<td>0.29</td>
<td>0.22</td>
<td>0.16</td>
</tr>
<tr>
<td>RTComb</td>
<td></td>
<td>0.15</td>
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<tr>
<td>BKG</td>
<td>6.72</td>
<td>2.97</td>
<td>0.20</td>
</tr>
<tr>
<td>CNES</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>DLR</td>
<td>0.38</td>
<td>0.10</td>
<td>0.20</td>
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<tr>
<td>ESOC</td>
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<tr>
<td>ESOC2</td>
<td>0.36</td>
<td>0.30</td>
<td>0.19</td>
</tr>
<tr>
<td>GFZ</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NRC</td>
<td>0.67</td>
<td>0.62</td>
<td>0.24</td>
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<tr>
<td>GMV</td>
<td>1.67</td>
<td>1.66</td>
<td>0.28</td>
</tr>
<tr>
<td>TUW</td>
<td>-</td>
<td>0.70</td>
<td>0.53</td>
</tr>
</tbody>
</table>

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### Products in Real Time

![IGS Logo](http://igs.bkg.bund.de/ntrip/orbits)

**Centre** | **Description** | **NTRIP Mountpoint**
--- | --- | ---
RTACC | RT combination from BKG, CNES, DLR, ESOC, ESOC2 and GFZ streams (CoM/APC) | CLK30/31
CNES | RT clocks based on IGU orbits (CoM/APC) | CLK90/91
BKG with TU Prague | GPS and GPS + GLONASS RT clocks using IGS ultra-rapid orbits (CoM/APC). | CLK00/10, CLK01/11
DLR | RT clocks using IGS ultra-rapid orbits. | CLK11/A1
ESOC | RT clocks and TZD NRT batch orbits every 2 hours (ESOC) and using IGS ultras (ESOC2) (CoM/APC). | CLK50/51, CLK52/53
GFZ | RT clocks (CoM/APC) | CLK70/71
GMV | RT clocks based on GMV orbit solution (CoM/APC). | CLK11/A1
TUW | RT clocks based on IGU orbits (CoM/APC) | CLK80/81

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### Concluding Remarks

- **The IGS provides a reference for many GNSS applications**
  - Reliable, rapidly available, highest accuracy products for a large user community.
- **Quality Control is a key driver for the IGS**
  - Continuous product comparisons, “combined products”, and feedback motivate improvements.
- **After more than 15 years of “routine operations”, innovation and R&D within the IGS continues.**
- **Constantly increasing synergies with higher-level initiatives such as GGOS.**
- **IGS seeks greater cooperation, participation and contributions… the FIG can help us!**
Can I get involved?

- The IGS is open to more participation
  - Tracking stations, DCs, ACs, attendance at meetings/workshops
- IGS Network can grow - *but note IGS standards!*
  - Not all data are processed by ACs, *but raw data is also a valuable product for geoscientific applications*
- Reference Frame stations need long time series observations - *new stations must prove themselves!*
- “Rule-of-thumb” goal is dense network of 1000km spacing.
- Need to fill geographic “gaps” with *geodetic infrastructure*.
- Need new types of GNSS capabilities, e.g. RT, multi-GNSS receivers, etc., *to generate new products.*
- *Encourage the spread of the “IGS spirit” of openness and collaboration.*

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