# The International GNSS Service (IGS): Product and Services

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**FIG Working Week**
**18-22 May 2011**
**Marrakech, Morocco**

## IGS Mission

***"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.



## The IGS: IAG's First Operational Service (1)

- Some important dates:
  - Announcement of Opportunity 1991: *International GPS Service for Geodynamics* (until 1999, then simply IGS)
  - 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

## 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.
- Coordinators: AC, Infrastructure & Operations, Timing, Reference Frame, Infrastructure.
- 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** | 415 |
| - Global Stations (ITRF 2005) | 132 |
| - VLBI Co-located | 25 |
| - SLR Co-located | 37 |
| - Doris Co-located | 55 |
| **Project Stations or Experimental Capabilities** | |
| - Timing stations | 80 |
| - Reprocessing campaign 2003-2007 | 667 |
| - Tide Gauge Co-located | 103 |
| - Multi GNSS | 93 |
| - 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

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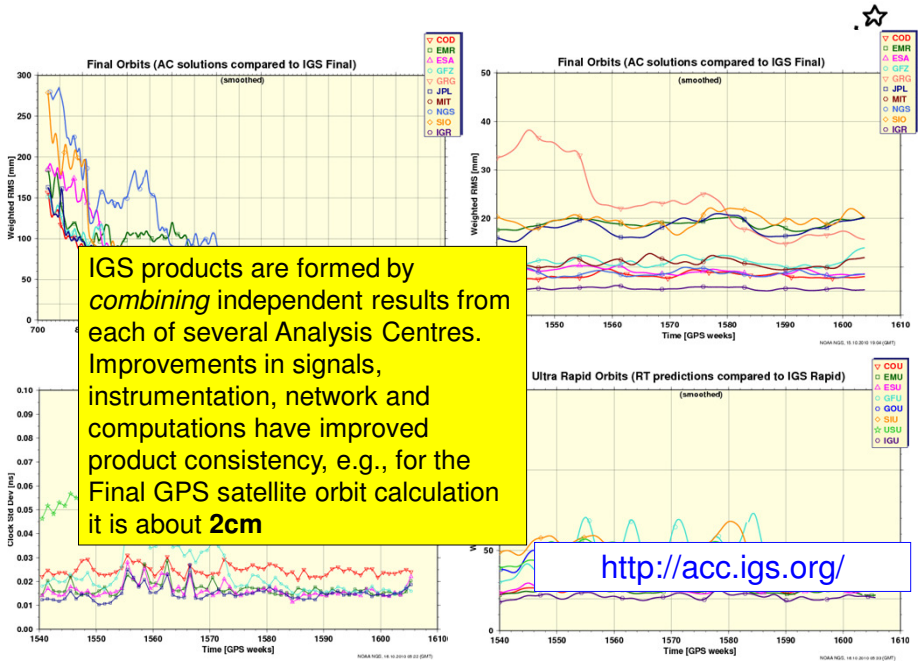



IGS products are formed by *combining* independent results from each of several Analysis Centres. Improvements in signals, instrumentation, network and computations have improved product consistency, e.g., for the Final GPS satellite orbit calculation it is about **2cm**

http://acc.igs.org/



# IGS Product Summary (1)

http://igs.org/components/prods.html

| | | Accuracy | Latency | Updates | Sample Interval |
|---|---|---|---|---|---|
| **GPS Satellite Ephemerides/ Satellite & Station Clocks** | | | | | |
| Broadcast | orbits | ~100cm | real time | -- | daily |
| | Sat. clks | ~5ns rms | | | |
| Ultra-Rapid (predicted half) | orbits | ~5cm | real time | four x daily (03, 09, 15, 21 UTC) | 15 min |
| | Sat. clks | ~3ns rms | | | |
| Ultra-Rapid (observed half) | orbits | ~3cm | 3-9 hours | four x daily | 15 min |
| | Sat. clks | ~0.15ns rms | | | |
| Rapid | orbits | ~2.5cm | 17-41 hours | Daily @ 17 UTC | 15 min |
| | Sat. & Stn. clks | ~0.075ns rms | | | 5 min |
| Final | orbits | ~2.5cm | 12-18 days | every Thursday | 15 min |
| | Sat. & Stn. clks | ~0.075ns rms | | | Sat.: 30 sec Stn.: 5 min |
| **GLONASS Satellite Ephemerides** | | | | | |
| Final | | ~5cm | 12-18 days | every Thursday | 15 min |
| **Geocentric Coordinates of IGS Tracking Stations (>250 sites)** | | | | | |
| Final positions | horizontal | 3mm | 11-17 days | every Wednesday | weekly |
| | vertical | 6mm | | | |
| Final velocities | horizontal | 2mm/yr | 11-17 days | every Wednesday | weekly |
| | vertical | 3mm/yr | | | |

# IGS Product Summary (2)

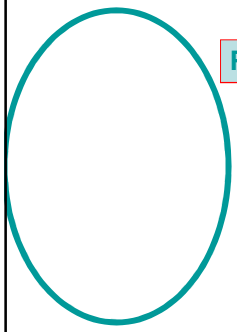
http://igs.org/components/prods.html

| | | Accuracy | Latency | Updates | Sample Interval |
|---|---|---|---|---|---|
| **Earth Rotation Parameters** | | | | | |
| Ultra-Rapid (predicted half) | PM | ~0.2mas | real time | four x daily (03, 09, 15, 21 UTC) | four x daily (00,06,12,18 UTC) |
| | PM rate | ~0.3mas/day | | | |
| | LOD | ~0.05ms | | | |
| Ultra-Rapid (observed half) | PM | ~0.05mas | 3-9 hours | four x daily | four x daily (00,06,12,18 UTC) |
| | PM rate | ~0.25mas/day | | | |
| | LOD | ~0.01ms | | | |
| Rapid | PM | ~0.04mas | 17-41 hours | Daily (17 UTC) | daily (12 UTC) |
| | PM rate | ~0.2mas/day | | | |
| | LOD | ~0.01ms | | | |
| Final | PM | ~0.03mas | 11-17 days | every Wednesday | daily (12 UTC) |
| | PM rate | ~0.15mas/day | | | |
| | LOD | ~0.01ms | | | |
| **Atmospheric Parameters** | | | | | |
| Final tropospheric zenith path delay | | | | | |
| Ultra-Rapid tro zenith path dela | | | | | |
| Final Ionosphe | | | | | ) x 2.5 |
| Rapid Ionospheric TEC grid | | 2-9 TECU | <24 hours | daily | 2 hours; 5 deg (lon) x 2.5 deg (lat) |

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

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

**Operations…**



R&D…

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

## IGS Workshop 2010 Resources

- IGS Workshop was held at Newcastle, U.K. June/July 2010
- See 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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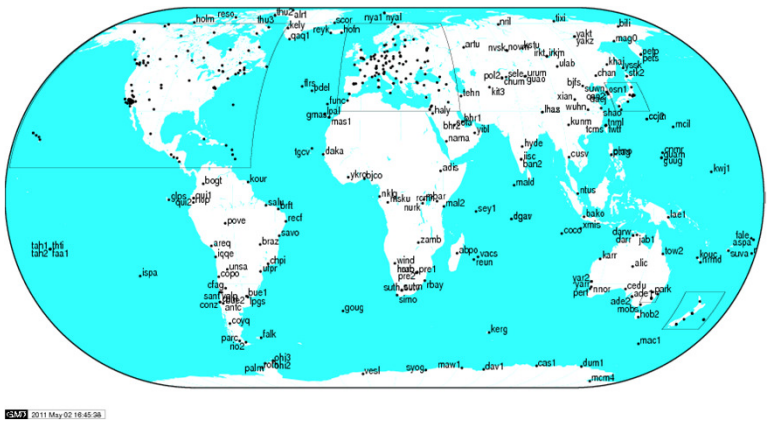
# IGS Tracking Networks

GPS



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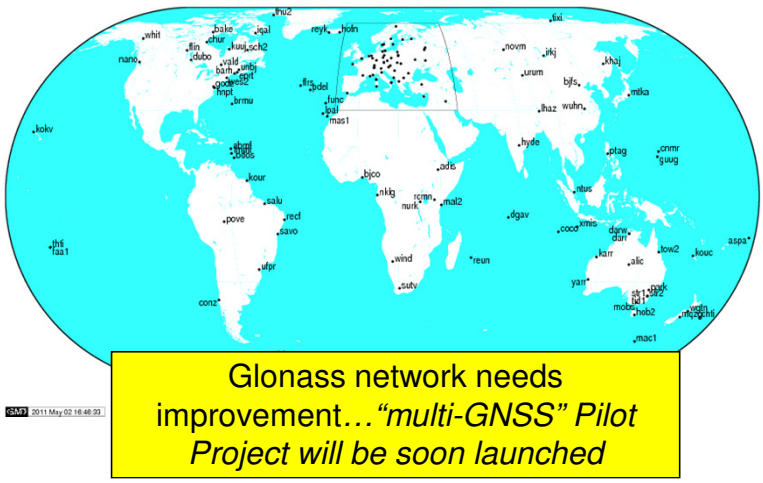
# IGS Tracking Networks

Glonass



Glonass network needs improvement…*"multi-GNSS" Pilot Project will be soon launched*

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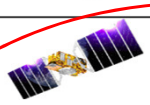
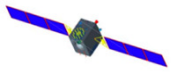
## Our Changing World of GNSS!

**GPS (32)**
L1 C/A, L1and L2 P, L1 and L2 phase
Modernized - L2C and L5, first launches in 2005 and 2009
IOC 2012+ for L2C, 2015+ for L5

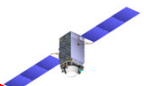
**GLONASS (23, 21 operational)**
L1 C/A Code, L1 P and L2 P, L1 and L2 phase
Full constellation of 24 satellites expected 2010+
Switch to CDMA with GLONASS K satellite – first launch 2010



**Galileo (2)**
Current test satellites in orbit – Giove A and B
First launch 2010+, IOC 2013+
Full constellation of 30 satellites expected ?



**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 International Committee on Global Navigation Satellite Systems

- 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.

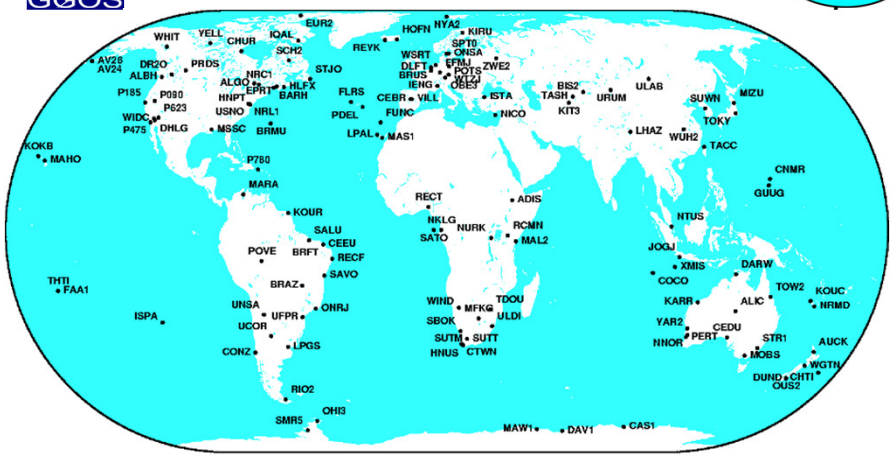
# IGS Real-time Pilot Project

- 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

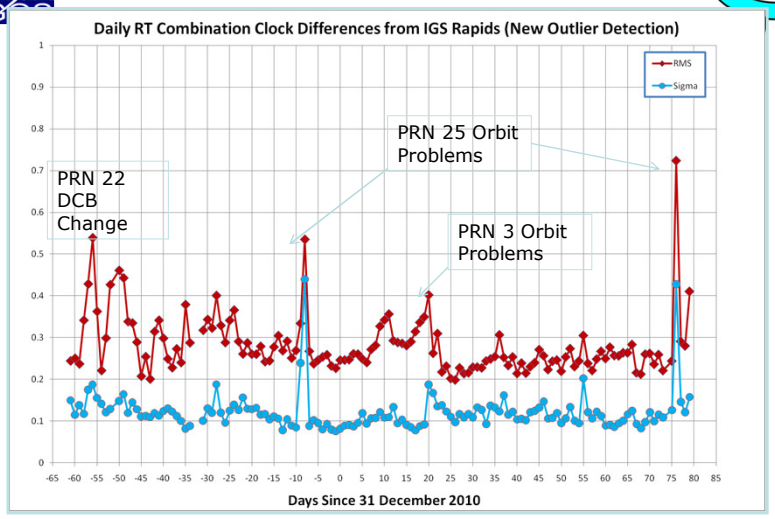
http://www.rtigs.net



# RT Tracking Network 2011



# RT Combination Performance

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# AC Performance

| AC | Feb 6 2009 | | June 8 2010 | | March 9 2011 | |
|---|---|---|---|---|---|---|
| | Clock RMS (ns) | Clock Sigma (ns) | Clock RMS (ns) | Clock Sigma (ns) | Clock RMS (ns) | Clock Sigma (ns) |
| Comb | 0.29 | 0.22 | 0.16 | 0.10 | 0.18 | 0.08 |
| RTComb | - | - | 0.15 | 0.11 | 0.21 | 0.08 |
| BKG | 6.72 | 2.97 | 0.20 | 0.12 | 1.20 | 0.08 |
| CNES | - | - | - | - | 0.24 | 0.10 |
| DLR | 0.38 | 0.10 | 0.20 | 0.12 | 0.38 | 0.26 |
| ESOC | 0.42 | 0.38 | 0.21 | 0.12 | 0.20 | 0.16 |
| ESOC2 | 0.36 | 0.30 | 0.19 | 0.11 | 0.30 | 0.09 |
| GFZ | - | - | - | - | 0.31 | 0.07 |
| NRC | 0.67 | 0.62 | 0.24 | 0.10 | 0.23 | 0.08 |
| GMV | 1.67 | 1.66 | 0.28 | 0.14 | 0.34 | 0.17 |
| TUW | | | 0.70 | 0.53 | 0.71 | 0.55 |

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## Products in Real Time
## http://igs.bkg.bund.de/ntrip/orbits

| Centre | Description | NTRIP Mountpoint |
|---|---|---|
| RTACC ESOC | 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. | CLKC1/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). | CLKC1/A1 |
| TUW | RT clocks based on IGU orbits (CoM/APC) | CLK80/81 |



## 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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