Recent Developments in the International GNSS Service (IGS)

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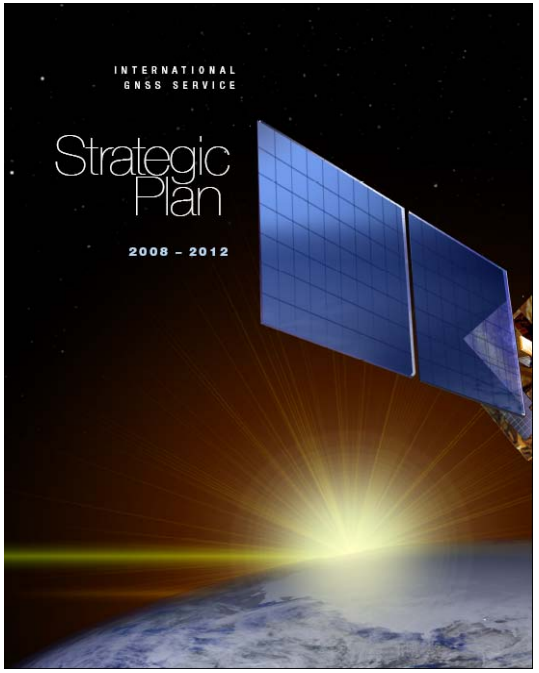
IGS Products

- Data from a global network of tracking stations
- Precise orbits (few cm), predictions (<10 cm)
- Clock corrections (satellite, ground: <1 ns)
- Ground positioning (<1 cm)
  - Consolidated input of GNSS to the International Terrestrial Reference Frame (ITRF)
- Ionosphere maps
- Troposphere corrections
- Differential code biases
- Antenna phase centre models

IGS products in constant development, quality control as key driver

IGS Components

- Tracking network
- Network Coordinator
- Data Centres
- Analysis Centres and Associate Analysis Centres
- **Analysis Centre Coordinator**
- **Reference Frame Coordinator**
- **Timing Products Coordinator**
- **Infrastructure Committee (2009-)**
- Working Groups and Pilot Projects
- Central Bureau
- Governing Board



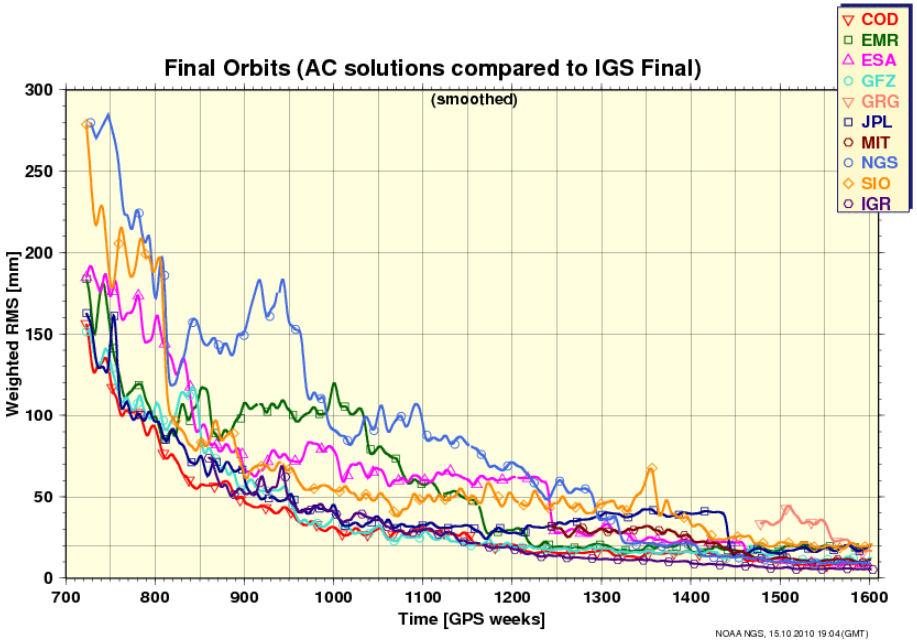
IGS Core Product Lines (2010)

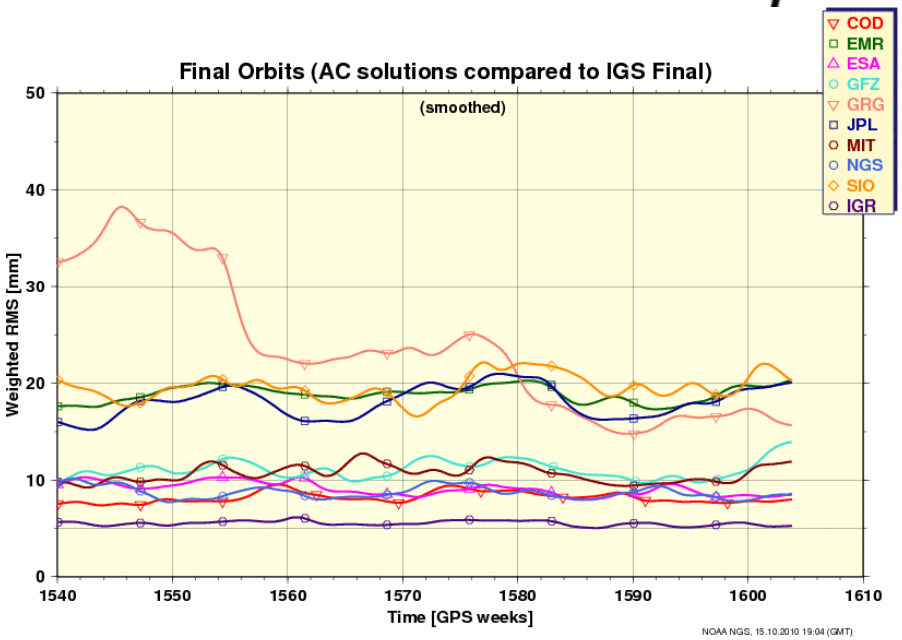
Series	ID code	Latency	Issue times (UTC)	Data spans (UTC)	Remarks
Ultra-Rapid (predicted half)	IGU	real-time	@ 03:00, 09:00, 15:00, 21:00	+24 hr @ 00:00, 06:00, 12:00, 18:00	• for real-time apps • GPS only • issued with prior IGA
Ultra-Rapid (observed half)	IGA	3 - 9 hr	@ 03:00, 09:00, 15:00, 21:00	-24 hr @ 00:00, 06:00, 12:00, 18:00	• for near real-time apps • GPS only • issued with following IGU
Rapid	IGR	17 - 41 hr	@ 17:00 daily	±12 hr @ 12:00	• for near-definitive, rapid apps • GPS only
Final	IGS	11 - 17 d	weekly each Thursday	±12 hr @ 12:00 for 7 d	• for definitive apps • GPS & GLONASS

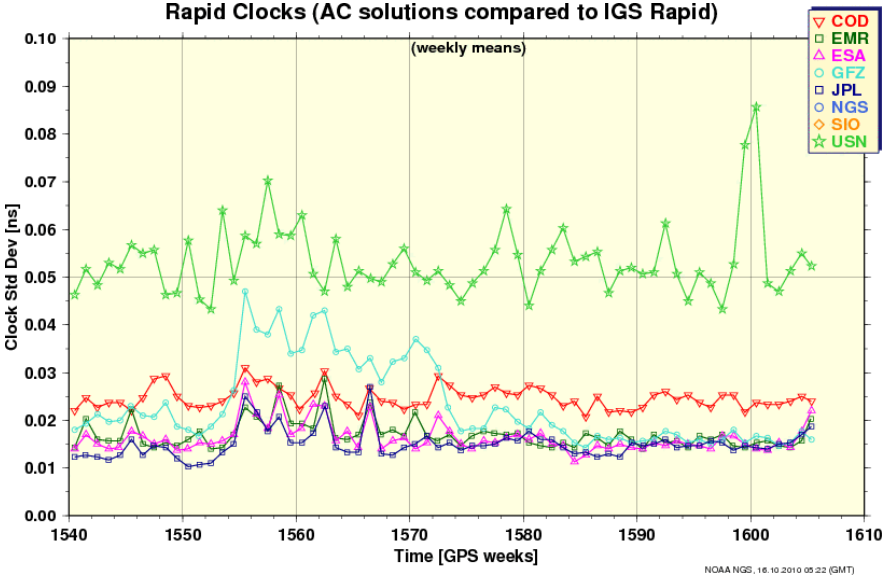
J. Ray, IGS ACC

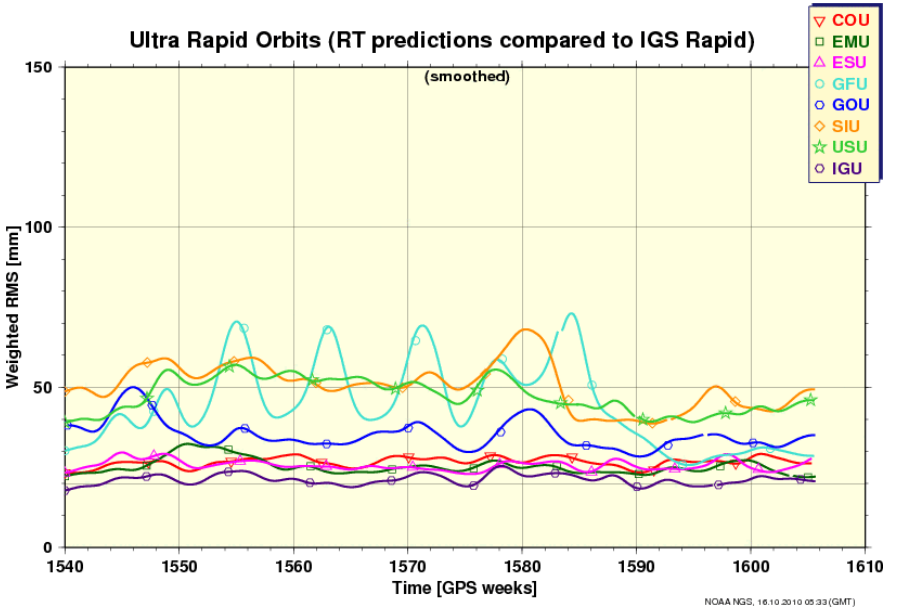
IGS Product Types & ACs (June 2010)

Series	Product types	# of contributing ACs Submit	Reject	Used	Output sample interval
Ultra-Rapid (IGA + IGU)	• GPS orbits	7	3	4	15 min
	• GPS SV clocks	4	1	3	15 min
	• ERPs: PM / LOD	6 / 6	2 / 3	4 / 3	6 hr
Rapid (IGR)	• GPS orbits	8	0	8	15 min
	• GPS SV clocks	6	1	5	5 min
	• station clocks	6	1	5	5 min
	• ERPs: PM / LOD	8 / 8	2 / 1	6 / 7	daily
Final (IGS)	• GPS orbits	9	~1	~8	15 min
	• GPS SV clocks	7	1	6	5 min
		5	1	4	30 s
	• station clocks	7	1	6	5 min
	• GLO orbits	6	1	5	15 min
	• GLO SV clocks	3	3	0	none
	• ERPs: PM / LOD	9 / 9	~2 / ~3	7 / 6	daily
	• Terrestrial frame	9	~1	~8	weekly


Final Orbits (AC solutions compared to IGS Final)
(smoothed)
COD
EMR
ESA
GFZ
GRG
JPL
MIT
NGS
SIO
IGR
Weighted RMS [mm]
Time [GPS weeks]
NOAA NGS, 15.10.2010 19:04(GMT)


Final Orbits (AC solutions compared to IGS Final)
(smoothed)
COD
EMR
ESA
GFZ
GRG
JPL
MIT
NGS
SIO
IGR
Weighted RMS [mm]
Time [GPS weeks]
NOAA NGS, 15.10.2010 19:04 (GMT)


Rapid Clocks (AC solutions compared to IGS Rapid)
(weekly means)
COD
EMR
ESA
GFZ
JPL
NGS
SIO
USN
Clock Std Dev [ns]
Time [GPS weeks]
NOAA NGS, 16.10.2010 05:22 (GMT)


Ultra Rapid Orbits (RT predictions compared to IGS Rapid)
(smoothed)
COU
EMU
ESU
GFU
GOU
SIU
USU
IGU
Weighted RMS [mm]
Time [GPS weeks]
NOAA NGS, 16.10.2010 05:33 (GMT)

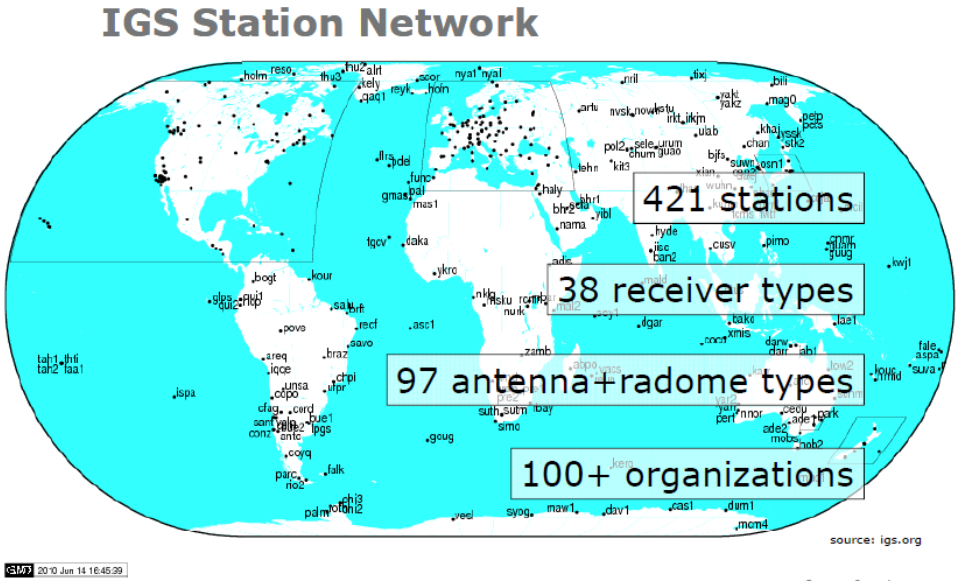
IGS Working Groups and Pilot Projects

- **Antenna Working Group**
- **Bias and Calibration Working Group**
- **Clock Products Working Group**
- Data Centre Working Group
- **GNSS Working Group**
- Ionosphere Working Group
- Low Earth Orbiters (LEO) Working Group
- Troposphere Working Group
- **Real-Time Working Group**
- **Reference Frame Working Group**
- Tide Gauge Benchmark Monitoring Pilot Project
- **Orbit Modelling Working Group (2010-)**

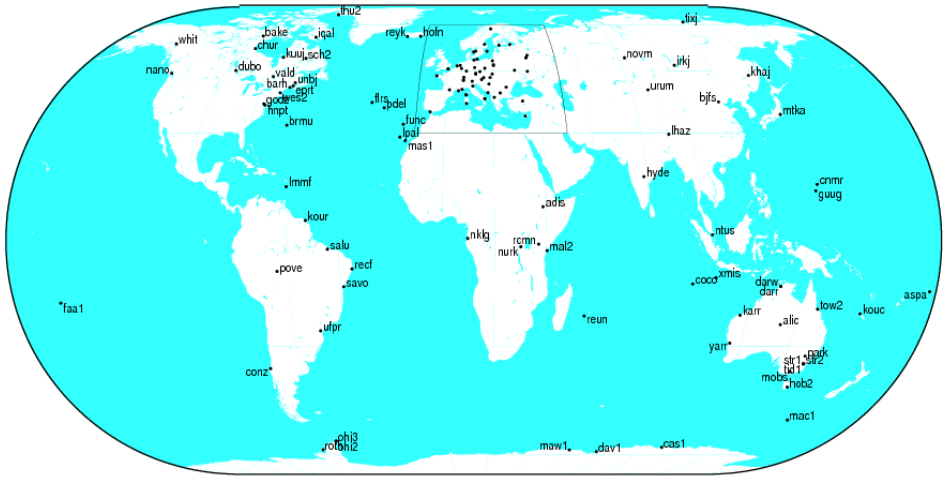
IGS as a multi-GNSS Service

- Galileo: IGS/IAG centres are involved in
  - 13 station global Galileo Experimental Sensor Station network, now tracking GIOVE-A & -B
  - Galileo Geodetic Reference Provider Prototype
  - Giove tracking data evaluation in coordination with Galileo Project Office
- Continuing independent monitoring of operational GNSS's (currently GPS, GLONASS) and their spatial and time references
  - Glonass orbit solutions from 5 IGS centres consistent to 3-4 cm
- Multi-system GNSS solutions
  - Four AC´s are providing fully compatible ultra-rapid GNSS solutions: GPS + GLONASS > experimental combination under evaluation
  - Routine multi-system IGS GNSS product is feasible, but GLONASS tracking network still lacks optimal global distribution
  - Focus on inter-system biases
- A Multi-GNSS Campaign is in the early planning stage

IGS Tracking Networks



GPS



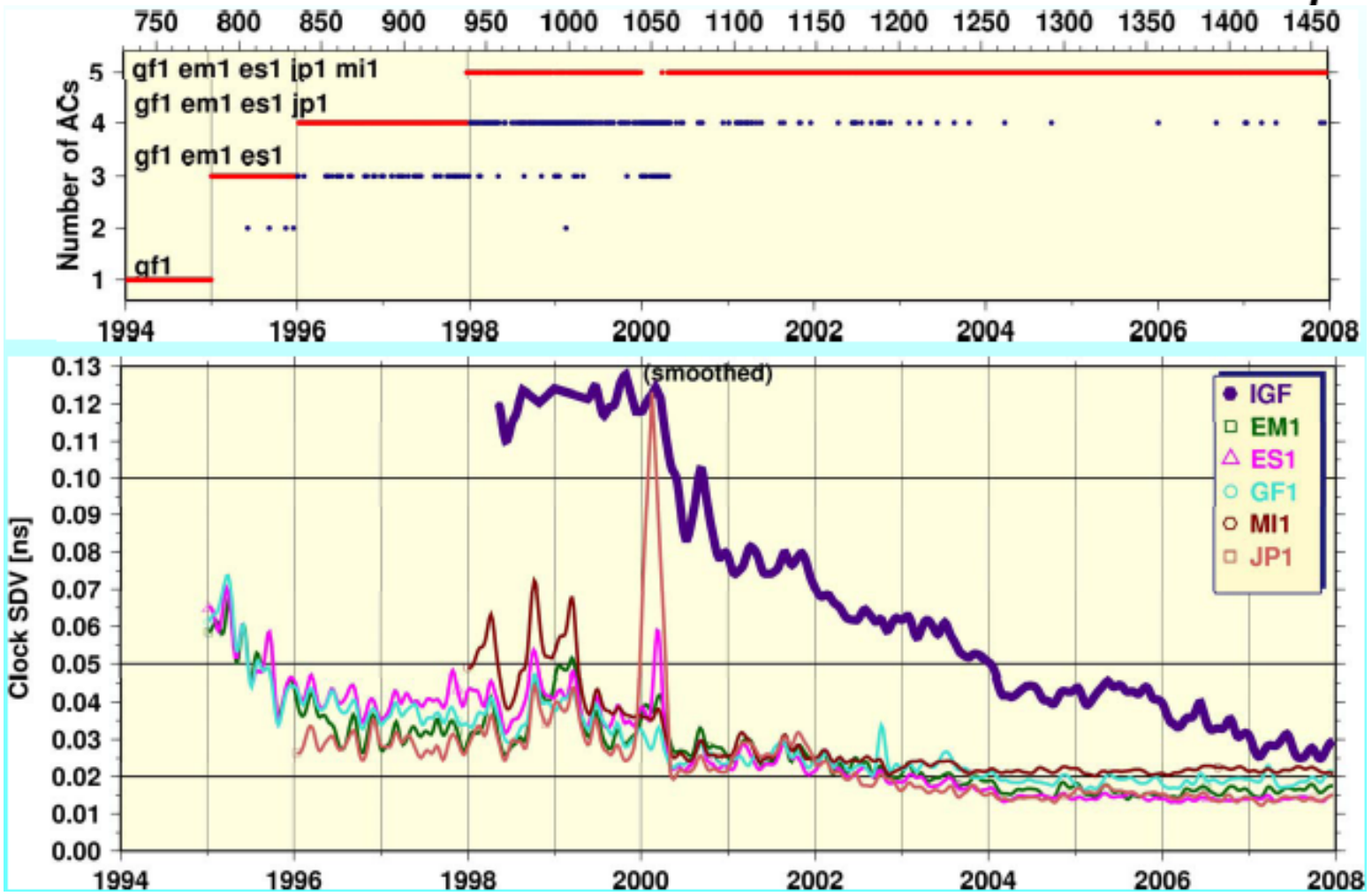
Glonass/
GPS

GNSS (GPS, GLONASS, Galileo) at Malindi, Kenya

Reprocessing: 1st Campaign (IG1)

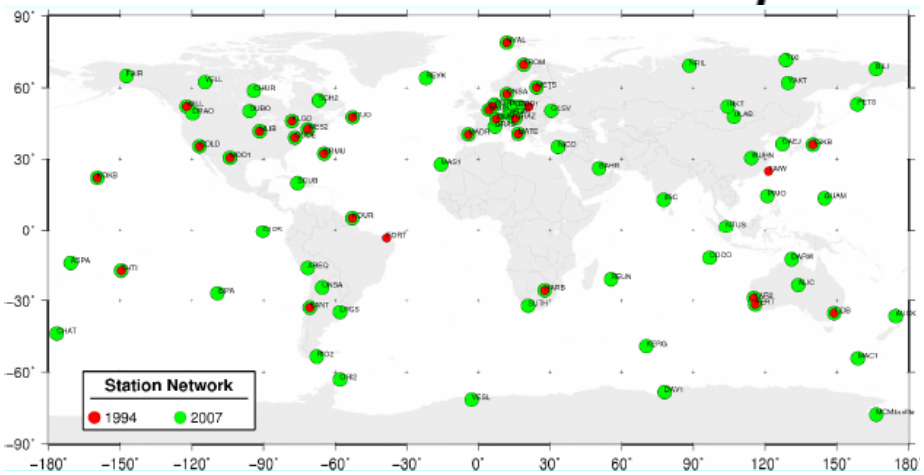
- To obtain a full history of IGS Final products in a fully consistent framework (IGS05)
- Absolute antenna model (igs05.atx)
- P1-C1 satellite code biases updated
- IERS 2003 Conventions generally implemented
- Participation of 11 Analysis Centres
- Time series for ~900 stations, 643 with > 2 years data
- Provided IGS contribution with homogeneous products to ITRF2008

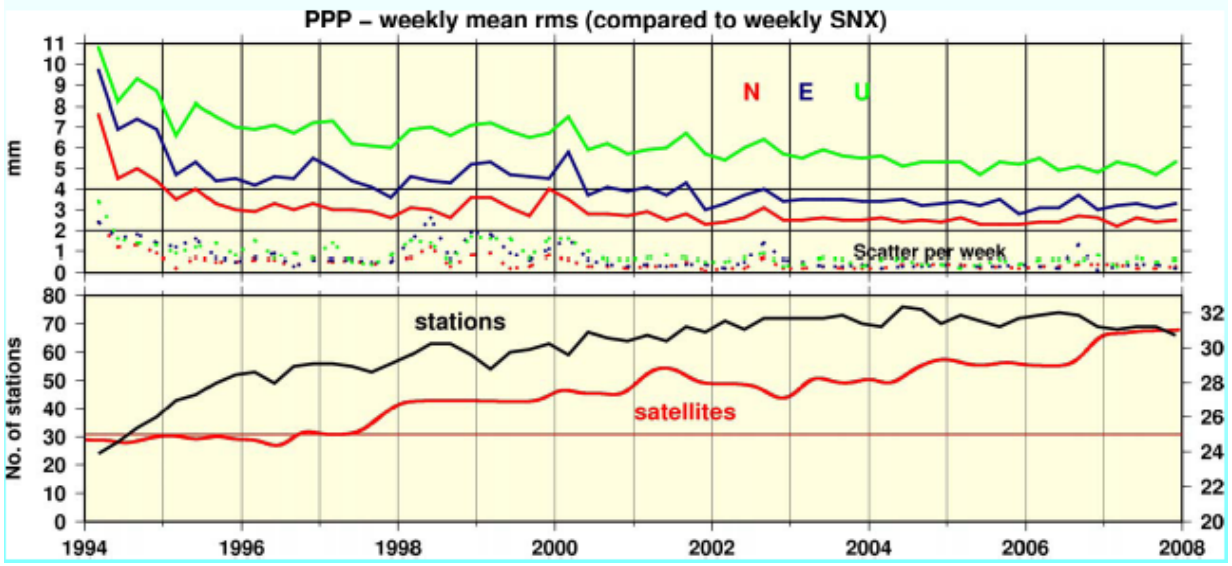
Reprocessing: clock combination



Checking the solution series with PPP

- PPP with IG1 orbits & clocks, 4 weeks/year
- Network of ~80 stations (~25 in 1994)
- Plot shows weekly mean rms difference between PPP and weekly SINEX

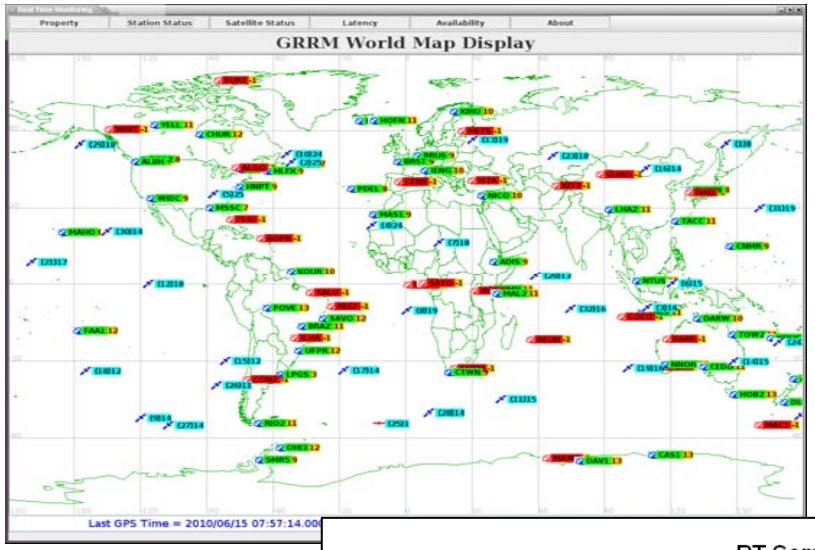




IGS Real-time Pilot Project

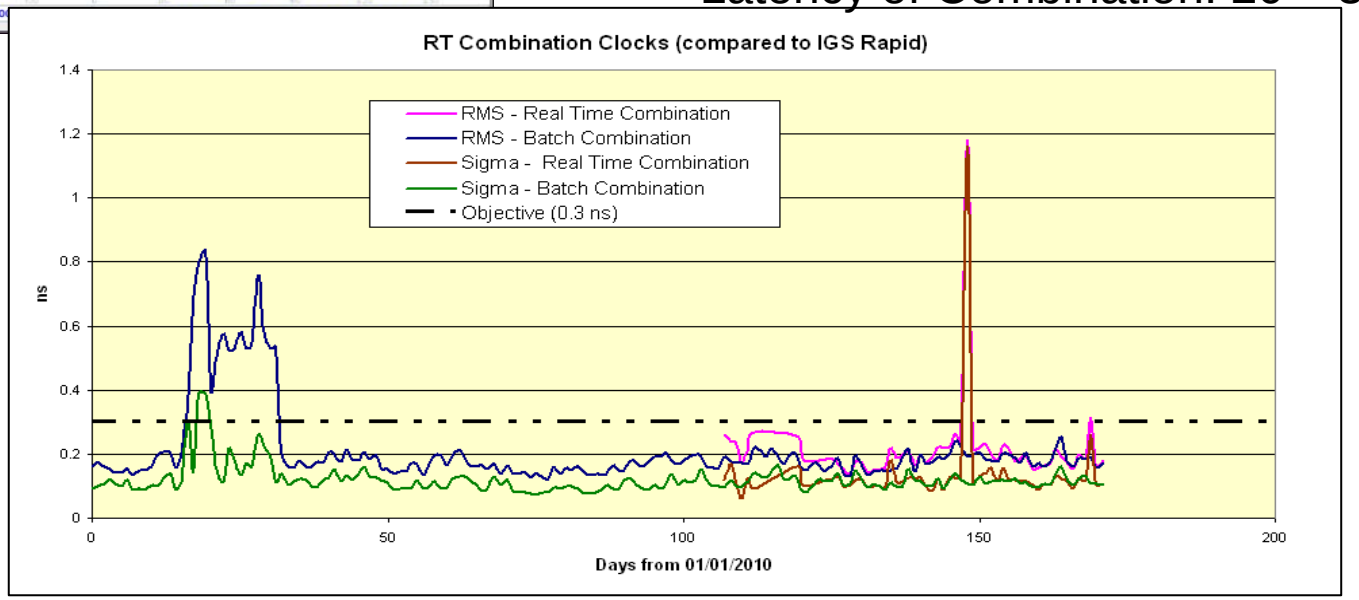
- Maintain a global IGS RT receiver network, generate RT products (orbits, clocks), and investigate standards for RT data and products
- Currently ca. 120 RT stations, >35 participating organisations, 6 active Analysis Centres (NRCan, ESA, BKG, DLR, GMV, TUW)
- ESA/ESOC provides Analysis Centre Coordinator and Combination Centre
- Target real-time clock rms: 0.3 ns (vs 4ns for Broadcast); 5-6 cm for orbits; 10 sec latency

Real Time Combination Solution



Accuracy (compared to IGS Rapids)

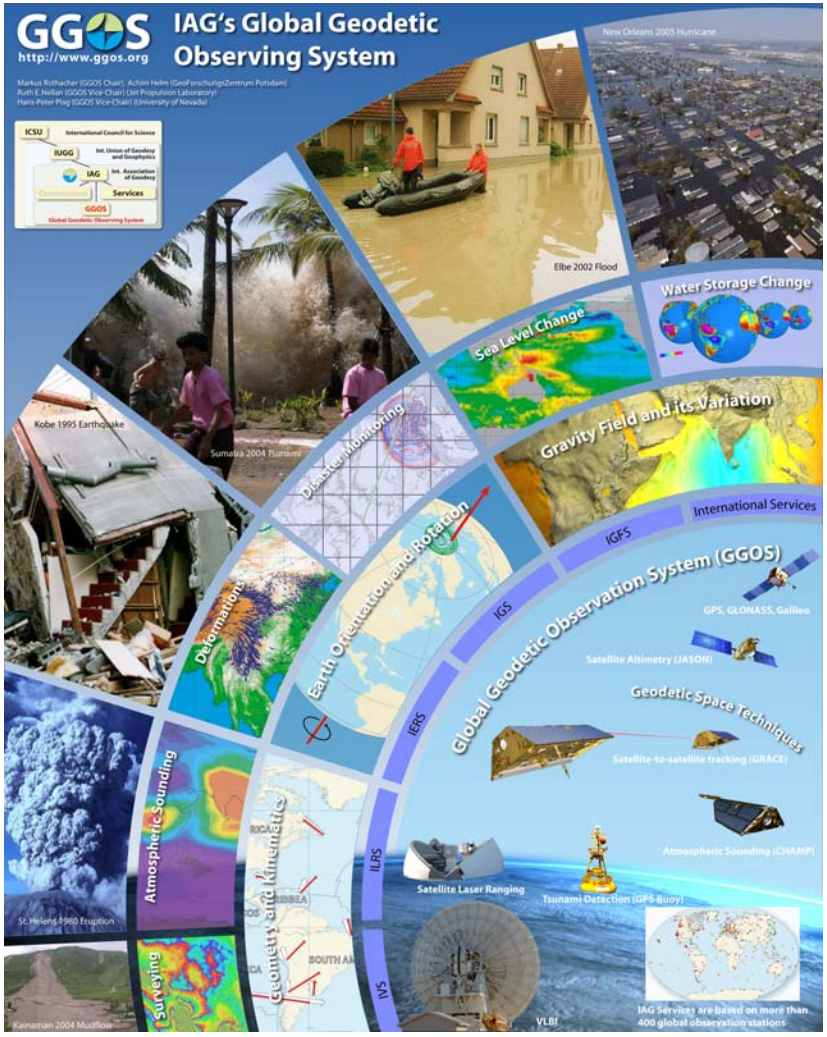
- Orbit: 4-6 cm 1-D RMS
- Clock RMS: 0.2 ns
- Clock Sigma: 0.1 ns
- Latency of Individual Solutions: 7-15 s
- Latency of Combination: 20 – 30 s



Standards and Formats for Real-Time

- Promotion of new formats and protocols through IGS participation in the Radio Technical Commission for Maritime Services (RTCM), Special Committee 104 (SC-104) on DGNSS
  - Supporting the introduction of State Space Representation formats, allowing dissemination of global orbit and clock corrections via IP using NTRIP
  - Proposing and participating in the development of High Precision multi-constellation observation messages
  - Working with RTCM facilitates acceptance and introduction of these formats directly into GNSS receiver firmware

Global Geodetic Observing System



- IGS is one of the building blocks of IAG's **Global Geodetic Observing System (GGOS)**, the contribution of geodesy to the Global Earth Observing System of Systems (GEOSS)
- Bringing strengths of GNSS to observing system of all geodetic techniques
- Integrated Standards and Conventions (IERS Conventions 2010)
- Unified Analysis Workshop 2009, GGOS Retreat 2010

IGS Workshop 2010

- IGS Workshop was held at Newcastle, U.K. from 27 June to 2 July 2010
- Topics included:
  - 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
- See http://igs.org for program, presentations and (soon) consolidated recommendations
- A meeting of ICG WG-D took place, minutes via ICG Secretariat

Conclusions

- IGS continues its long history of successful, leading-edge projects and products – supported by long- and medium-term strategic planning
- The IGS provides *the* reference for many GNSS applications
  - Reliable, rapidly available, highest accuracy products for a wide community of users
- Quality control is a key driver for the IGS: systematic comparisons and feedback motivate improvements
- Innovation and new developments, e.g.,
    - Multi-system GNSS infrastructure and analysis products
    - Real Time Pilot Project
    - Re-processing
    - Infrastructure Committee
    - GGOS
- More information at http://igs.org