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Status of IGS Ultra-Rapid Products for Real-Time Applications

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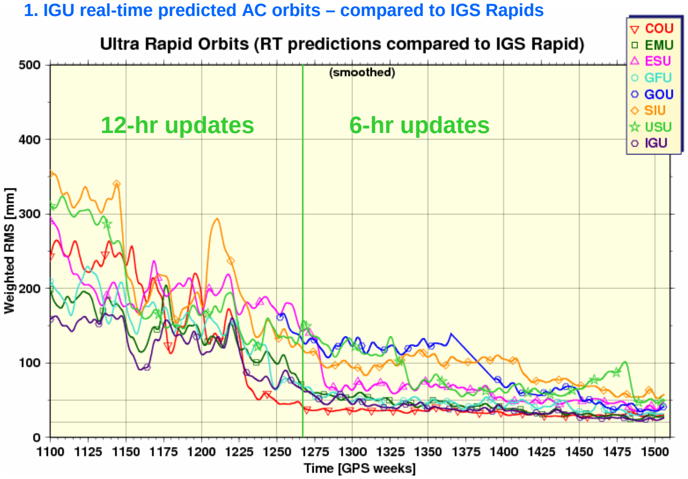
Abstract. Since November 2000 the International GNSS Service (IGS) has produced Ultra-rapid (IGU) products for near real-time (RT) and real-time applications. They include GPS orbits, satellite clocks, and Earth rotation parameters for a sliding 48-hr period. The first day of each update is based on the most recent GPS observational data from the IGS hourly tracking network. At the time of release, these observed products have an initial latency of 3 hr. The second day of each update consists of predictions. So the predictions between about 3 and 9 hr into the second half are relevant for true real-time uses. Originally updated twice daily, the IGU products since April 2004 have been issued four times per day, at 3, 9, 15, and 21 UTC. Up to seven Analysis Centers (ACs) contribute to the IGU combinations: Astronomical Institute of the University of Berne (AIUB/COU), European Space Operations Center (ESOC/ESU), Geodetic Observatory Pecny (GOP/GOU), GeoForschungsZentrum (GFZ/GFU) Potsdam, Natural Resources Canada (NRCan/EMU), Scripps Institution of Oceanography (SIO/SIU), U.S. Naval Observatory (USNO/USU). This redundancy affords a high measure of reliability and enhanced orbit accuracy.

IGU orbit precision has improved markedly since late 2007. This is due to a combination of factors: decommissioning of the old, poorly behaved PRN29 in October 2007; upgraded procedures implemented by GOP around the same time, by ESOC and SIO in spring 2008, and by USNO in June 2008; better handling of maneuvered satellites at the combination level starting July 2008; and stricter AC rejection criteria since July 2008. As a consequence, the weighted 1-D RMS residual of the IGU orbit predictions over their first 6 hr is currently about 24 ± 6 mm (after a Helmert transformation), compared to the IGS Rapid orbits and averaged over the constellation. The median residual is about 18 ± 3 mm. When extended to the full 24 hr prediction period, the IGU orbit errors double. Systematic rotational offsets are probably more important overall than random errors due to limitations in EOP predictions, especially UT1, reaching up to about ±34 mm around the Z axis (equatorial at GPS altitude). The near real-time observed orbits in the first half of each IGU update have WRMS residuals of about 10 to 15 mm recently. Note that while the precision of the Rapid orbits is <10 mm (compared to the IGS Finals) discontinuities between successive daily orbits imply an inaccuracy in the IGS orbits of at least 21 mm WRMS. So it is likely that the observed IGU orbits are nearly comparable in accuracy to the Rapids and that the current IGU real-time orbit predictions are not normally worse by more than a factor of two or so.

Only four ACs (ESOC, GFZ, NRCan, USNO) contribute estimates of the satellite clocks, which limits the robustness and quality of the IGU clock products. Because the stochastic component of clock variations is not predictable, errors for the second-half IGU clock predictions grow quickly to the same level as the broadcast navigation values. But the IGU observed clocks have typical errors just about double that of the Rapids, most of the time. The scatters of precise point positions using the IGU observed products are only slightly greater than for the Rapids.

1. IGU real-time predicted AC orbits – compared to IGS Rapids

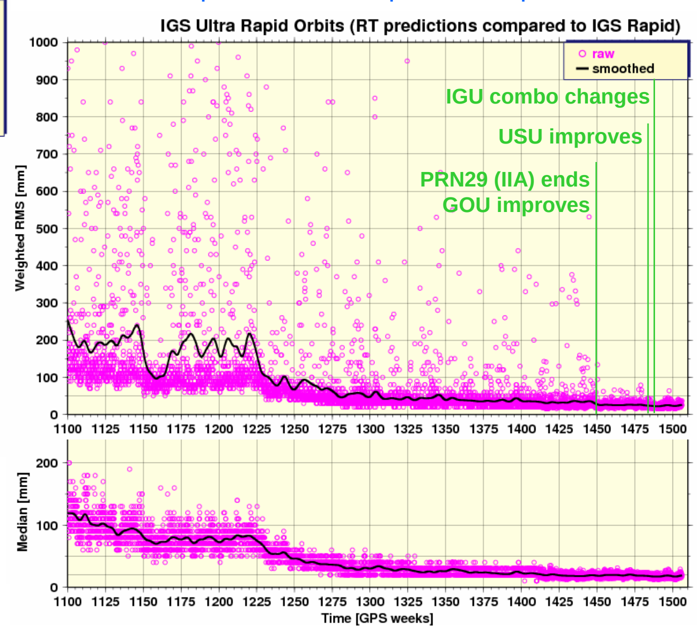


(all plots show: 2001-02-04 to 2008-11-17)

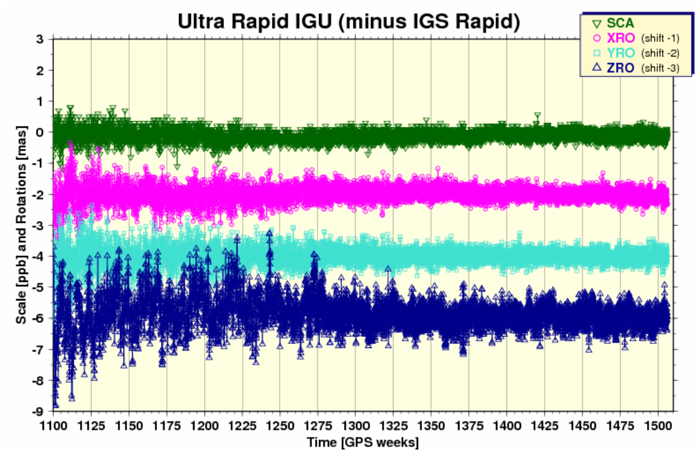
- WRMS quality of IGU & AC RT orbit predictions (over first 12/6 hr) has improved dramatically
- but shorter update cycle starting in 2004 had little direct effect
- main improvements: better AC procedures, decommissioning of old satellites, changes in combination
- main problems: eclipse season for old IIA satellites & PRN19 (IIR)

- since fixing maneuver bug in July 2008, combined RT orbit predictions (first 6 hr) have:
  average WRMS = 23.9 ± 5.9 mm; average median residual = 18.0 ± 2.8 mm
- small, stable orbit prediction median implies users should be able to detect RT outliers easily

2. IGU combined RT predicted orbits – compared to IGS Rapids



3. IGU combined RT predicted orbit rotations – compared to IGS Rapids



- Z rotation systematic errors – due to UT1 predictions – are largest overall IGU RT prediction error

IGU Orbit Helmert & 1-D Position Differences wrt IGS Rapids
(during 2008-07-23 06:00 to 2008-11-16 18:00)

	DX mm	DY mm	DZ mm	RX mm	RY mm	RZ mm	SCL mm	RMS mm	WRMS mm	MEDI mm
Mean	2.9	0.6	1.1	-10.5	0.2	-2.6	-0.7	31.5	23.9	18.0
SDev	4.5	3.9	3.1	20.3	22.7	34.2	0.8	14.9	5.9	2.8

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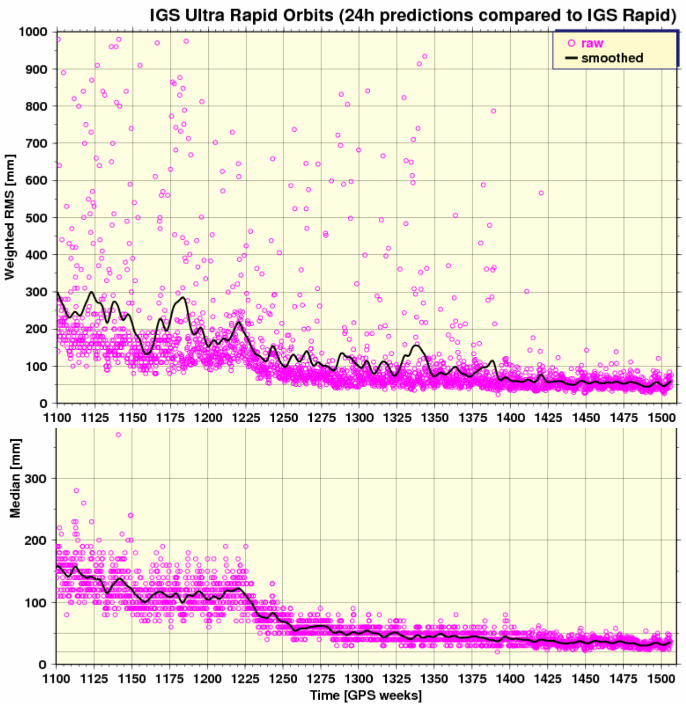
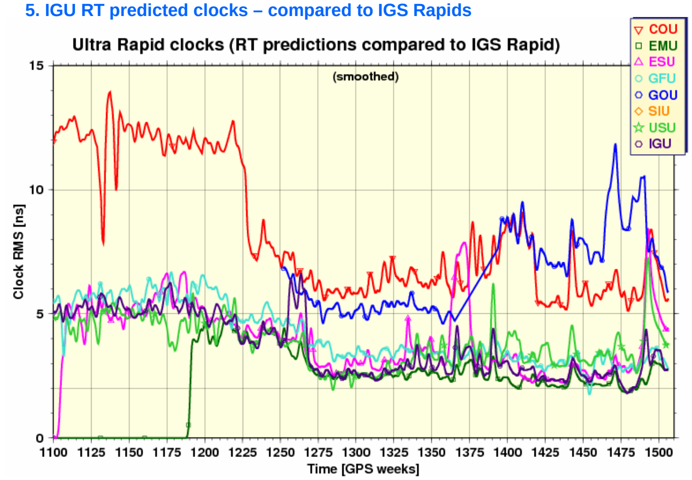
4. IGU predicted orbits over 24 hr – compared to IGS Rapids



- IGU orbit prediction errors over 24 hr are approximately double those over first 6 hr
- median orbit errors remain small & stable, permitting easy detection of RT orbit outliers
- implies that brief delays in delivery of IGU products should have minimal impact on RT users

5. IGU RT predicted clocks – compared to IGS Rapids



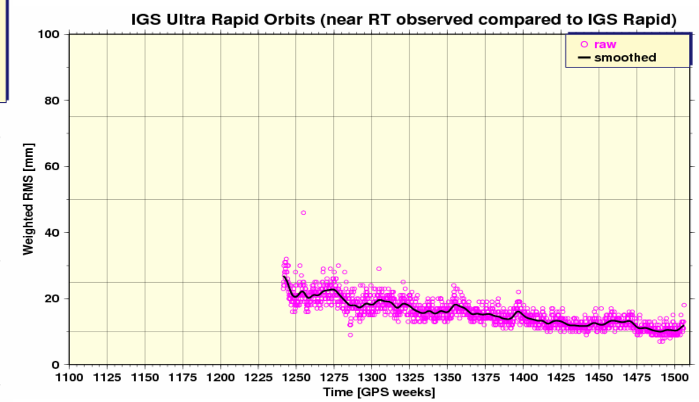
- only 4 ACs contribute observed & predicted clocks – COU & GOU submit BRDC clocks
- so IGU clock products are limited in robustness & quality
- unpredictable nature of stochastic clock variations renders IGU predictions no better than BRDC
- occasional GPS clock resets cause special problems
- best solution is to develop true real-time clock monitoring & broadcasting capability ➡ IGS Real-Time Pilot Project

7. Conclusions & consequences

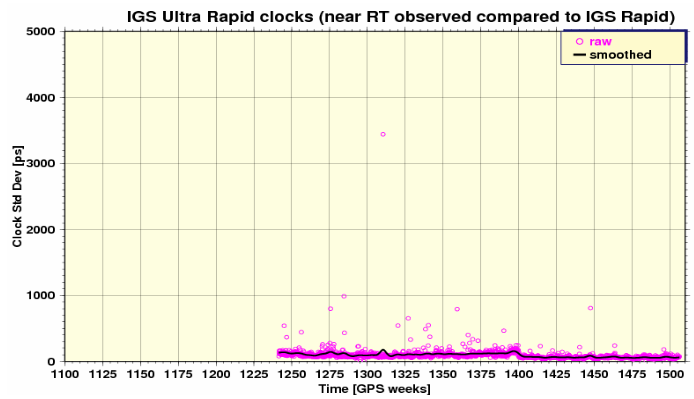
- IGS Ultra-rapid products for real-time and near real-time applications have improved dramatically
- current real-time predicted orbit precision is about 24 ± 6 mm average WRMS (1-D) over first 6 hr
- median orbit prediction error is better and more stable: 18 ± 3 mm averaged over first 6 hr
- orbit prediction errors do not grow fast – only double from 6-hr to 24-hr intervals
- Ultra-rapid observed orbits for near real-time applications nearly approach accuracy of IGS Rapid orbits
- Ultra-rapid observed satellite clocks normally have errors about double IGS Rapid clocks, but are occasionally worse due to weak redundancy
- precise point position errors with Ultra-rapid observed (near real-time) products are usually only slightly worse than using IGS Rapid products
- Ultra-rapid predicted clocks perform no better than GPS BRDC clocks
- need true real-time satellite clock monitoring from IGS Real-Time Pilot Project for accurate RT PPP
- but IGS Ultra-rapid predicted orbits probably suffice for nearly all RT applications

6. IGU near real-time observed products – compared to IGS Rapids

- first half of each IGU sp3 update from observations using IGS hourly network, not predictions
- available with 3 hr latency every 6 hr, for near RT applications



- WRMS residual of near RT observed orbits currently reaches about 10 to 15 mm level
- median orbit residuals are nearly identical



- near RT observed clocks have typical std devs of ~0.1 ns, but are occasionally worse