



Multi-GNSS Based Processing at the USNO



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Purpose

- Describe Experimental Processing of Multi-GNSS Based Products
 - Focus on Ultra-Rapids
- Compare to Similar GPS-based Signal Processing
- Future Plans

Software Setup & Processing

- Generated Using *Bernese 5.0 Software* or *Bernese 5.2 Software* (as noted)
- A Priori: Most Recent IGS Ultra-rapid GNSS Clocks, ERPs, and Orbits (IGV)
- 27 or 40 (Long-arc) hour Observation Window with GPS+GLONASS Observations (as noted)
- Network Processing (Ultra-Rapids and Rapids):
 - Use Subset of the Available Stations that Define the IGB08 Reference Frame
 - 25% of Stations Receive GLONASS + GPS Signals
 - Estimate GNSS Satellite Orbits, EOP, Receiver- and Satellite-Clock Offsets
- Precise Point Positioning (PPP) (Rapids):
 - Remaining Available Stations Yield Receiver Clock Estimates
 - Network Solutions as PPP Inputs
- No Process Tuning to Account for GLONASS Signal Difference or Biases

Comparison to 40 hr Long-arc Ultra-Rapid Solution

- Comparison of 27 hr Arc GLO+GPS Solution, 40 hr Long-arc GLO+GPS, and GPS Based Solutions wrt IGU/IGV Combinations
 - Different Baselines and Station Set Used
 - All Processed with *Bernese 5.0*

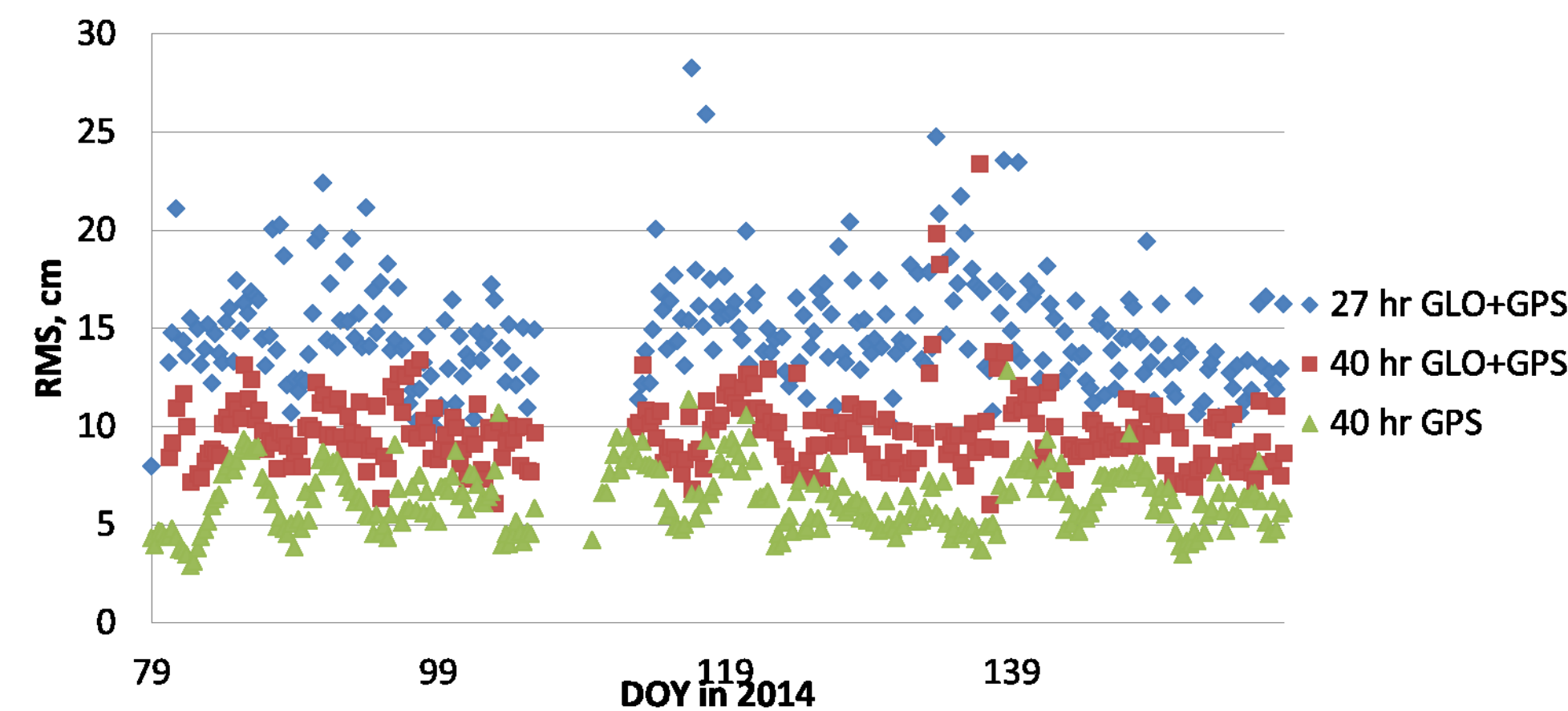
Helmert Transformation

- 7-Parameter Helmert Transformation wrt IGU/IGV Ultra-Rapid Orbit Combination

		GPS (40 hr Arc)		GLO+GPS (27 hr Arc)		GLO+GPS (40 hr Arc)	
		Av.	Std. Dev.	Av.	Std. Dev.	Av.	Std. Dev.
Translation	X [mm]	-0.7	2.3	0.1	4.3	-0.5	2.4
	Y [mm]	-0.1	2.2	-1.3	3.9	0.6	2.2
	Z [mm]	0.9	3.2	2.8	5.4	2.3	3.2
Rotation	X [μ as]	-31.3	125.2	41.4	107.7	20.0	127.9
	Y [μ as]	-63.1	124.9	-51.2	104.6	-93.6	159.9
	Z [μ as]	128.9	566.3	7.8	377.8	41.6	696.7

7 Parameter Helmert Transformation Statistics for Orbit Solutions

- Significant Improvement in RMS for 40 hr Arc Over 27 hr Arc



RMS (cm) of 7 Parameter Helmert Transformation Results for Entire 48 hrs in Orbit Solutions (Some Days Missing due to Insufficient Data)

Earth Orientation

- Difference in the Polar Motion wrt IGU
- Significant Improvement in the X Direction Polar Motion 40 hr Arc Over 27 hr Arc GLO+GPS

	GPS (40 hr Arc)		GLO+GPS (27 hr Arc)		GLO+GPS (40 hr Arc)	
	Av.	Std. Dev.	Av.	Std. Dev.	Av.	Std. Dev.
PM X [μ as]	5.2	74.9	81.8	23.8	13.8	-24.4
PM Y [μ as]	14.8	74.0	78.3	68.6	69.0	69.1

Polar Motion Statistics with Respect to IGU Combination

Future Plans

- Explore and Implement GLONASS Observations Processing Enhancements
- Incorporate into IGS Final Troposphere Estimates (Improve Estimates at Higher Latitude Stations?)
- Inclusion into IGV Combination?
- Test 40 hr Long-arc Solution in *Bernese 5.2*

Comparison to Bernese 5.2 Processing

- Comparison of 27 hr Arc GLO+GPS Solution to IGU/IGV Combinations
 - Different Baselines and Station Set Used

Observed 24 hrs

- 7-Parameter Helmert Transformation wrt IGU/IGV Ultra-Rapid Orbit Combination

		GLO+GPS (Bernese 5.0)		GLO+GPS (Bernese 5.2)	
		Av.	Std. Dev.	Av.	Std. Dev.
Translation	X [mm]	0.2	2.1	-0.2	1.6
	Y [mm]	-0.5	2.0	-0.1	1.4
	Z [mm]	1.4	3.4	2.6	3.0
Rotation	X [μ as]	-16.7	64.8	9.0	57.3
	Y [μ as]	-84.9	74.6	-90.3	78.6
	Z [μ as]	18.0	66.8	1.0	50.8

7 Parameter Helmert Transformation Statistics for 24 hrs of Observed Orbit Solutions

- Bernese 5.2* Models Align Better with IGV/IGU
 - Improvement in RMS in *Bernese 5.2* (Average 3.8 cm vs 3.4 cm)

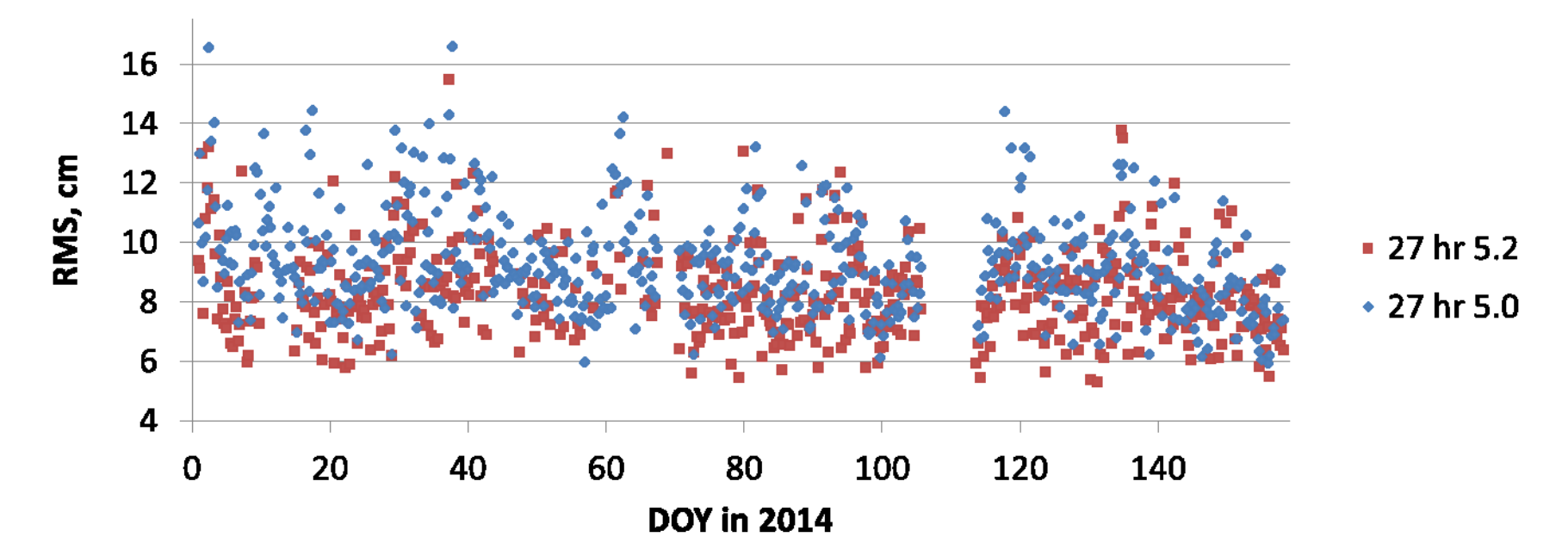
Predicted 6 hrs

- 7-Parameter Helmert Transformation wrt IGU/IGV Ultra-Rapid Orbit Combination

		GLO+GPS (Bernese 5.0)		GLO+GPS (Bernese 5.2)	
		Av.	Std. Dev.	Av.	Std. Dev.
Translation	X [mm]	-0.5	13.5	0.4	11.6
	Y [mm]	0.9	12.6	0.9	9.4
	Z [mm]	3.4	13.0	2.8	11.5
Rotation	X [μ as]	-39.6	268.4	-75.0	216.2
	Y [μ as]	-171.0	293.8	-108.0	282.3
	Z [μ as]	81.6	314.5	-3.9	326.7

7 Parameter Helmert Transformation Statistics for 6 hrs of Predicted Orbit Solutions

- Improvement in RMS in *Bernese 5.2* (Average 8.1 cm vs 9.4 cm)



RMS (cm) of 7 Parameter Helmert Transformation Results for Predicted 6 hrs in Orbit Solutions (Some Days Missing due to Insufficient Data)

Conclusions

- GLONASS Signal Processing Integrated into Experimental Ultra-Rapid-like Product
- Updated Models and Processing in *Bernese 5.2* Show Improvement as Does 40 hr Long-arc Solution
- Process Enhancements Still Needed for Using GLONASS Data

USNO Products Available Online: <ftp://maia.usno.navy.mil/GPS/>

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