

# An evaluation of the IGS real time service based on PPP



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# IGS real-time service

- launched at April 2013
- Aim: to enable sub-dm accuracy real time PPP
- Provides: satellite orbit and clock corrections to broadcast ephemeris
- 139 real time stations, 10 contributors, 8 ACs provide individual correction streams

IGS products	Latency	orbit accuracy	clock accuracy
Ultra Rapid (predict)	real time	~5 cm	~1.5 ns STD
Real Time	real time	~5 cm	0.1-0.15 ns STD
Rapid	17-41 hours	~2.5 cm	~25ps STD

- Objective of this study:  
evaluation, comparison of the IGS real time correction streams



Shown are the stations streaming real-time data to the IGS.

Source: IGS, 2013

# SSR - State Space Representation corrections

- State Space Representation: Transmission of GNSS error components
- Messages:
  1. precise orbit, satellite clock and code bias, quality indicator
  2. vertical TEC and satellite phase biases
  3. slant TEC and troposphere

SSR Message Types			
1057	GPS orbit correction	1063	GLO orbit correction
1058	GPS clock correction	1064	GLO clock correction
1059	GPS code bias	1065	GLO code bias
1060	GPS orbit & clock correction	1066	GLO orbit & clock correction
1061	GPS User Range Accuracy	1067	GLO User Range Accuracy
1062	GPS high rate clock correction	1068	GLO high rate clock correction

# Correction Streams

Stream	GNSS	Message Type	Orbit	AC
IGS01	GPS	1059(10),1060(10)	IGS Ultra Rapid	ESA/ESOC, SE comb.
IGS02	GPS	1057(60), 1058(10),1060(10)	IGS Ultra Rapid	BKG, KF comb.
CLK10	GPS	1057(60), 1058(5),1060(5)	IGS Ultra Rapid	BKG
CLK16	GPS	1059(5), 1060(5)	IGS Ultra Rapid	WUHAN
CLK20	GPS	1059(5), 1060(5)	IGS Ultra Rapid	DLR
CLK22	GPS	1057(300), 1058(5), 1059(5)	Internal Ultra Rapid	NRCan
CLK53	GPS	1059(5), 1060(5)	IGS Ultra Rapid	ESA/ESOC
CLK70	GPS	1059(5), 1060(5)	IGS Ultra Rapid	GFZ
CLK80	GPS	1059(5), 1060(5), 1066(5)	Internal Ultra Rapid	GMV
CLK93	GPS	1059(10), 1060(10)	IGS Ultra Rapid	CNES
IGS03	GPS+GLO	1057(60), 1058(10), 1059(10), 1063(60), 1064(10), 1065(10)	CODE Ultra Rapid	BKG, KF comb.
CLK11	GPS+GLO	1057(60), 1058(5), 1059(5), 1063(60), 1064(5), 1065(5)	CODE Ultra Rapid	BKG
CLK80	GPS+GLO	1059(5), 1060(5), 1066(5)	Internal Ultra Rapid	GMV
CLK91	GPS+GLO	1059(5), 1060(5), 1065(5), 1066(5)	CODE Ultra Rapid	CNES

# IGS Combination Corrections

- IGS01 (ESA/ESOC)
  - single epoch combination
  - orbit: average value from all contributions
  - clock:
    - a weighted average clock
    - offset has been removed, outliers are detected and removed
  
- IGS02 (BKG)
  - kalman filter combination
  - need few minutes convergence time
  - orbit: extracted from one of the contribution
  - clock:
    - estimated with the adjustment process
    - using clocks from individual ACs as pseudo observations
    - outliers are detected
  
- IGS03 (BKG)
  - the same as IGS02 for GPS+GLO

Source: IGS, 2013

# Dataset and Software

## ➤ Data

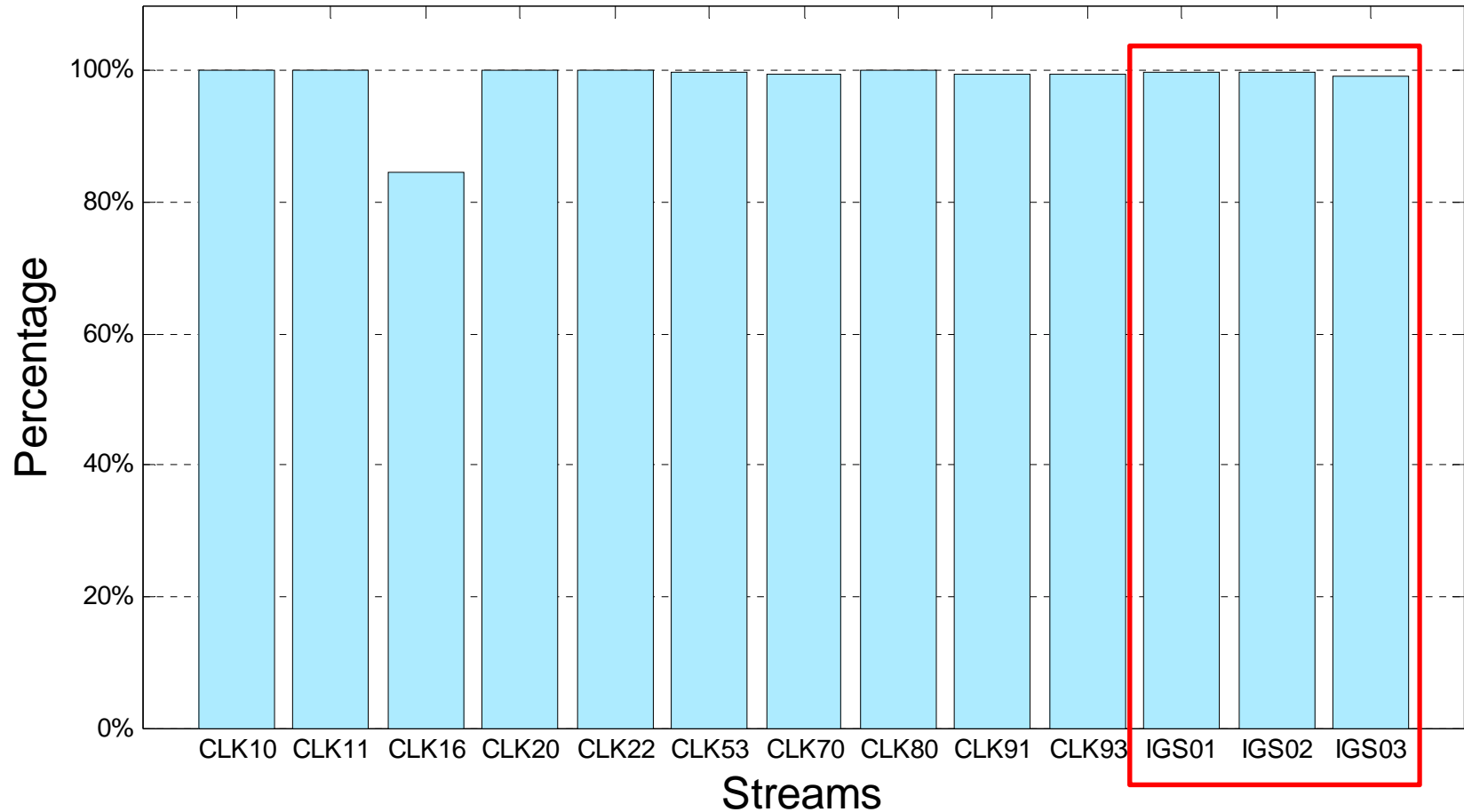
- 1 week data: 2013, Doy 227 – 233 (2013.8.15 - 8.21)
- Station: ZIM2, WTZR (1Hz)
- Eph+SSR: broadcast ephemeris stream, 14 ssr correction streams
- IGS rapid products used as reference

## ➤ Software

- BNC 2.9
  - retrieve real time data streams
- GEMon
  - developed by PSGD & BKG
  - retrieve real time data from BNC, generate PPP solution

# Outage & Latency

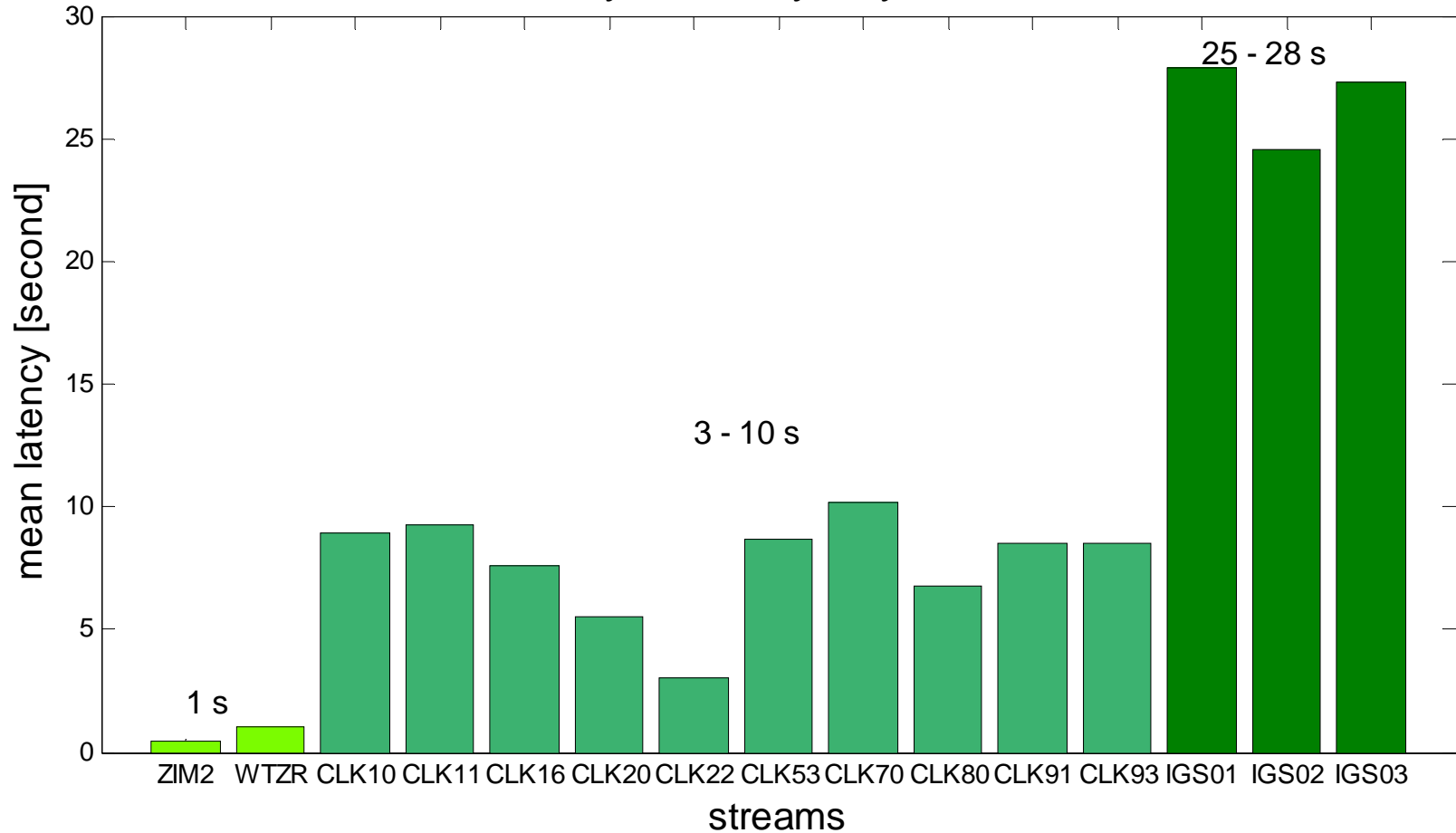
SSR correction availability



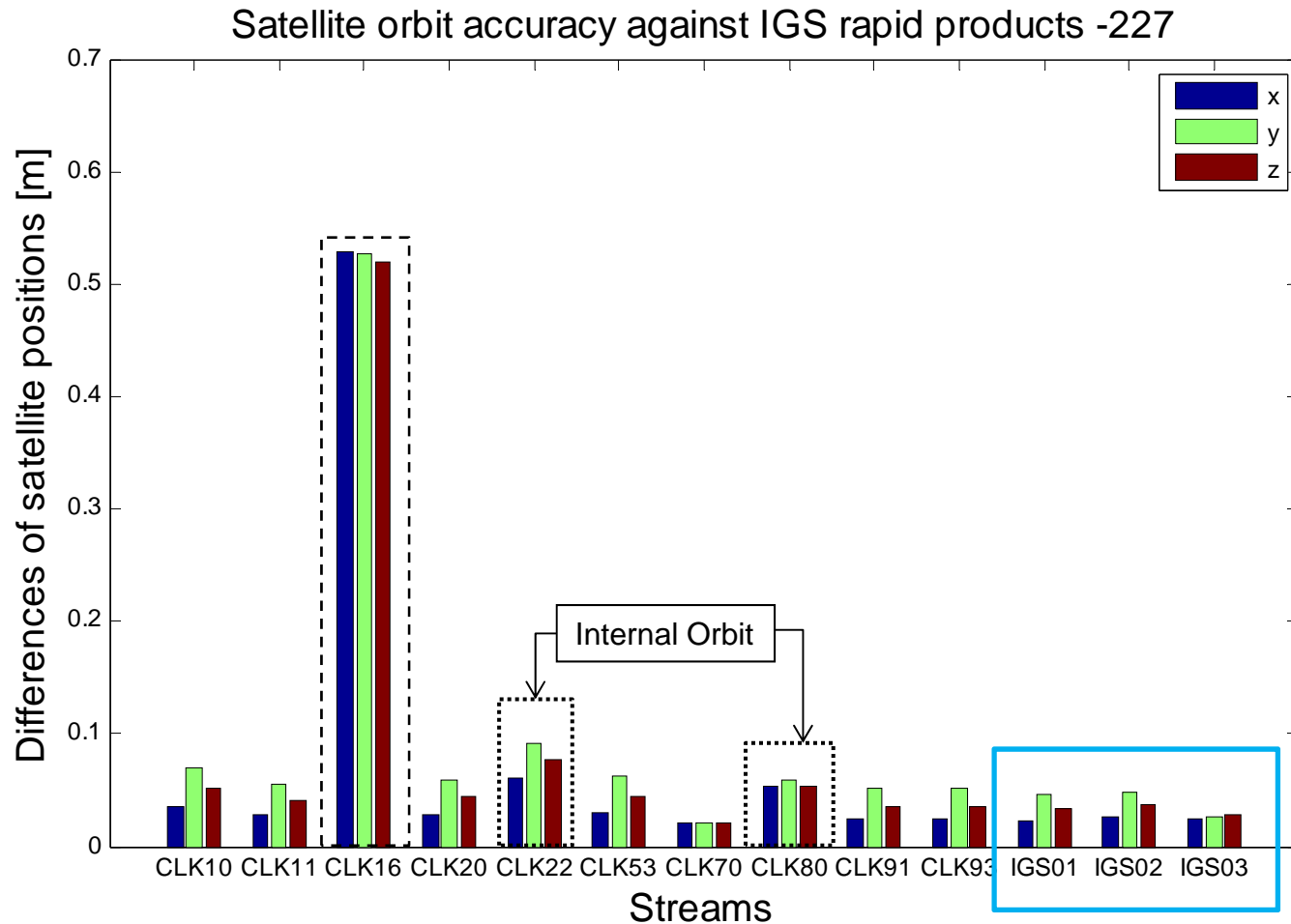


# Outage & Latency

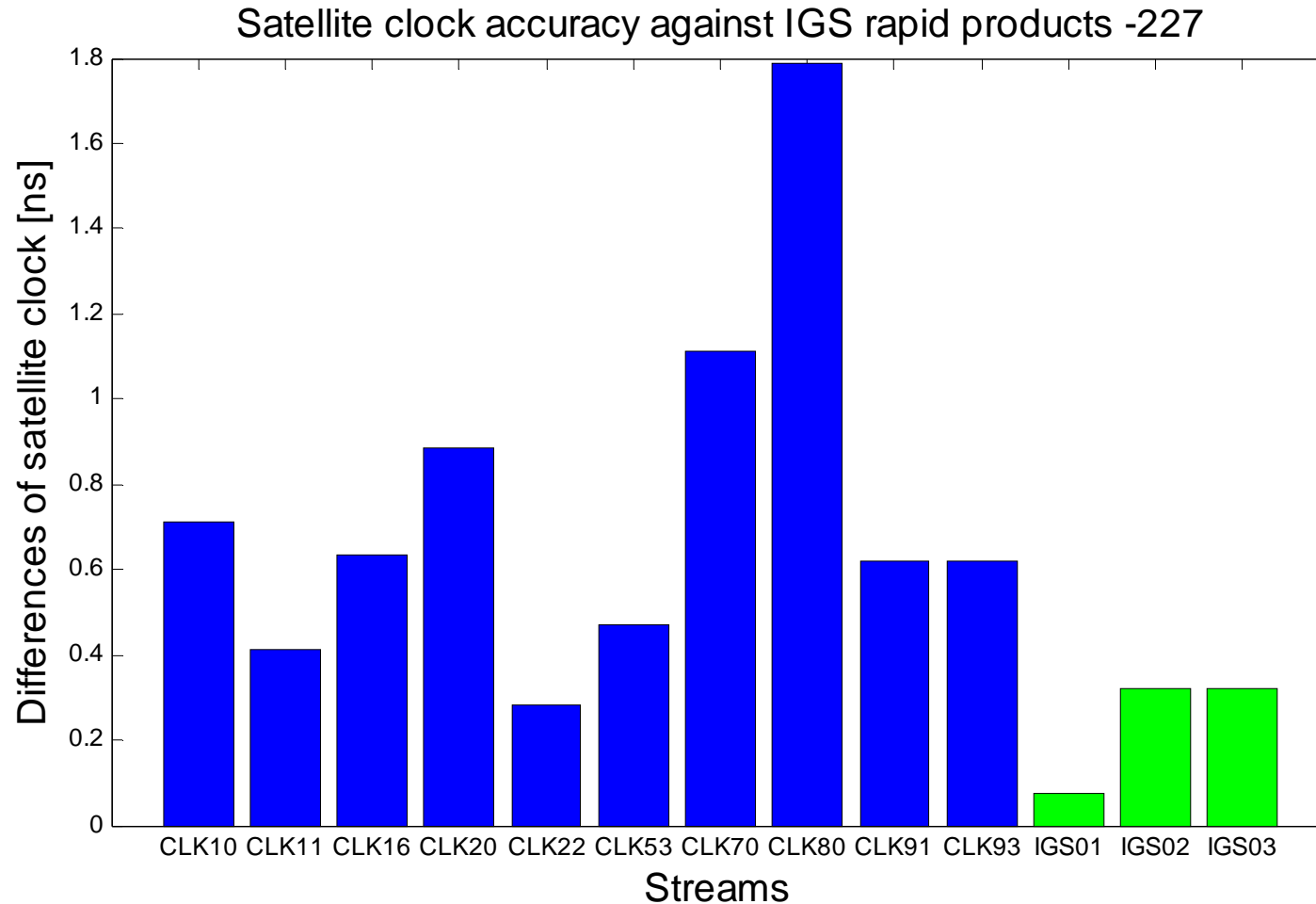
Mean latency from day of year 227 to 233



# Orbit against IGS rapid products



# Satellite Clock against IGS rapid products



# PPP Processing Strategy



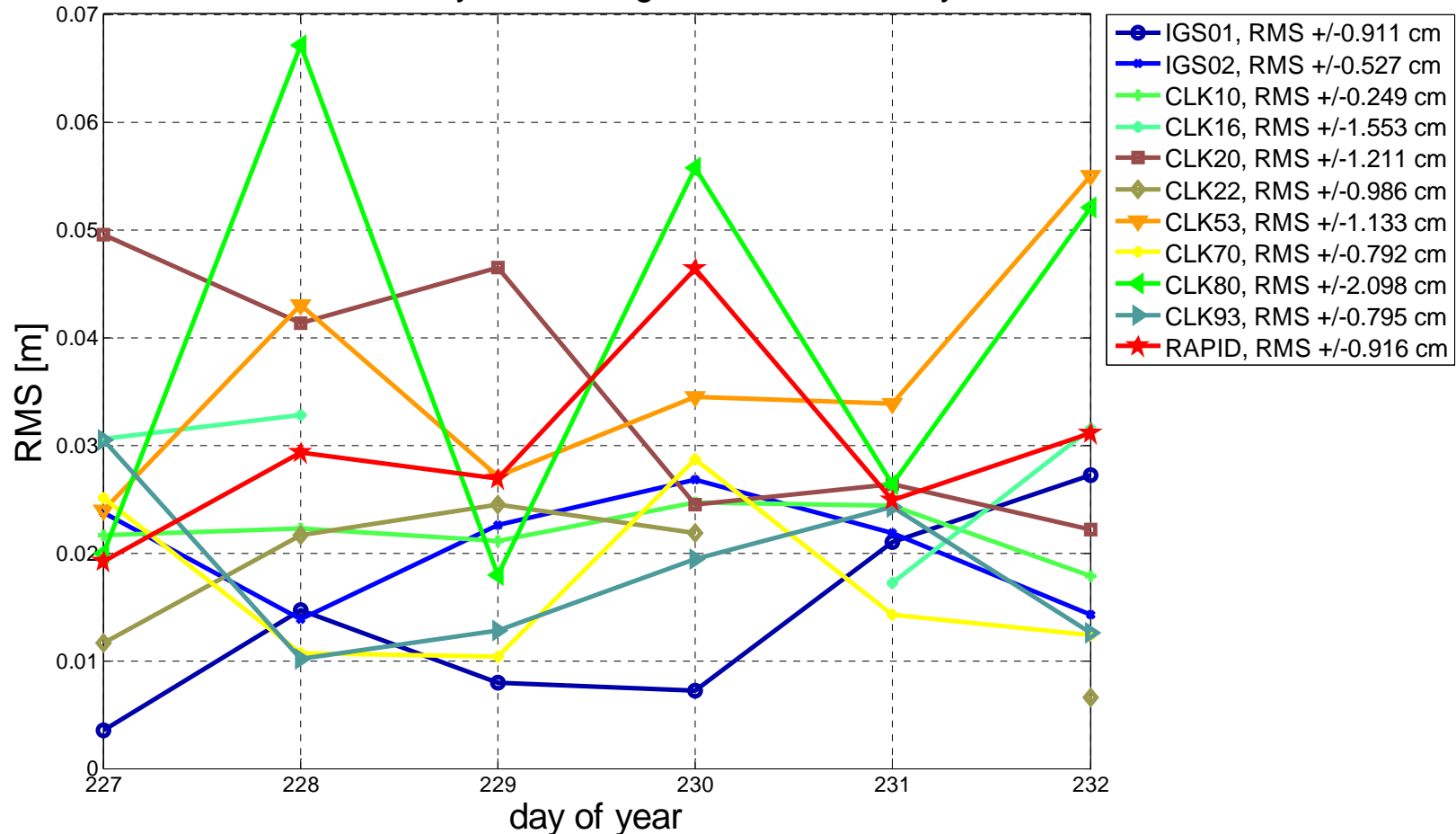
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## GEMon setup

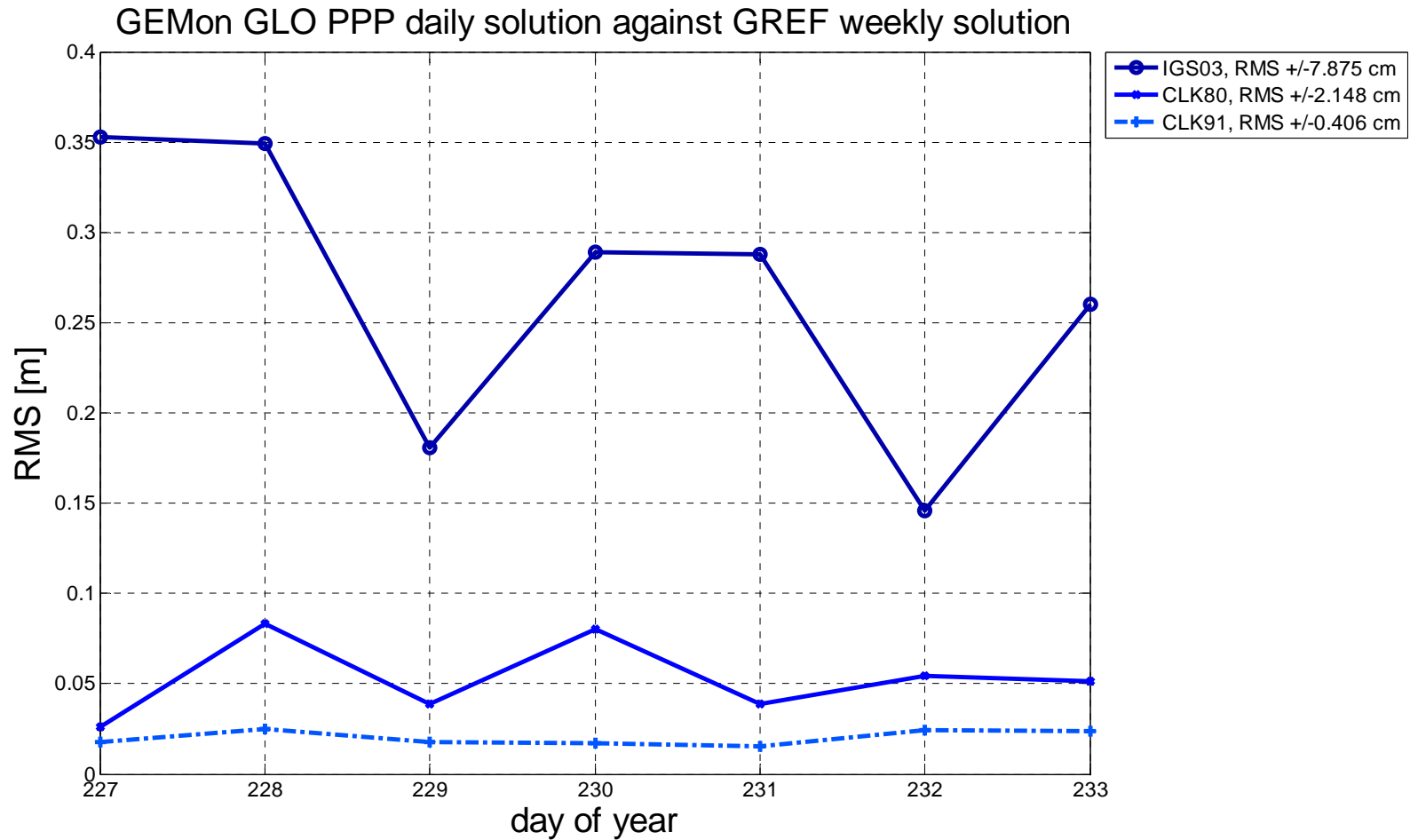
Estimation	normal equation stacking
Corrected	solid earth tides, ocean loading, antenna phase center correction
Troposphere Model	zenith hydrostatic delay: GPT/Saastamoinen mapping function: GMF
Estimated parameters	<ul style="list-style-type: none"><li>- receiver clock error [1 per epoch]</li><li>- troposphere zenith wet delay [1 per hour]</li><li>- Float ambiguity [1 per Satellite per Arc]</li><li>- Inter-system bias (GPS+GLO) [1 per day]</li><li>- Inter-frequency code bias (GLO only) [1 per satellite per day]</li></ul>
Obs. Sigma	code: 1.5 m, phase: 0.01 m
Ref. Coord.	grf17517.snx

# PPP Solution

GEMon GPS PPP daily solution against GREF weekly solution



# PPP Solution



# PPP Convergence Time

	Conv. Time [min]	CLK 10	CLK 16	CLK 20	CLK 22	CLK 53	CLK 70	CLK 80	CLK 91	CLK 93	IGS 01	IGS 02	IGS 03
N	<20	86.3%	91.0%	94.6%	88.2%	95.8%	93.8%	100%	100%	94.0%	81.5%	89.9%	100%
	20-30	8.9%	4.5%	2.4%	8.2%	4.2%	2.1%	0%	0%	3.6%	14.3%	7.1%	0%
E	<20	67.3%	79.3%	85.1%	82.7%	87.5%	81.3%	100%	100%	86.3%	72.6%	69.6%	57.1%
	20-30	27.4%	12.6%	9.5%	12.7%	12.5%	10.4%	0%	0%	10.7%	20.2%	25%	28.6%
U	<20	71.4%	75.7%	86.3%	70%	87.5%	79.2%	100%	100%	84.5%	70.2%	69.6%	85.7%
	20-30	20.2%	18.0%	8.9%	20.9%	12.5%	11.5%	0%	0%	11.9%	24.4%	23.2%	14.3%

- N: most of the test cases\* (over 90%) convergent in 20 minutes
  - E, U: most of the test cases\* (over 90%) convergent in 30 minutes
- \* restart PPP every hour

# Conclusion & Outlook

- IGS real time service enables cm level real time PPP
- GLONASS only PPP can reach dm accuracy
- IGS combination correction
  - Pros:
    - high availability, less outage
    - more stable and outliers have been removed
    - more reliable than individual corrections
  - Cons:
    - longer latency (30s)
    - inconsistency of the orbit and clock
- Recommend to use: IGS01 or IGS02 for GPS, CLK91 for GLO
  
- Ambiguity can be fixed with the biases provided by some AC, e.g. CNES, GFZ





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# Thank you for your attention!

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