

第59回宇宙科学技術連合講演会

2H13

MADOCAにおける PPP-AR機能の拡張と評価

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2015-10-7 ~ 9 @かごしま県民交流センター

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MADOCA

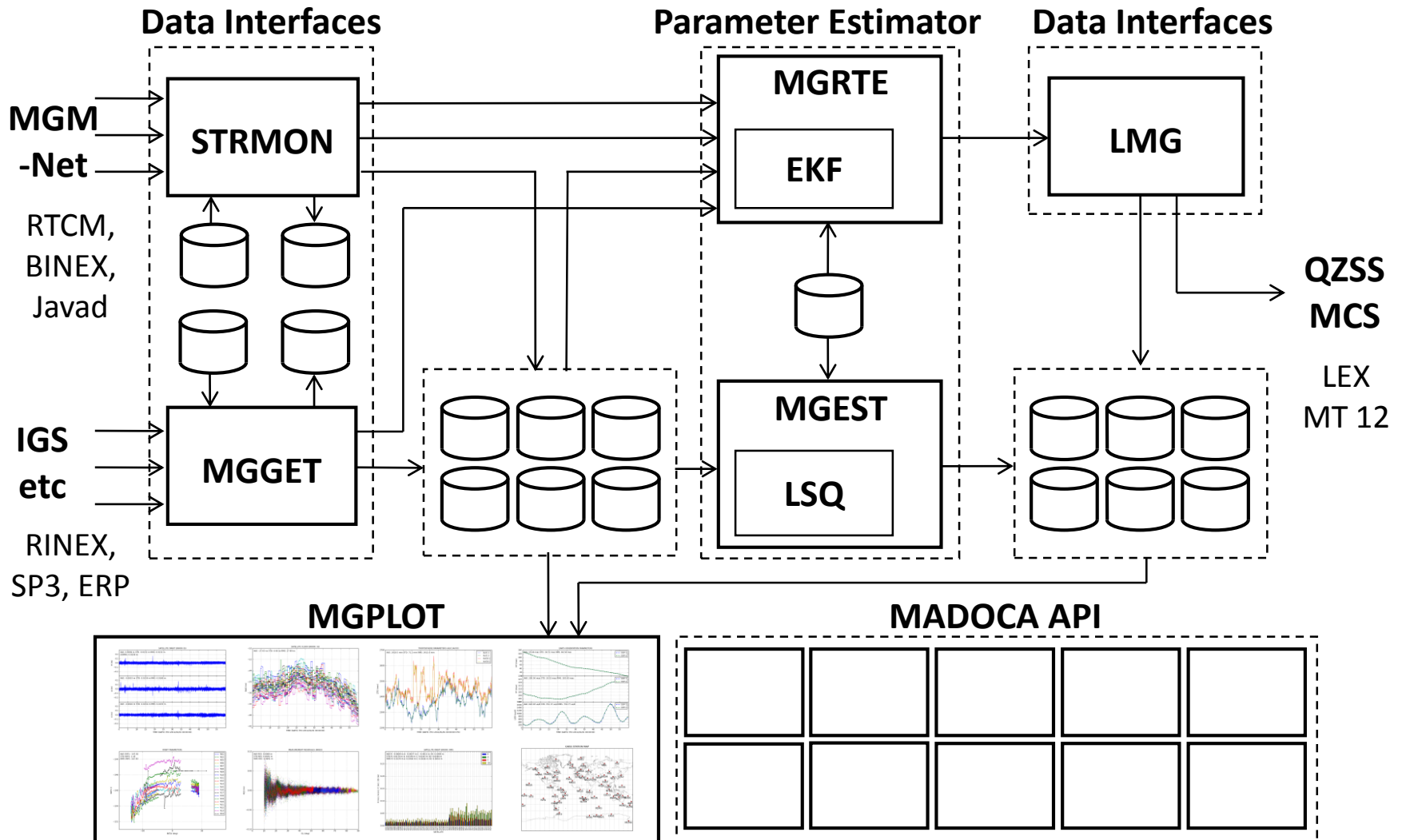
Overview

MADOCA

Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis

- **For real-time PPP service via QZSS LEX**
 - Many (potential) applications over global area
- **Precise orbit/clock for multi-GNSS constellation**
 - Key-technology for future cm-class positioning
- **Brand-new codes developed from scratch**
 - Optimized multi-threading design for recent CPU
 - As basis of future model improvements

MADOCA Architecture



PPP-AR

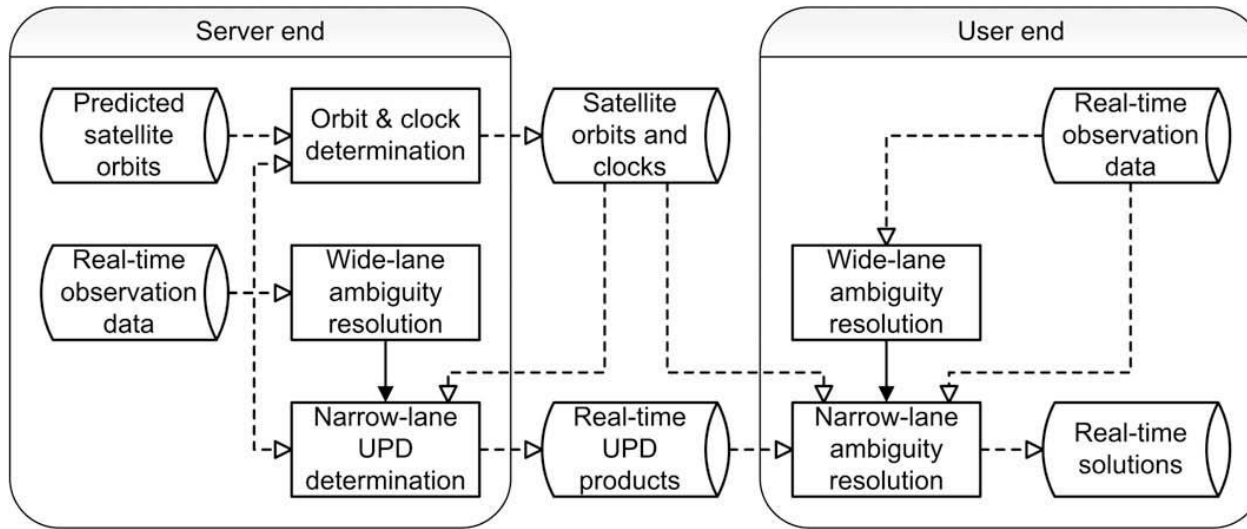
PPP-AR: References

- M. Ge et al., Resolution of GPS carrier-phase ambiguities in Precise Point Positioning (PPP) with daily observation, J Geod., 2008
- P. Collins et al., Precise Point Positioning with Ambiguity Resolution using the Decoupled Clock Model, ION ITM 2008
- D. Laurichesse et al., Real time-difference ambiguities fixing and absolute RTK, ION NTM 2008
- W. Bertiger et al., Single receiver phase ambiguity resolution with GPS data, J Geod., 2010

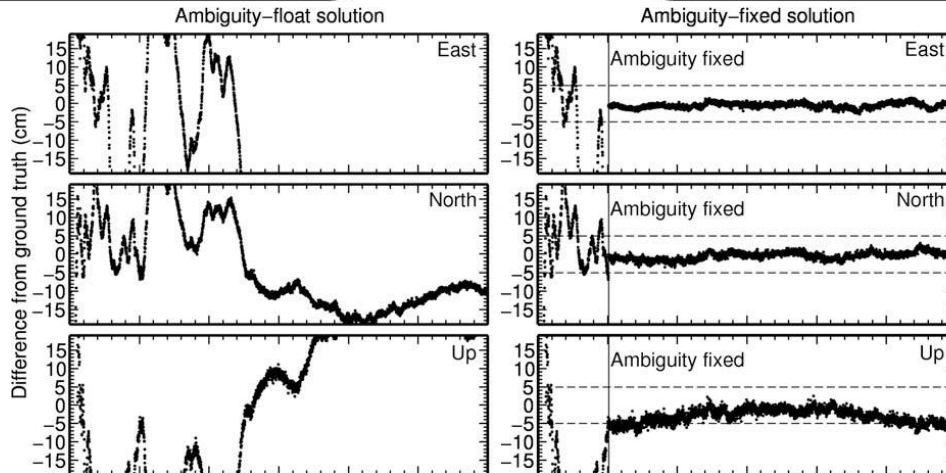
Techniques for PPP-AR

- **FCB (Fractional cycle bias) or UPD -based**
 - M. Ge et al., (2008) : WL/NL UPD estimation
- **IRC (Integer recovery clock) -based**
 - D.Laurichesse et al., (2008): WL FCB + NL FCB in clock estimation
 - P. Collins et al., (2008) : Decoupled clock model (estimation of carrier-phase clock)
- **Real-time PPP-AR**
 - D. Laurichesse et al., (2010) Real-time PPP with undifferenced integer ambiguity resolution (PPP-WIZARD)

Real-time Implementation



**Ambiguity-Float
Position**

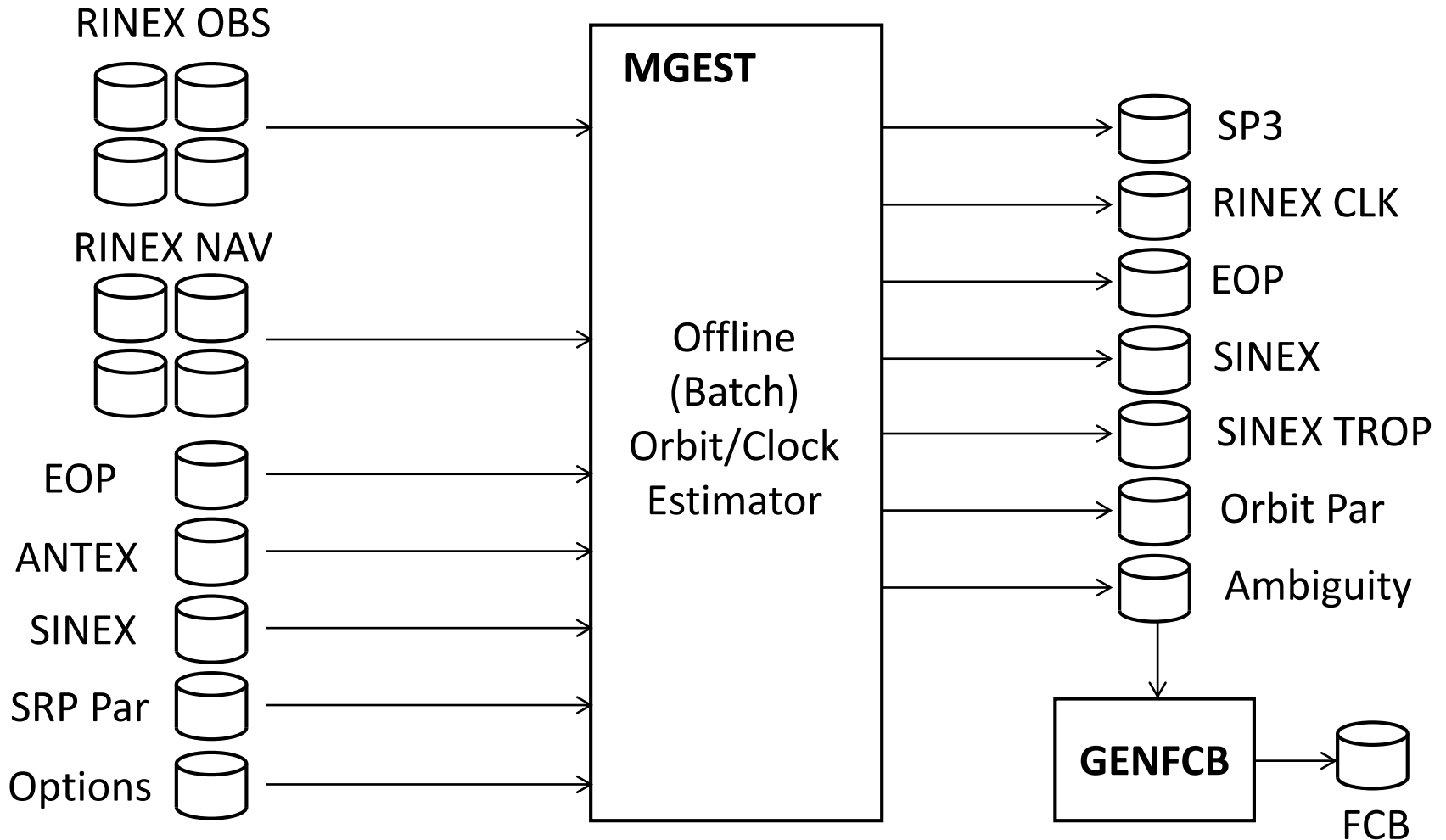


**Ambiguity-Fixed
Position**

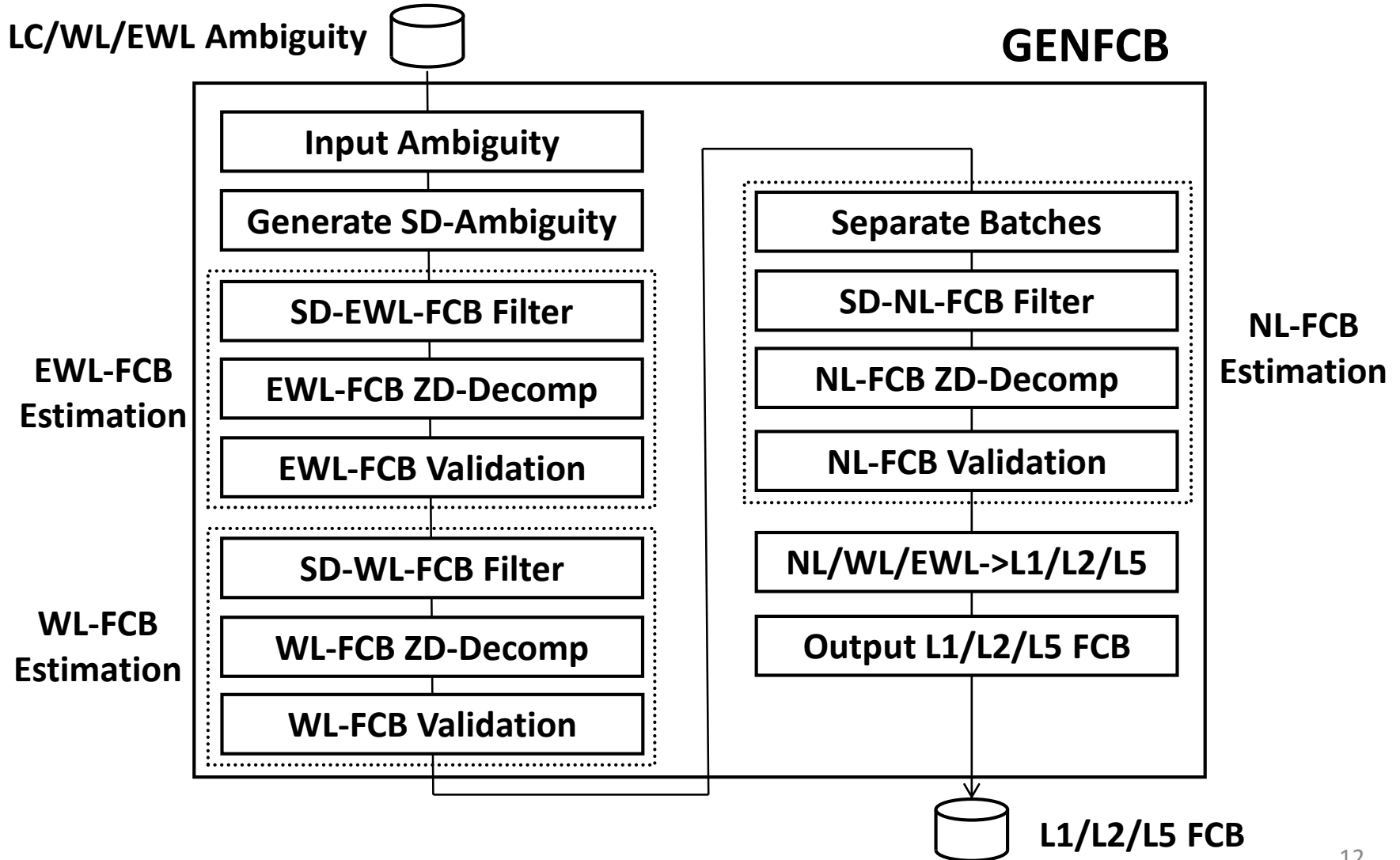
J. Geng et al., Towards PPP-RTK: Ambiguity resolution in real-time precise point positioning, *Advances in Space Research*, 2010

FCB Estimation by MADOCA

FCB Estimation Flow (1)



FCB Estimation Flow (2)



MADOCA FCB Product

```
## FRACTIONAL CYCLE BIAS BY GENFCB v.1.3
```

```
#s 3 L1 L2 L5
```

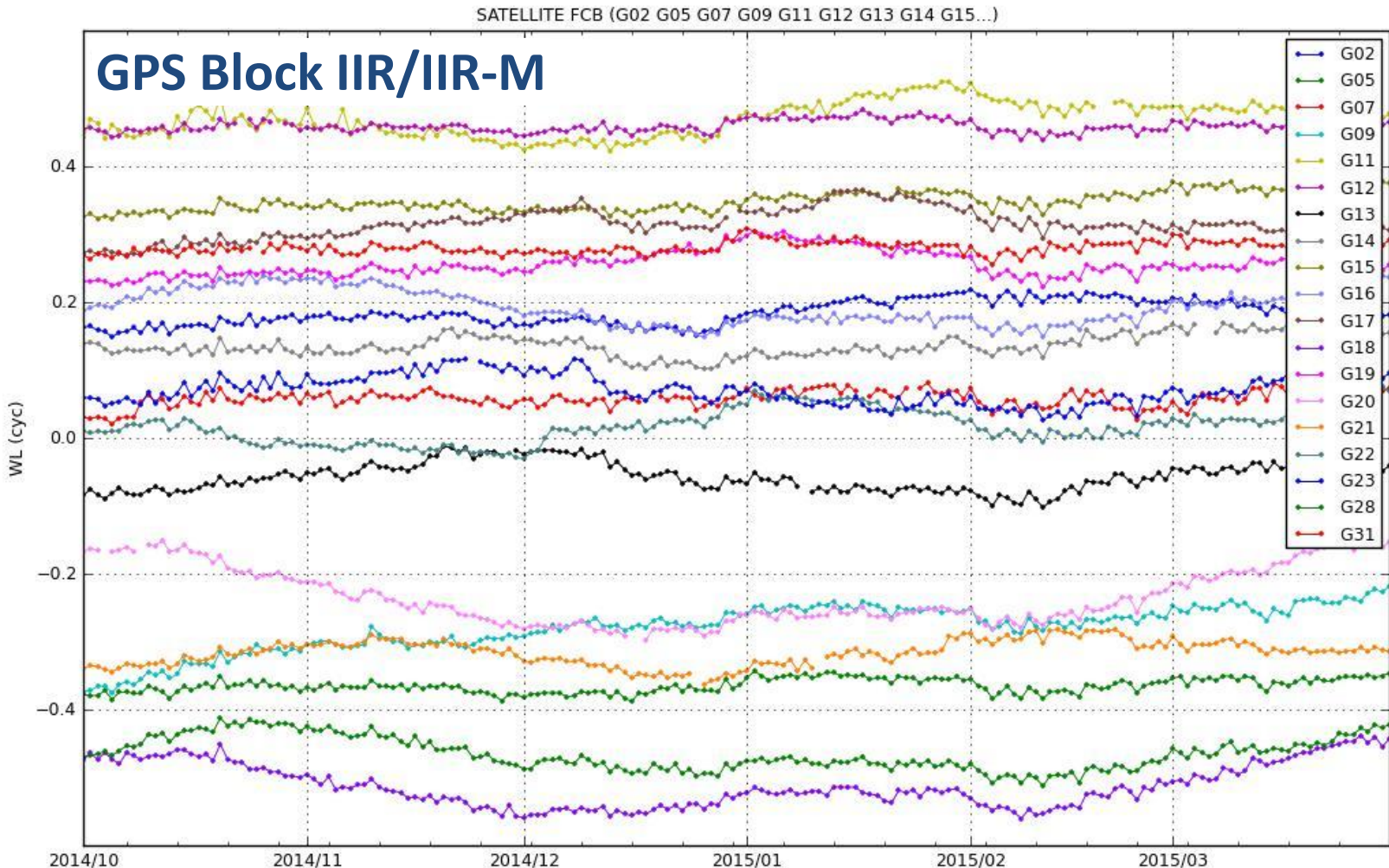
```
#
```

```
# UNIT: CYCLE
```

#	ARC-START	ARC-END	SAT	L1-FCB	L1-STD	L2-FCB	L2-STD	L5-FCB	L5-STD
2014/10/07	00:00:00	2014/10/07 00:05:00	G01	0.20367	0.10219	0.20551	0.13064	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G02	-0.59485	0.11444	-0.71000	0.13594	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G04	-1.38683	0.09203	-1.65885	0.11767	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G05	1.62260	0.09611	2.03821	0.12201	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G06	0.60561	0.12469	0.72626	0.14952	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G07	-0.17487	0.09220	-0.16464	0.11795	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G08	-1.26310	0.09242	-1.74532	0.11818	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G09	-1.30650	0.10005	-1.90609	0.12712	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G10	0.35956	0.11857	0.53682	0.14065	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G11	-1.19034	0.10116	-1.59458	0.12948	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G12	-1.63534	0.11846	-2.04824	0.14092	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G13	0.78335	0.09871	0.90689	0.12562	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G14	-0.31354	0.11955	-0.40365	0.14133	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G15	-1.25226	0.09473	-1.53965	0.12077	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G16	-0.53209	0.11189	-0.69963	0.13353	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G17	-0.70799	0.09507	-0.93581	0.12082	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G18	2.83625	0.10039	3.34118	0.12745	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G19	-0.36605	0.09612	-0.55828	0.12218	0.00000	0.00000
2014/10/07	00:00:00	2014/10/07 00:05:00	G20	-2.90687	0.11546	-3.70499	0.13877	0.00000	0.00000

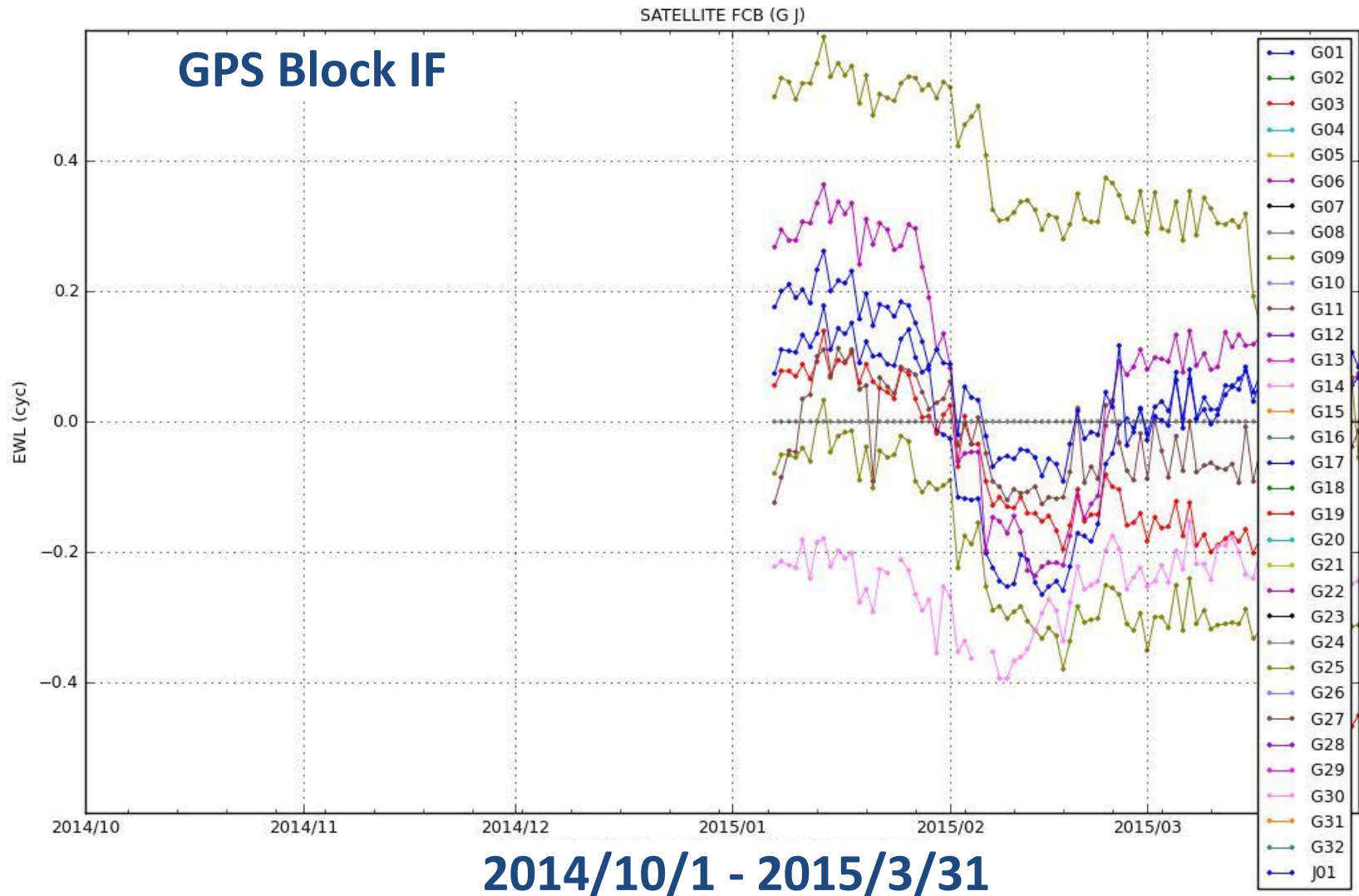
```
...
```

WL-FCB

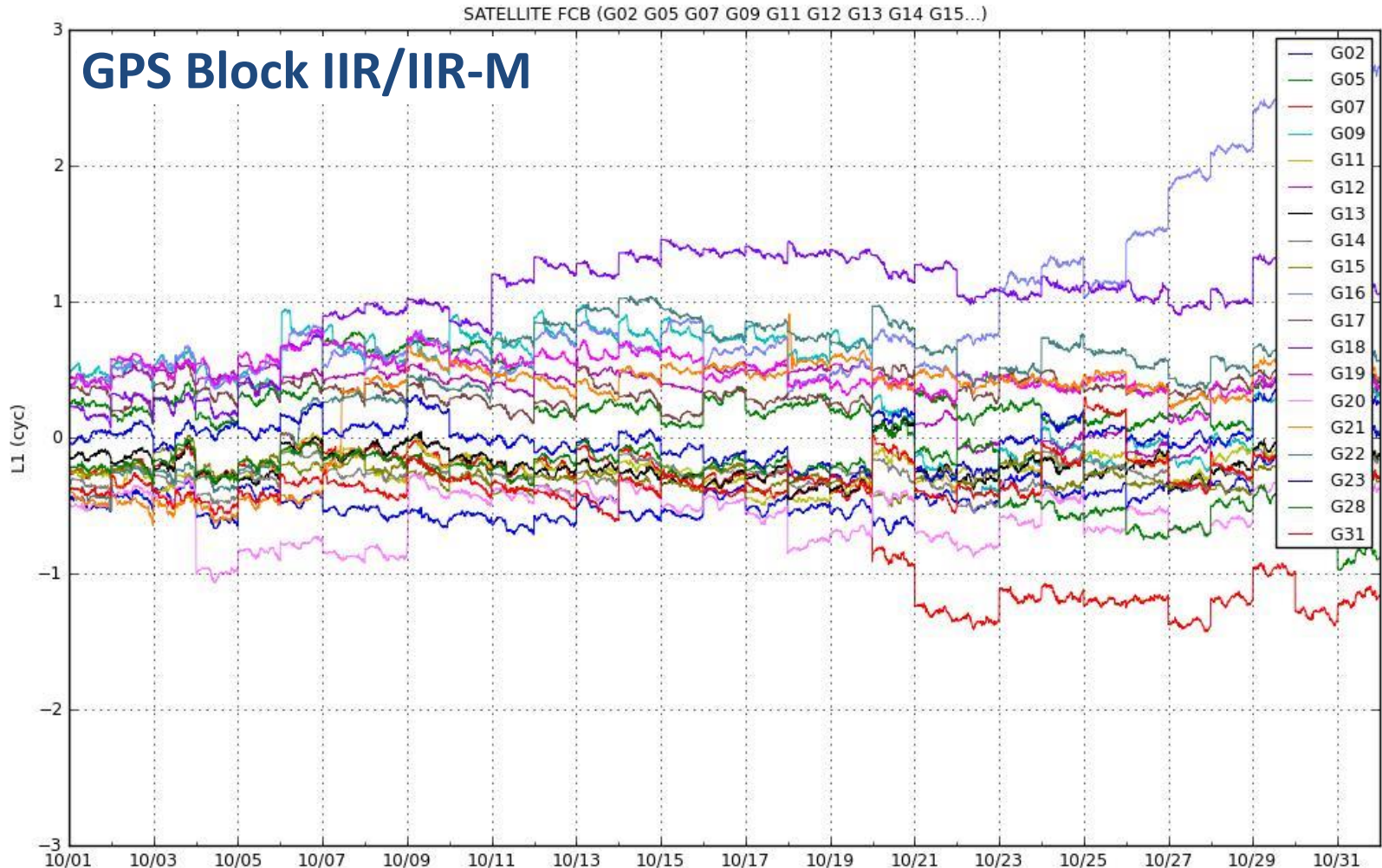


2014/10/1 - 2015/3/31

EWL-FCB



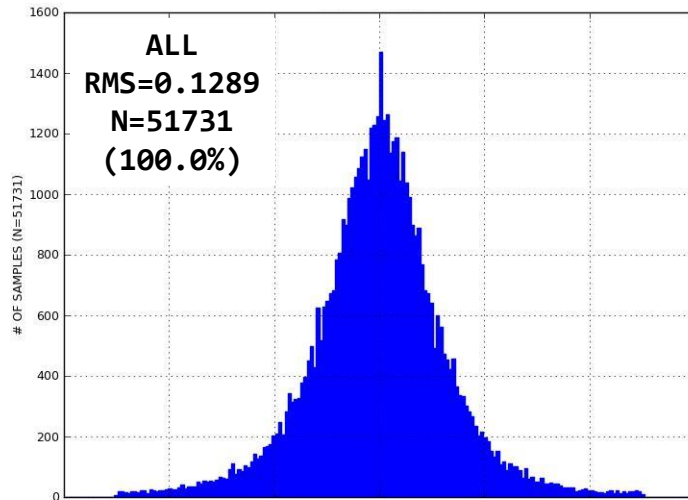
NL-FCB



2014/10/1 - 2014/10/31

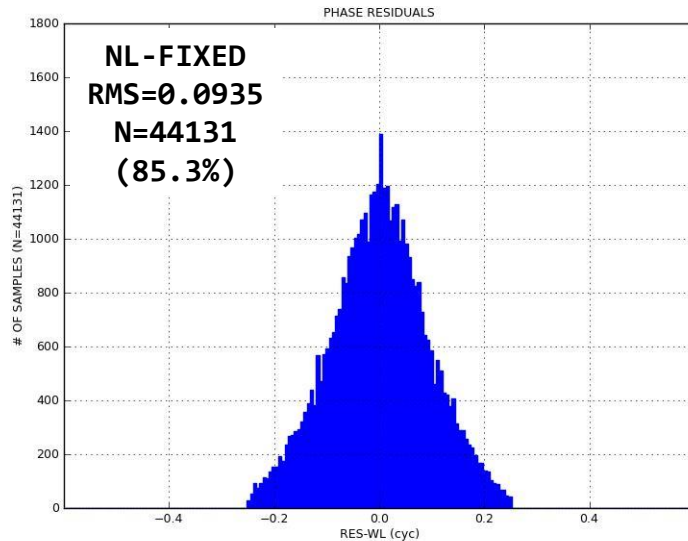
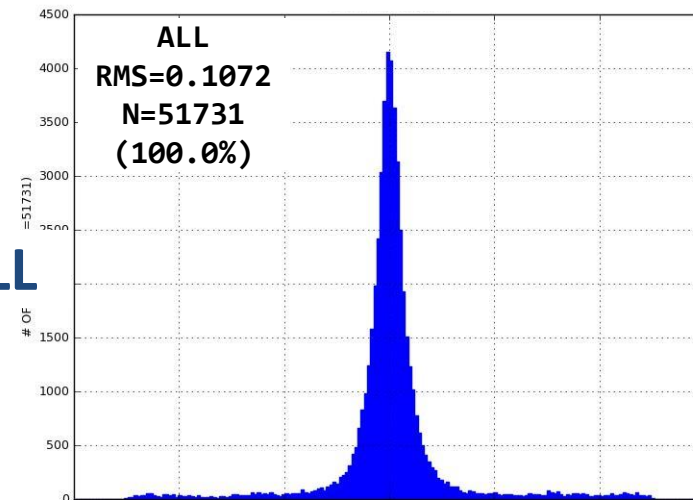
Histogram of FCB Residuals

WL-FCB

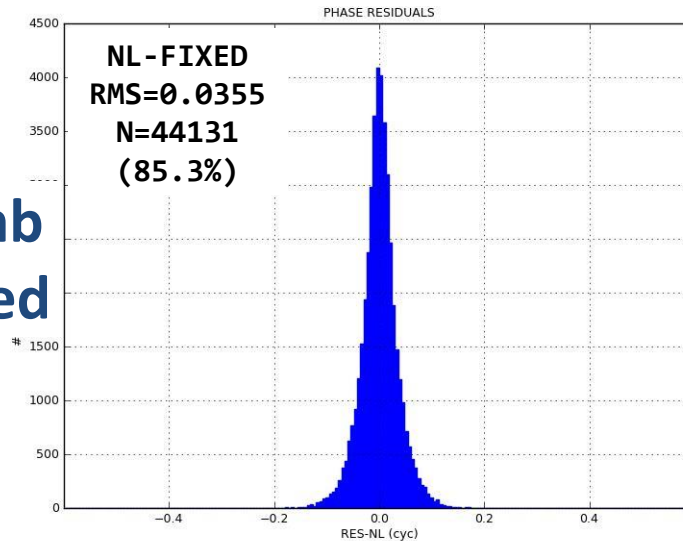


NL-FCB

ALL



Amb
Fixed



User PPP Client

User PPP Client

- **Based on RTKLIB 2.4.2 p11**
 - PPP codes are completely re-written
- **AR Modes**
 - Conventional WL/NL and rounding
 - Explicit STEC estimation and ILR (integer least square)
- **Batch and Real-time APs**
 - RNX2RTKP and RTKRCV AP
- **TEC and ZTD can be output for local-corrections**

Partial Fixing with ILS (1)

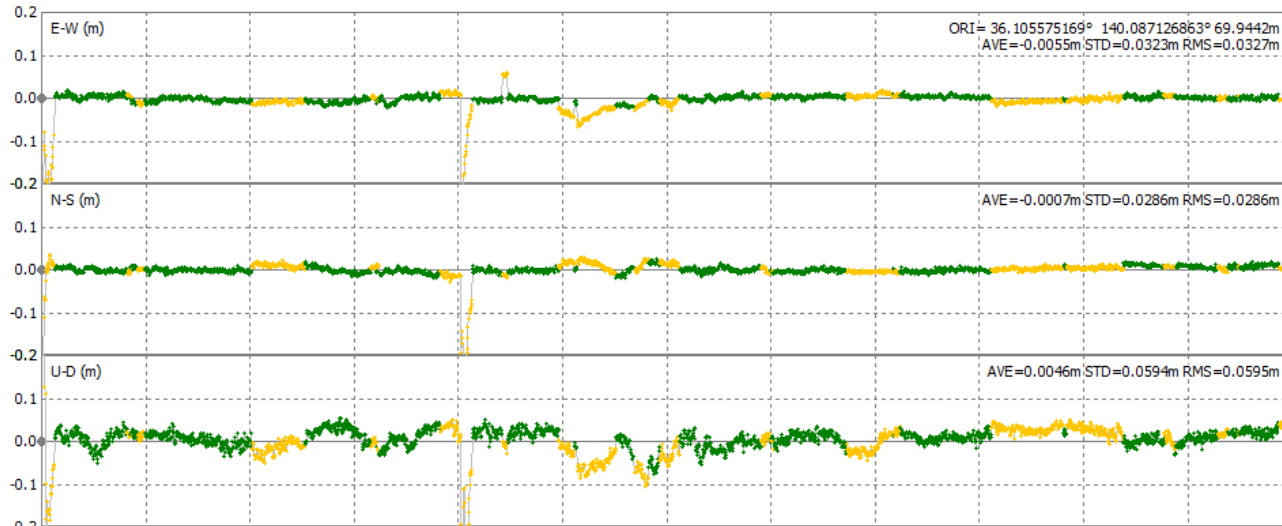
- LAMBDA decorrelation
- MLAMBDA search
- Validation by ratio-test
- Shrink search space



SOLUTION ERROR			RATIO	# OF FIXED AMBIGUITIES (N1,N2,...)
E(m)	N(m)	U(m)		
0.0024	0.0074	0.0141	1.577	12 (57 72 53 10 39 -78 40 607 -1496 -165 -576 812)
0.0026	0.0084	0.0132	1.484	11 (57 72 53 10 39 -78 40 607 -1496 -165 -576)
-0.0144	0.0301	-0.0198	1.537	10 (57 72 53 10 39 -78 40 607 -1496 -165)
0.0404	0.0129	-0.0962	5.401	9 (57 72 53 10 39 -78 40 607 -1496)
0.0295	0.0151	-0.1035	4.105	8 (57 72 53 10 39 -78 40 607)
-0.2267	0.0351	-0.1898	13.118	7 (57 72 53 10 39 -78 40)
-0.2288	0.0359	-0.1848	13.131	6 (57 72 53 10 39 -78)
-0.2492	0.0396	-0.1930	49.235	5 (57 72 53 10 39)
-0.2505	0.0391	-0.1943	102.132	4 (57 72 53 10)

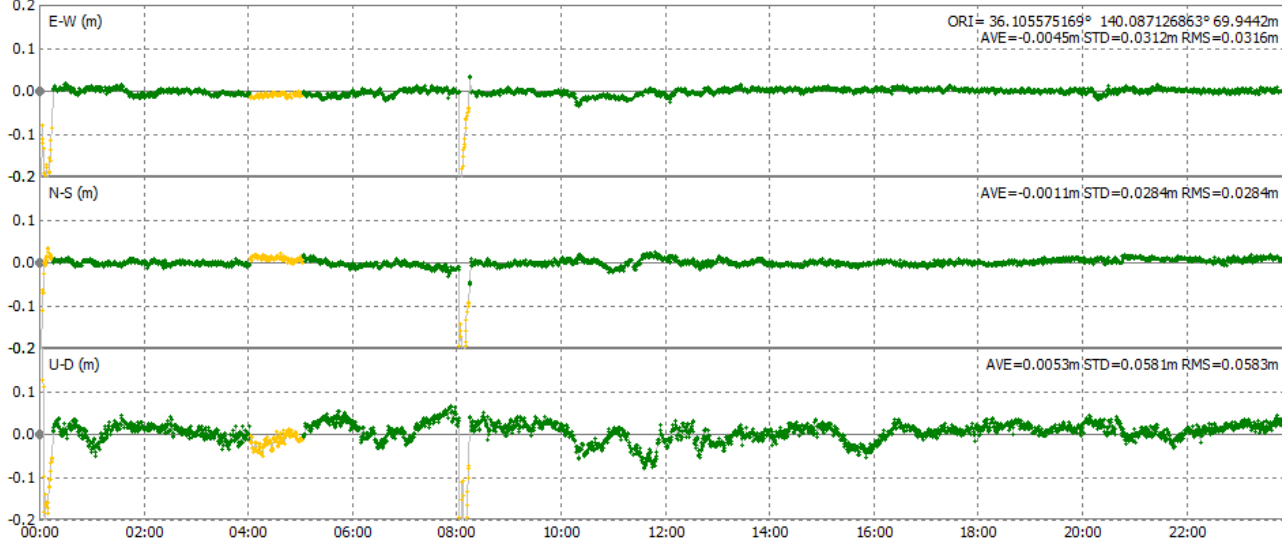
Partial Fixing with ILS (2)

Without
Partial
Fixing



**FIX RATE
= 64.9%**

With
Partial
Fixing

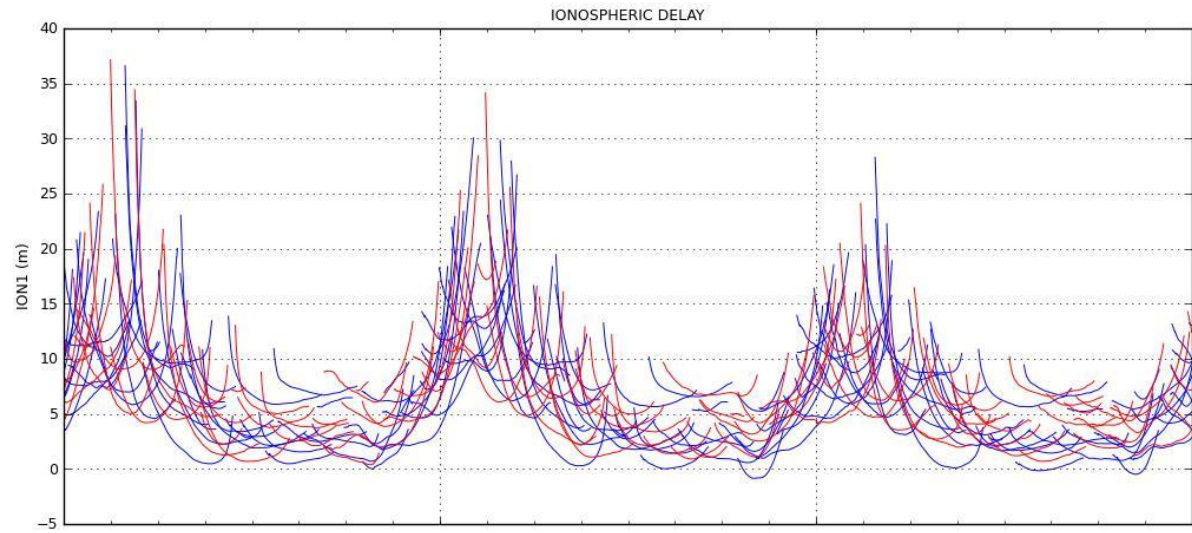


**FIX RATE
= 93.9%**

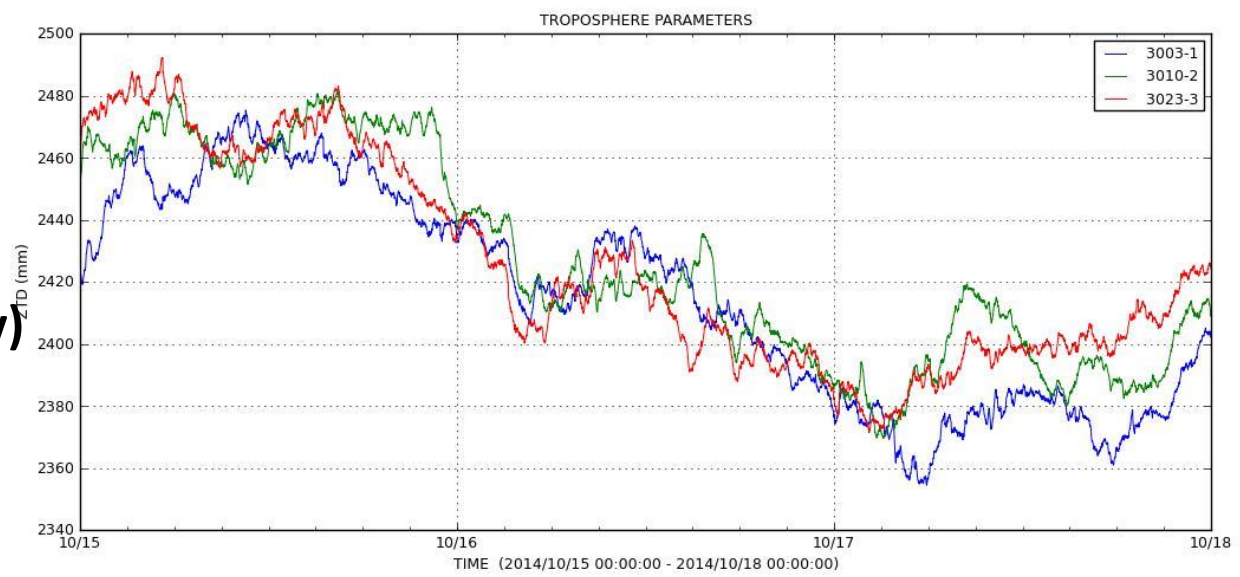
-- FIX -- FLOAT

Local TEC and ZTD by PPP-AR

TEC
(VTEC)



ZTD
(Zenith
Total Delay)

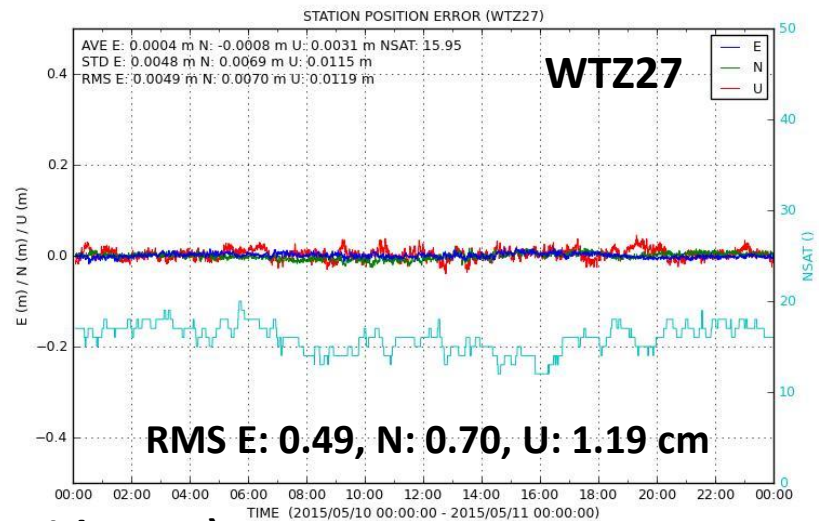
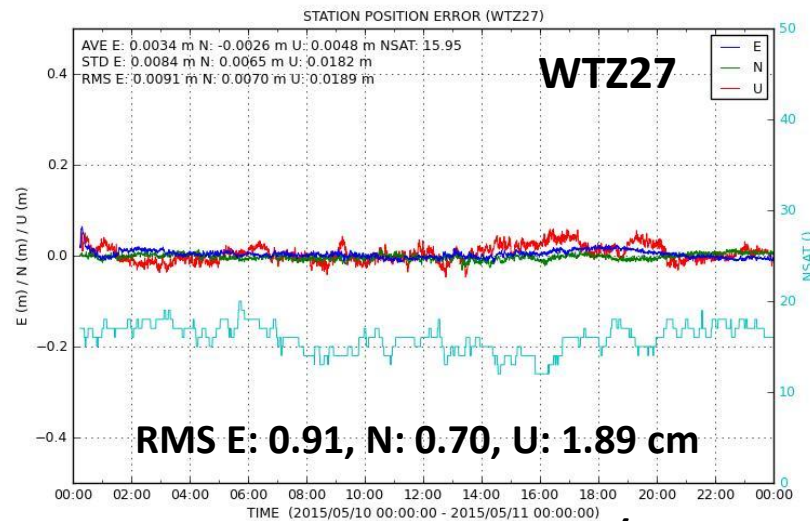
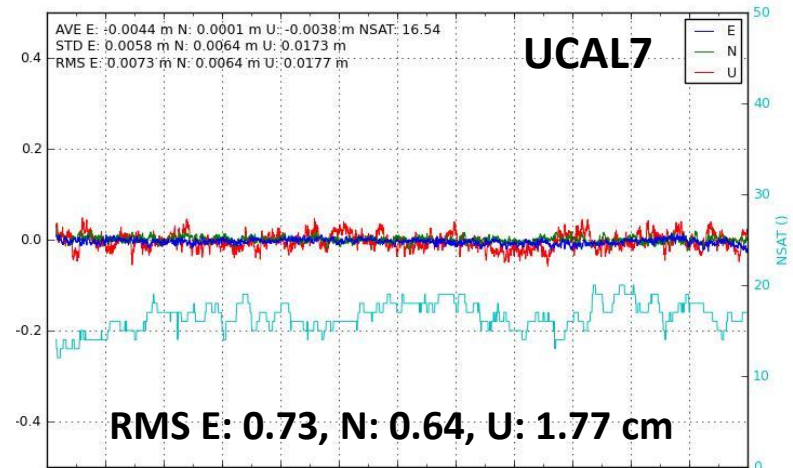
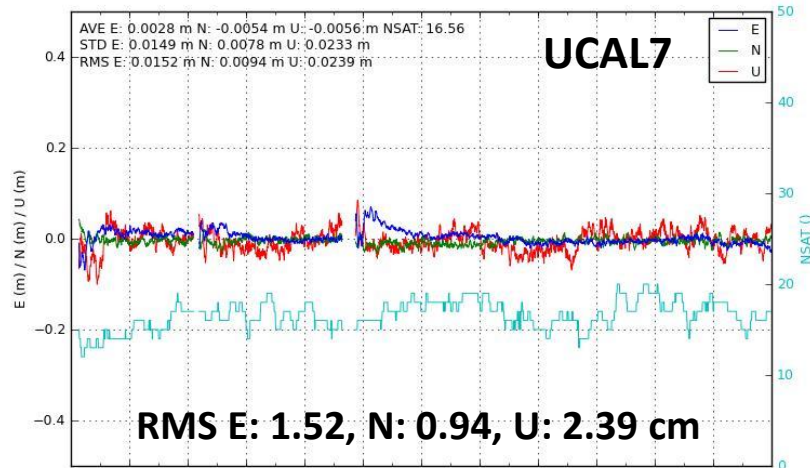


Performance Evaluation

Kinematic PPP Accuracy

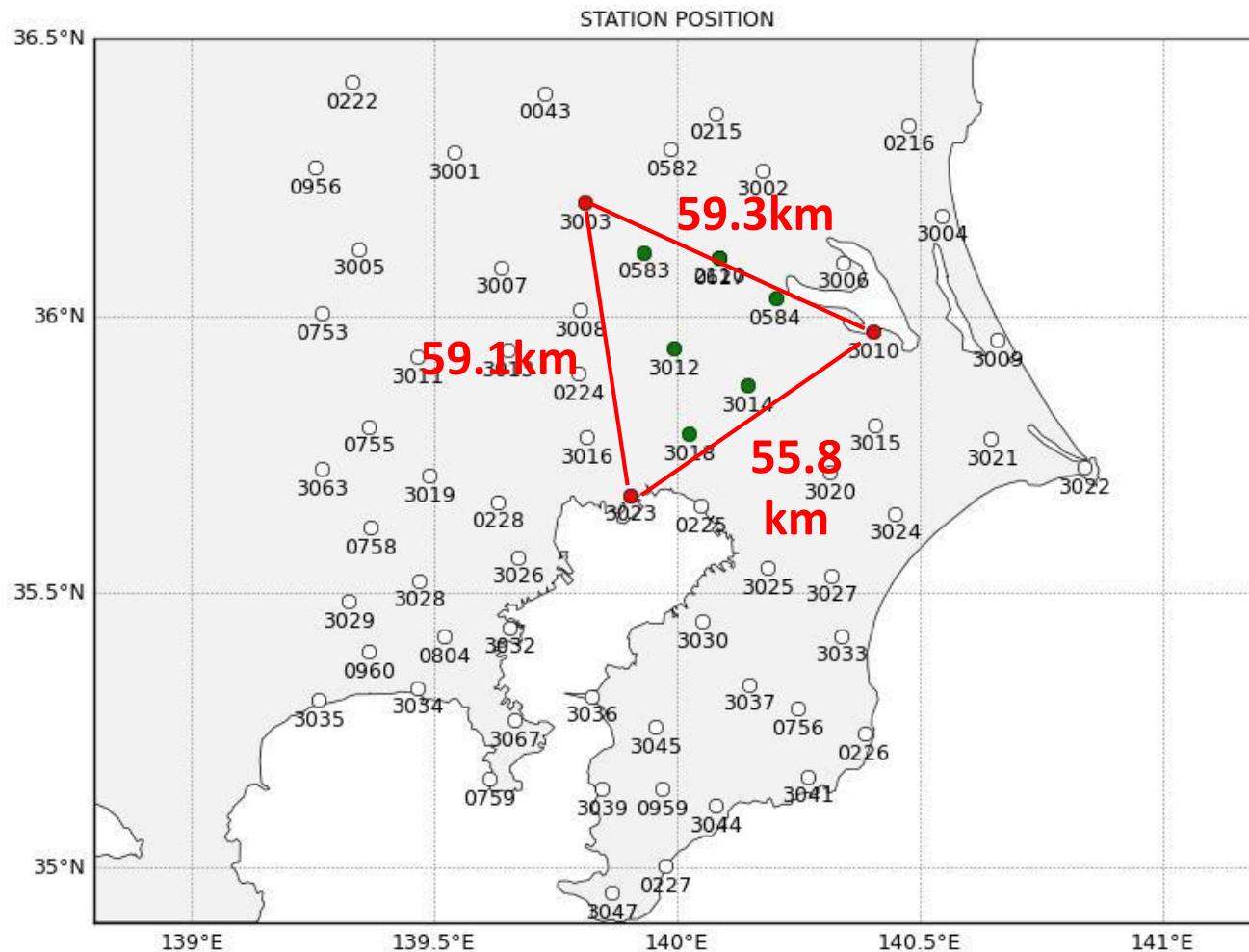
PPP

PPP-AR



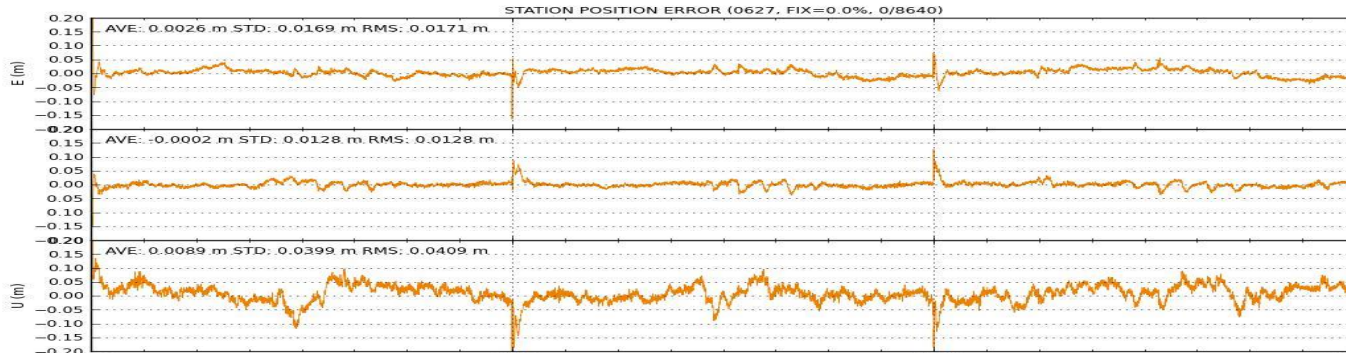
(GPS+GLO with MGF)

Local Corr. with PPP-AR (1)



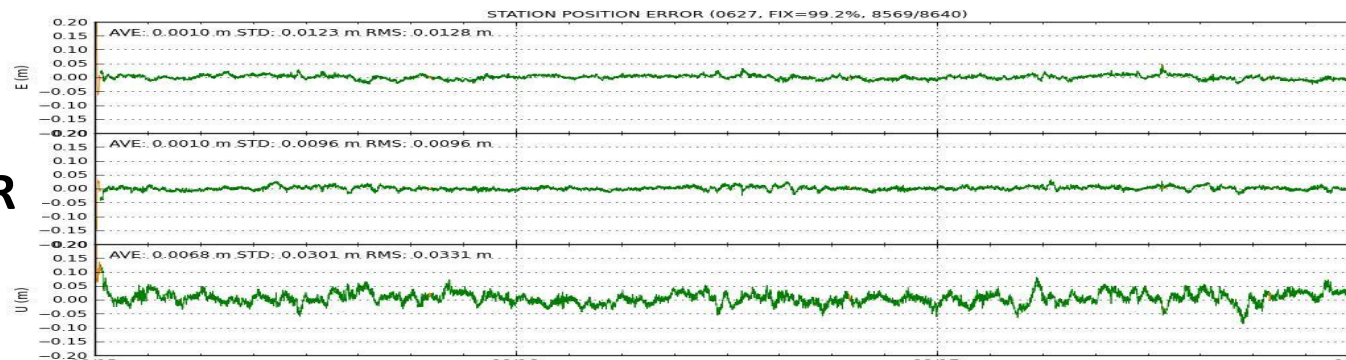
Local Corr. with PPP-AR (2)

PPP



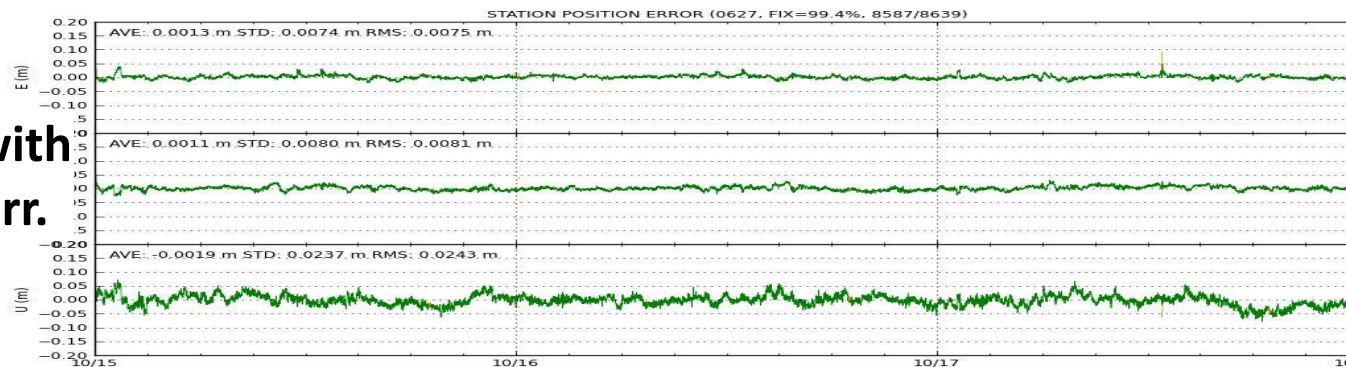
RMS (cm)
E: 1.71
N: 1.28
U: 4.09

PPP-AR



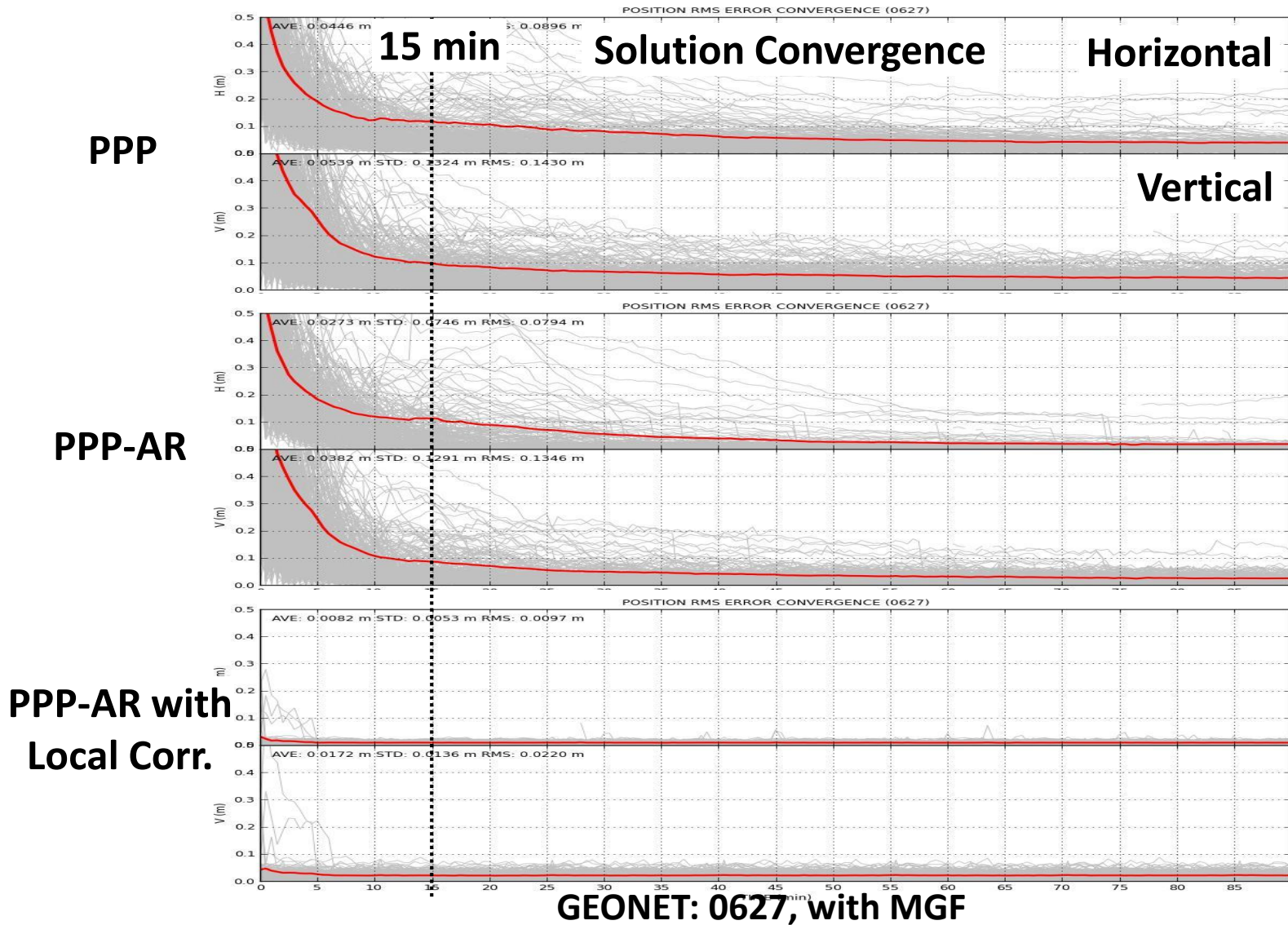
RMS (cm)
E: 1.28
N: 0.96
U: 3.31
Fix Rate: 99.2%

PPP-AR with
 Local Corr.

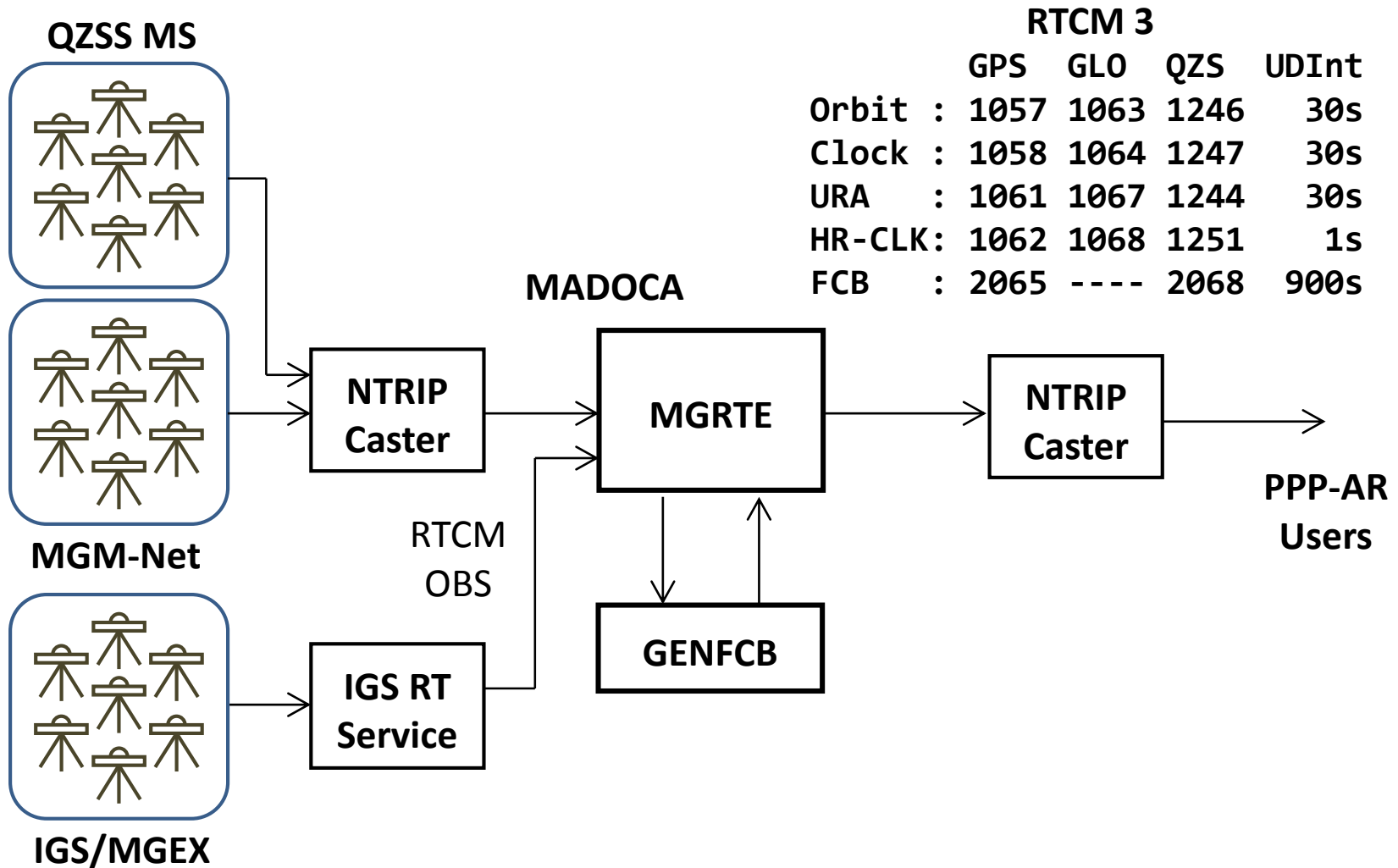


RMS (cm)
E: 0.75
N: 0.81
U: 2.43
Fix Rate: 99.4%

Local Corr. with PPP-AR (3)

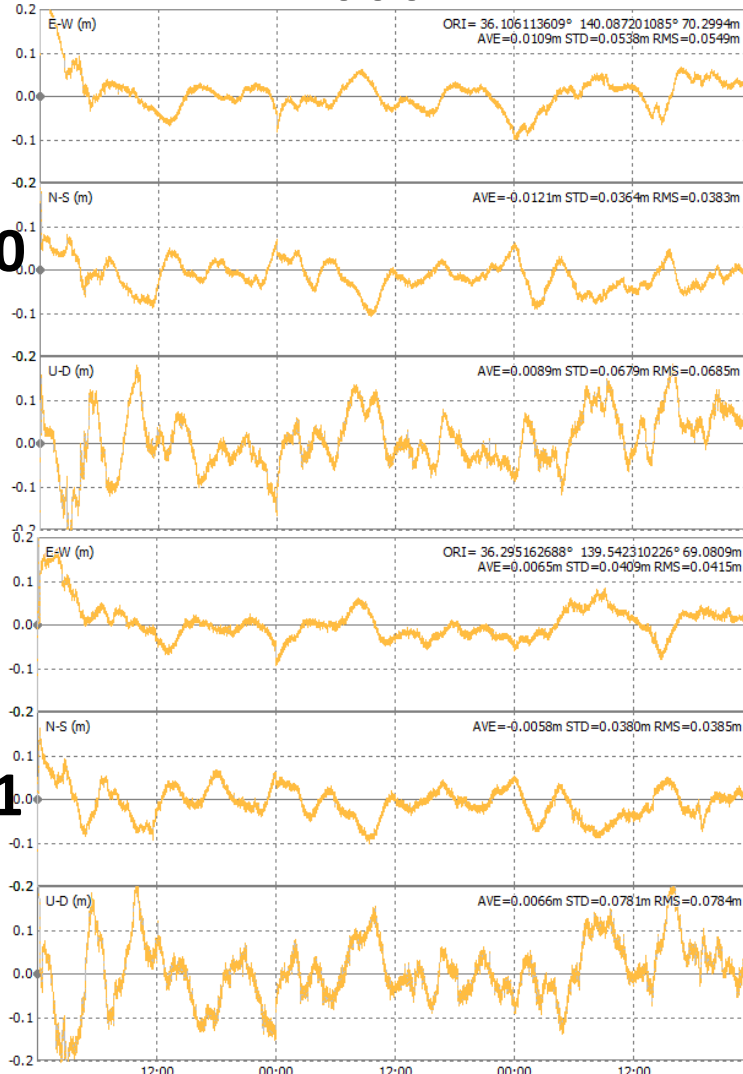


Real-Time PPP-AR (1)

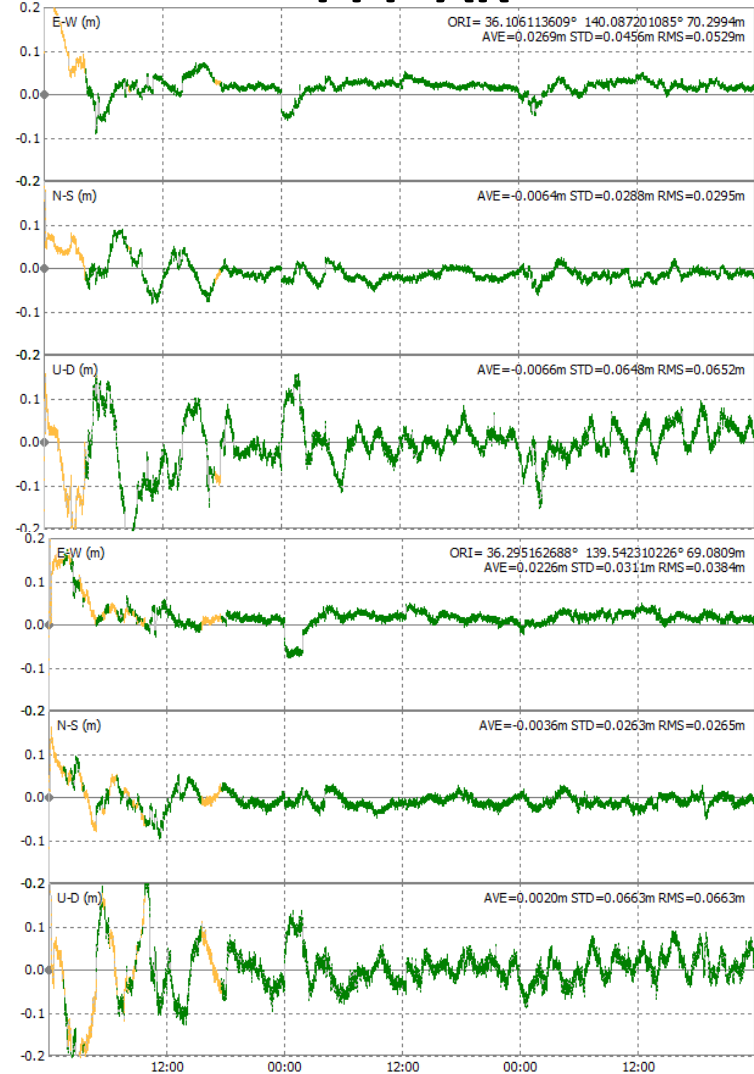


Real-Time PPP-AR (2)

PPP



PPP-AR



2110

3001

Future Plan

- **FCB Product by MADOCA**
 - Offline Products
 - Real-Time Products
 - Broadcast via QZSS LEX in extended LEX MT12 messages
- **PPP-AR-Client**
 - Release with RTKLIB 2.4.3 ?
 - The license depends on JAXA
- **Enhancement PPP-AR Features**
 - Triple Frequency (L1 - L2 - L5)
 - Galileo and BeiDou with Orbit/Clock