Real-time orbit and clock products at Wuhan University to support Multi-GNSS applications

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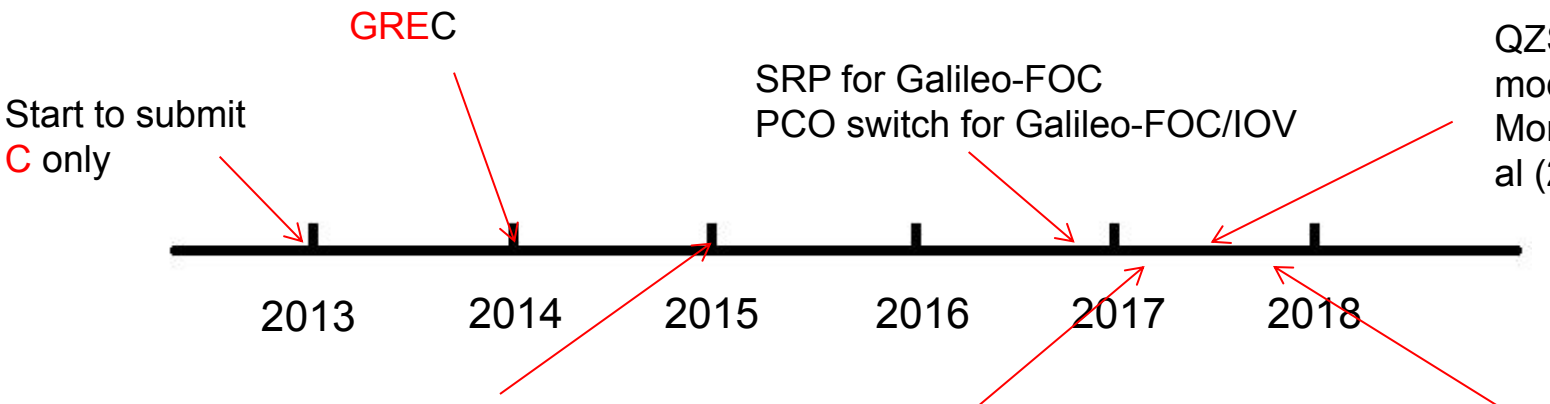
3) School of Geodesy and Geomatics, Wuhan University, China

Background

- IGS MGEX Multi-GNSS products of Wuhan University (WUM)



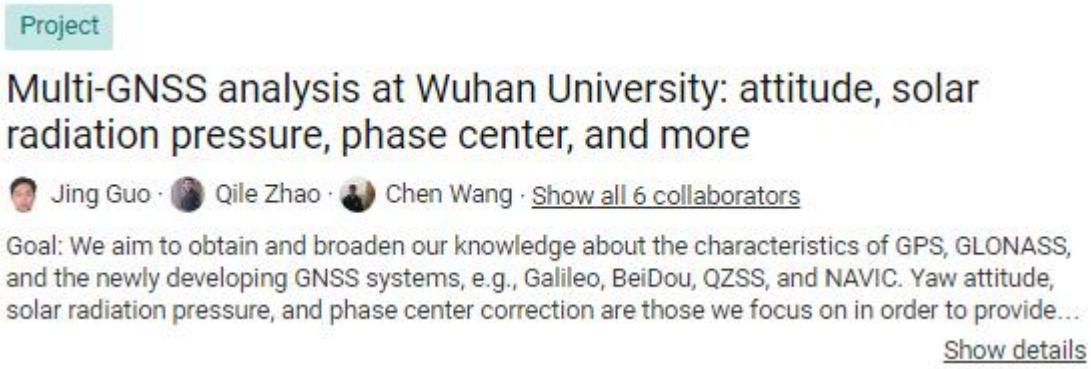
GRECJ
BDS PCO/PCV updated to Guo et al (2016) JoG
SRP for Galileo-IOV (Montebruck et al. 2015, JoG)

Align to IGS14
Ambfix for BDS and Galileo

C13 (I06) updated to (586.4, 0.0, 2896.2) mm
QZS-1 SRP switch from Montenbruck et al (2017, ASR) to Zhao et al (2017, JoG)
SRP for BDS GEO satellites (Wang et al. 2018, JoG)
ERP active for GPS, GLONASS, Galileo

Background

- iGMAS Multi-GNSS products of Wuhan University
  - ultra-rapid, rapid, and final orbits, clocks, and ERP
  - the products are avaliable at ftp://igs.gnsswhu.cn/pub/whu/MGEX/



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- WHU already provide the real-time orbit and clock for GPS only

```
STR;CLK15;BRDC_CoM_ITRF;RTCM 3.1;1059(5),1060(5);0;GPS;MISC;CHN;30.52;114.35;0;1;PANDA;none;B;N;1800;WUHAN
STR;CLK16;BRDC_APC_ITRF;RTCM 3.1;1059(5),1060(5);0;GPS;MISC;CHN;30.52;114.35;0;1;PANDA;none;B;N;1800;WUHAN
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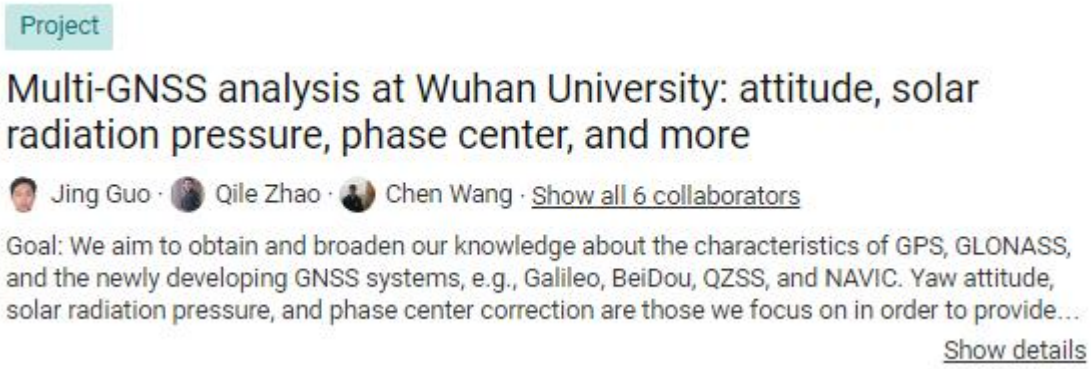

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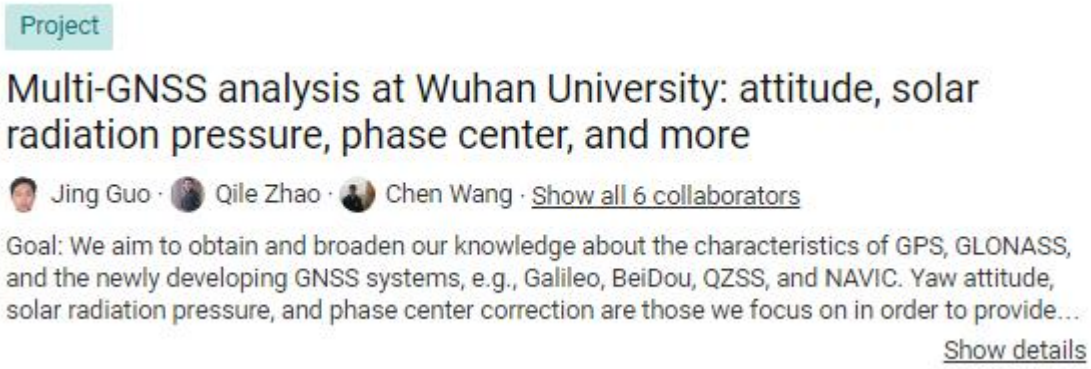
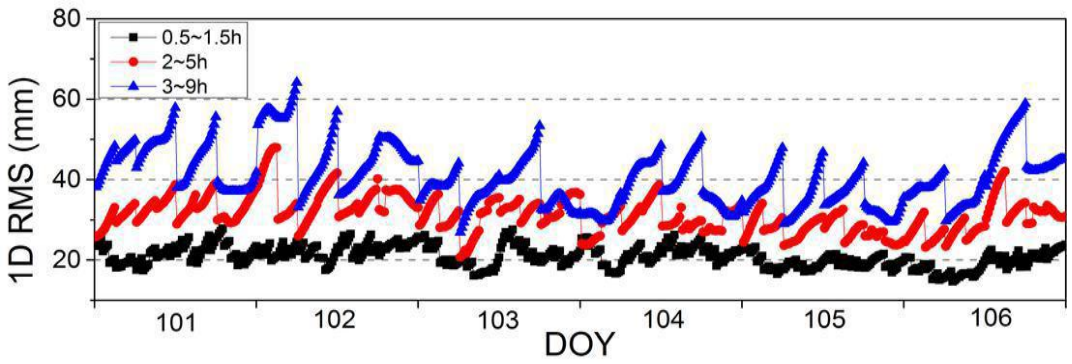
- Motivated by iGMAS and Multi-GNSS applications to generate the real-time orbit and clock



Ultra-rapid orbits

- Ultra-rapid orbits
  - 6-hour (whu): gweek 1904 to gweek 1909
  - 3-hour (whu): gweek 1910 to gweek 1948, and gweek 1975 to now
  - 1-hour (whu): gweek 1949 to gweek 1974
  - 1-hour (hour): gweek 1975 to gweek 2015
  - 1-hour (hour): since gweek 2016

Zhao et al (2017) IGS Workshop 2017



Ultra-rapid orbits

gweek, 1991; Courtesy by Blot Alixis @ CNES

Ultra-rapid orbits

- Ultra-rapid orbits avaliable
  - 6-hour (whu): gweek 1904 to gweek 1909
  - 3-hour (whu): gweek 1910 to gweek 1948, and gweek 1975 to now
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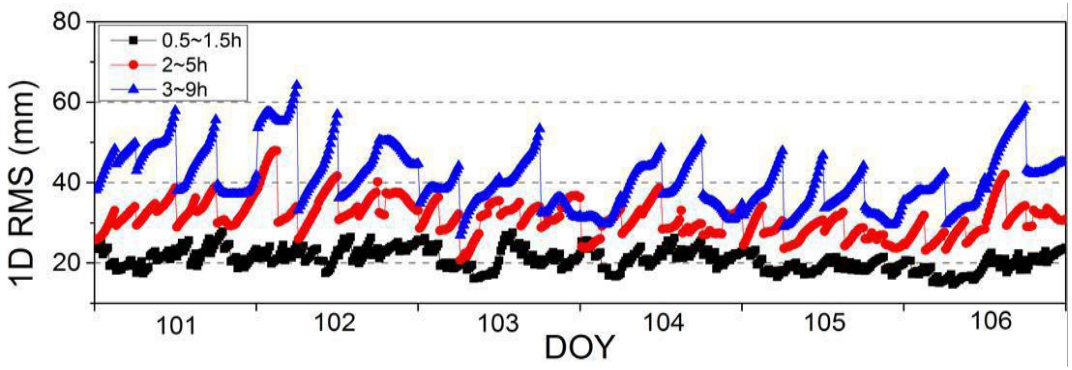
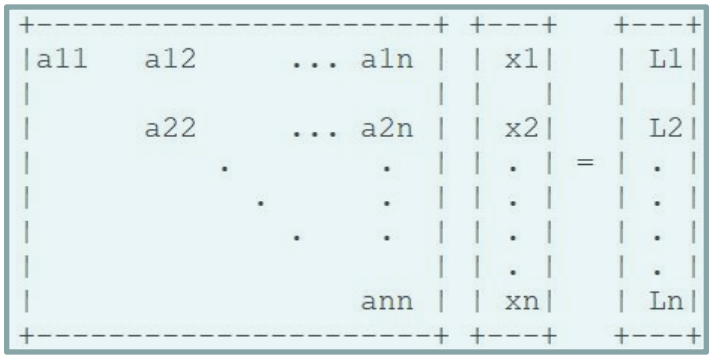


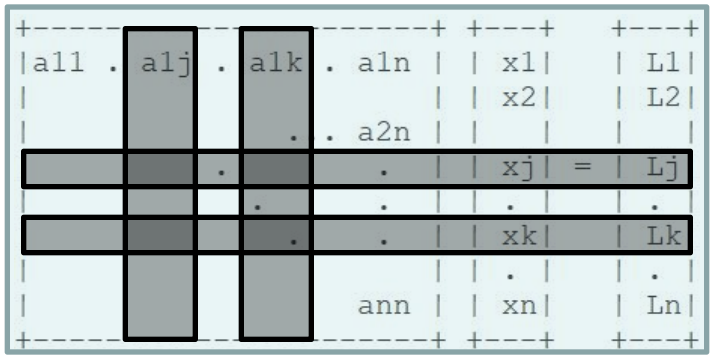
Ultra-rapid orbits

- Hourly ultra-rapid Multi-GNSS orbits
  - Huge computational burden and time consuming
  - For computation efficiency, Task Parallel mode used
    - ✓ SHAO (Chen et al. 2017): GPS+R/E/C
    - ✓ SGG of WHU (Li et al. 2018): 300s -> 600s, multi-thread for QC, OI, etc.
    - ✓ Other approach?
- Review of the parameter estimation algorithem used in PANDA
  - The efficient data processing strategy proposed by Ge et al. (2006) used in PANDA
  - The iead is to eliminate the non-active parameters in the normal equations to reduce the size
  - “one-by-one” elimination of parameters used

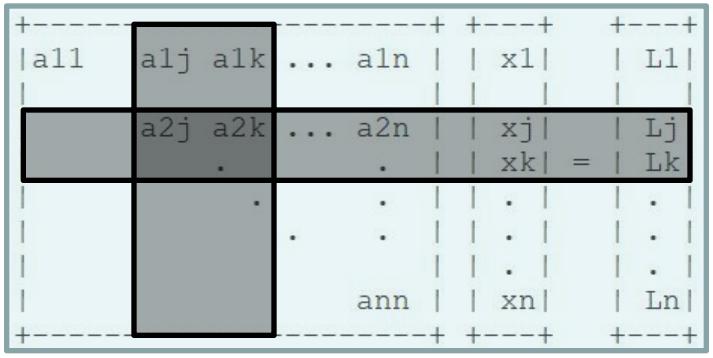
Ultra-rapid orbits



Origin Normal Equation



Deactivated parameters elimination



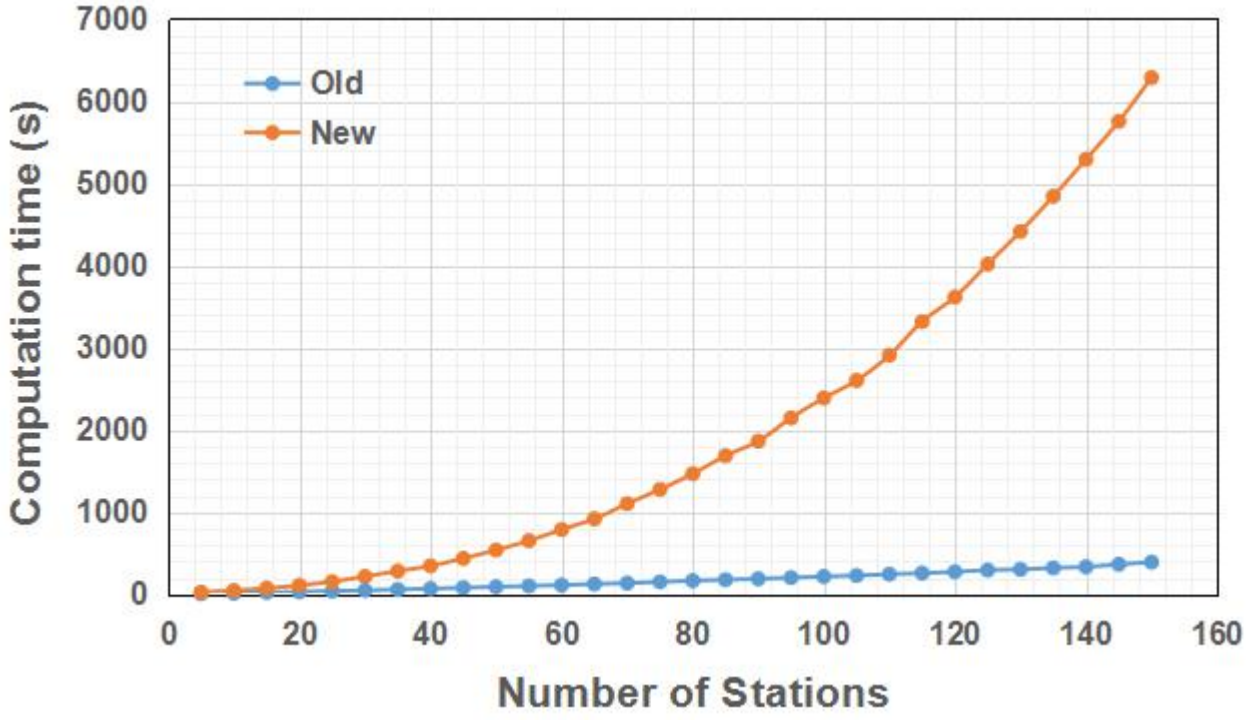
Deactivated parameters blocked and eliminated

Using block elimination and recovery to instead of “one-by-one” elimination and recovery

Using Cholesky factorization for Matrix inversion

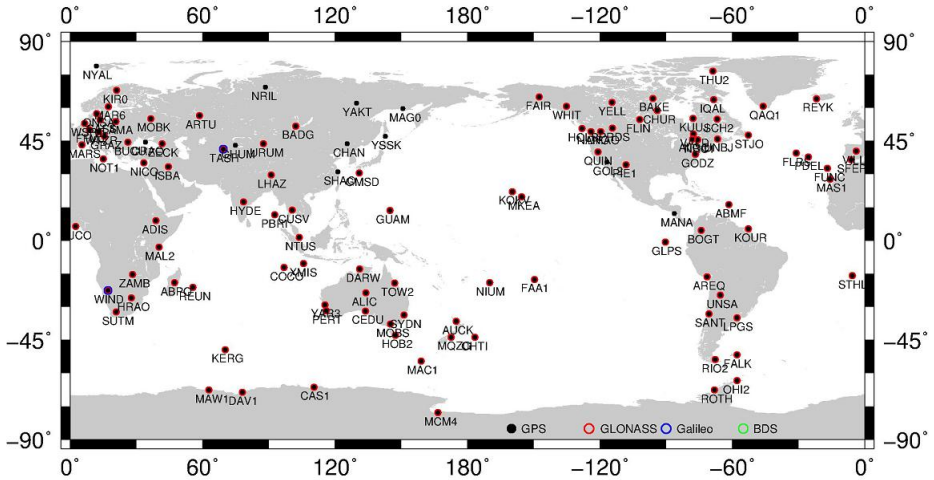
Ultra-rapid orbits

- Computation time (Intel Xeon 16 cores @ 2.9 GHz)
  - GPS+GLONASS



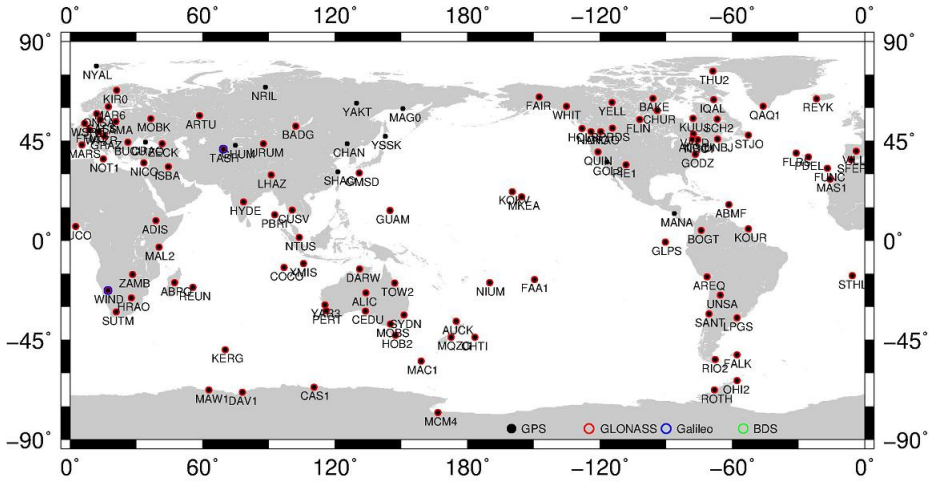
Ultra-rapid orbits

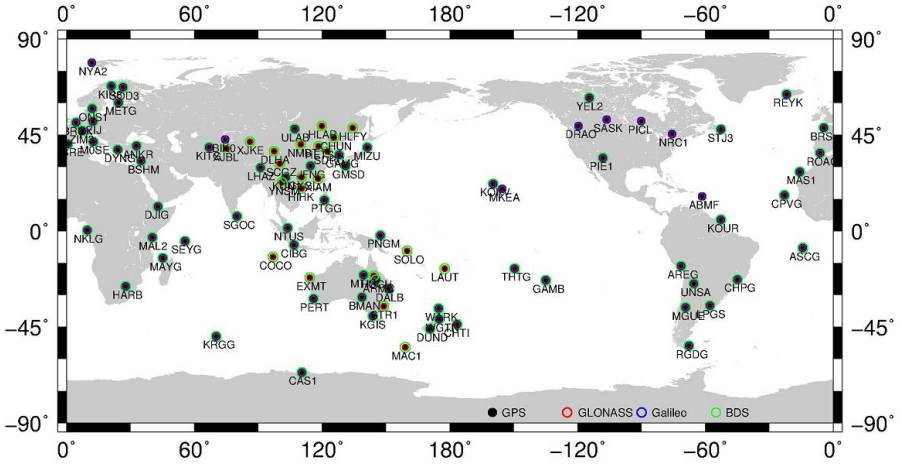
- Strategy
  - 120 stations used for GPS+GLONASS



Ultra-rapid orbits

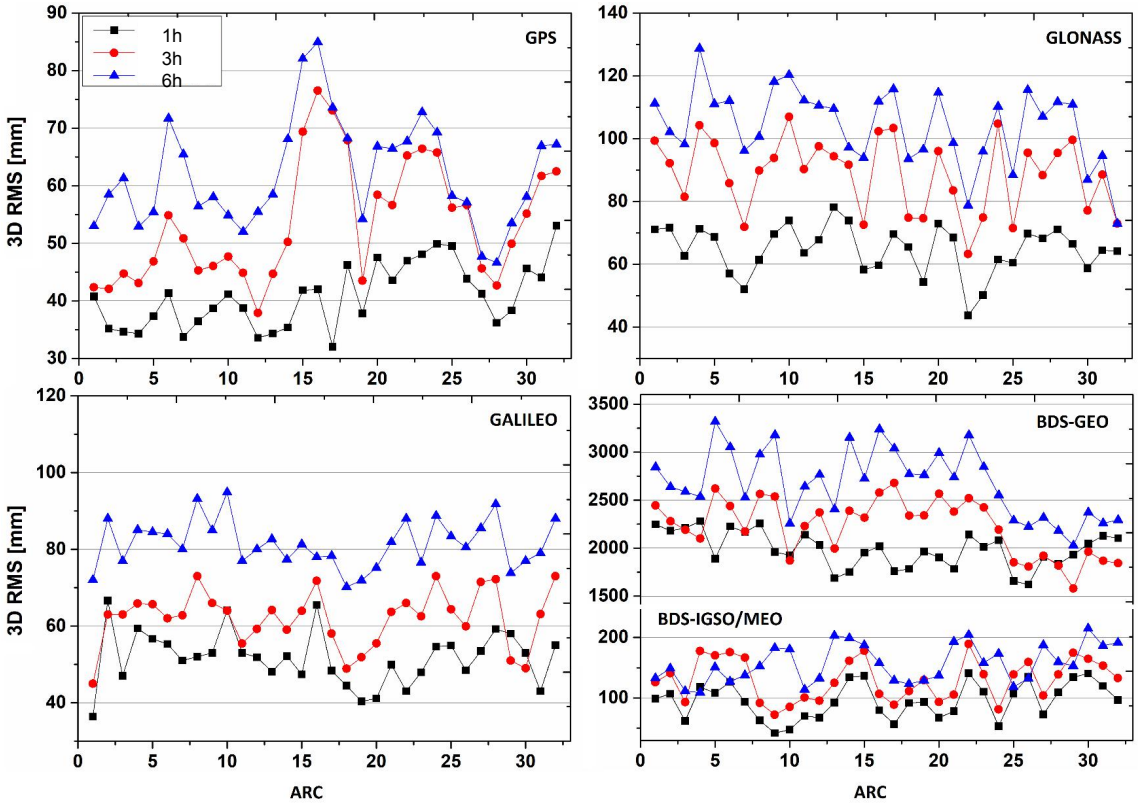
- Strategy
  - 120 stations used for GPS+GLONASS
  - 90 stations used for GPS+BDS+Galileo
  - ~30 min for generation of ultra-orbits





Ultra-rapid orbits

- Orbit accuracy
  - GPS/GLONASS (IGS final), Galileo/BDS (GBM)

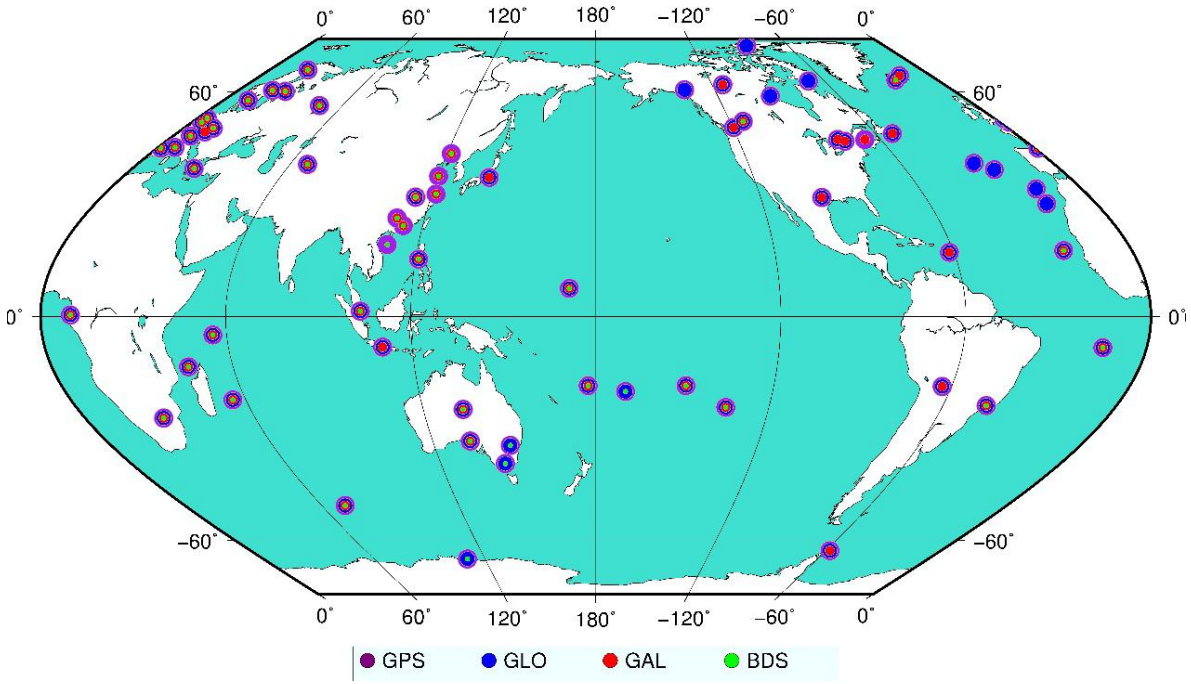


Latency (h)	Ava. Part(h)	Update Frequency
1	1-2	1 h
2	2-5	3 h
2	2-8	6 h

		3D RMS (mm)		
		1h	3h	6h
GPS		40	53	59
GLS		65	89	104
BDS	G	1987	2224	2678
	I / M	95	133	157
GAL		51	65	82

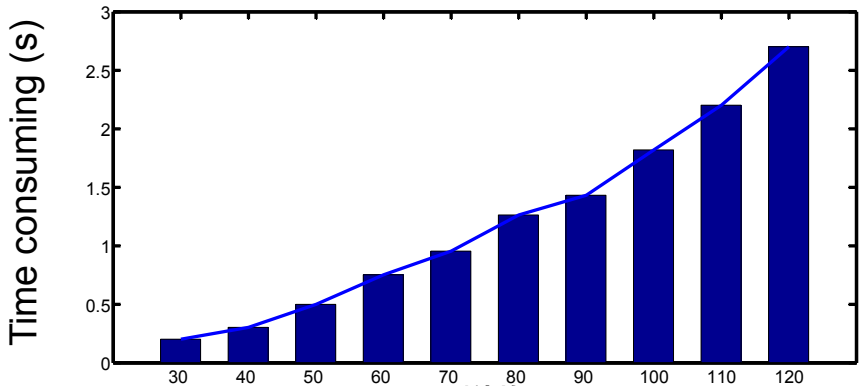
Real-time clock determination

- Squre-root Information Filter (SRIF)
- Using Ionosphere-Free (IF) observables
- 70 stations, 5s sampling
- GPS (32)/GLONASS (24)/Galileo (12)/BDS-2 MEO and IGSO (9)

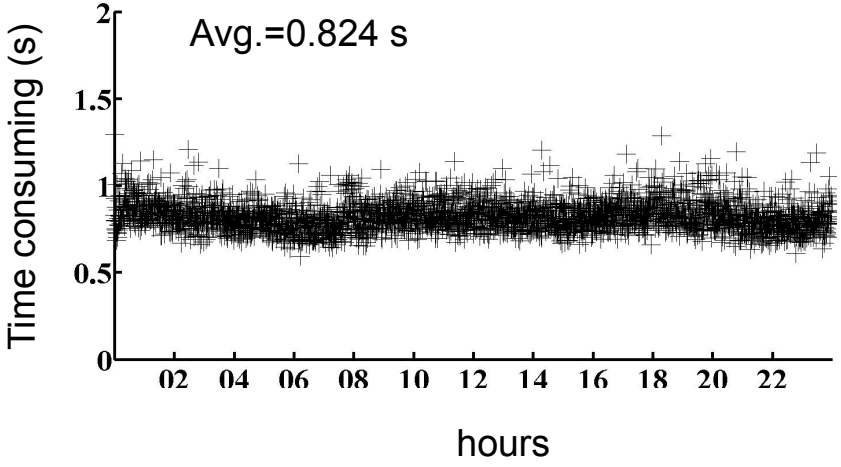


Real-time clock determination

- An efficient algorithm for SRIF
  - Blocked QR factorization (Gong et al. 2017)
  - LAPACK Library for matrix operations

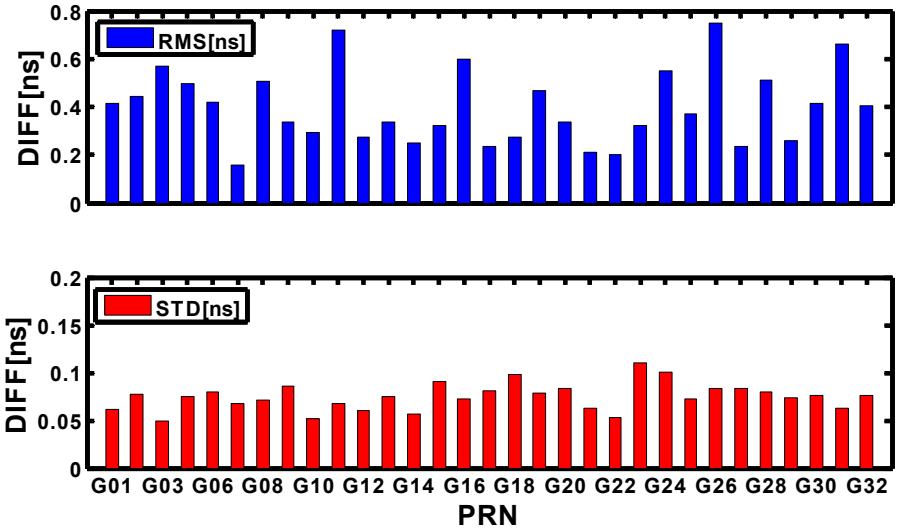


(Intel Xeon 4 cores @ 3.5 GHz)

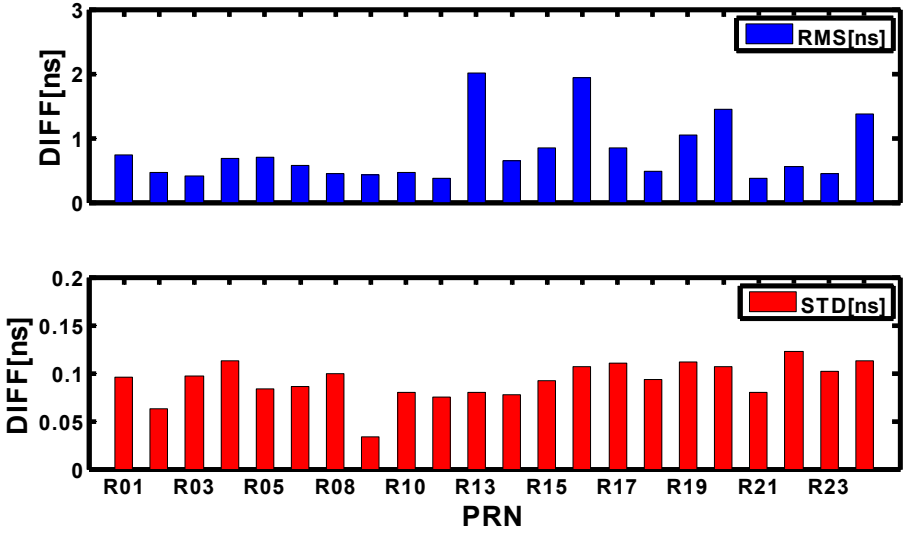


Real-time clock determination

- Accuracy (DOY281 to 298, 2018)
  - WUM clocks used as the reference



GPS: 0.08 ns



GLONASS: 0.1 ns

Real-time clock determination

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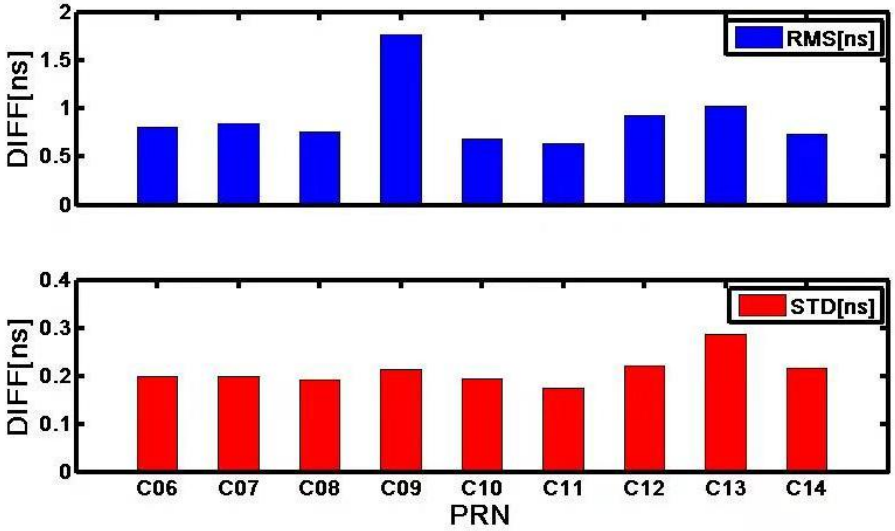
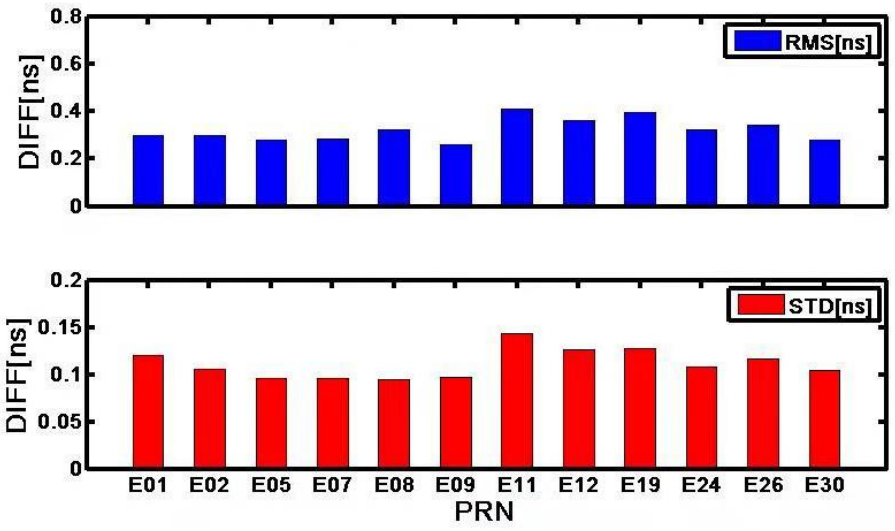


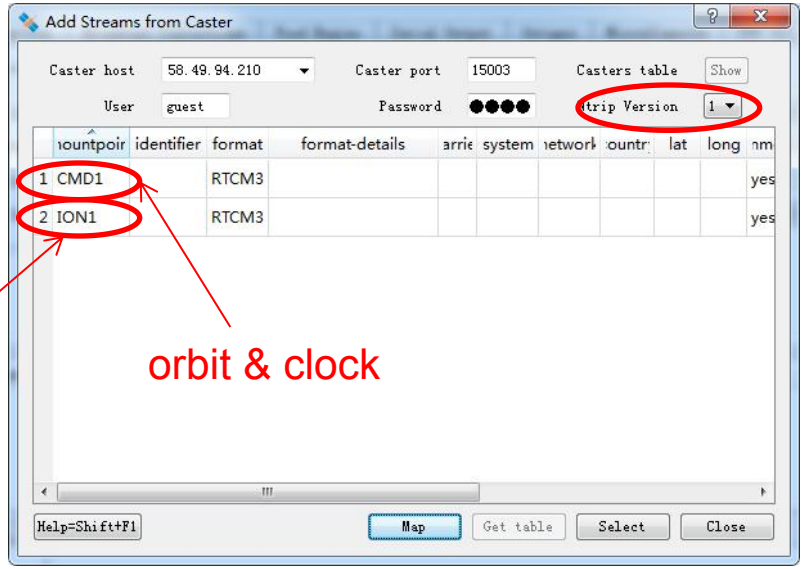
BDS: 0.21 ns



Galileo: 0.12 ns

Real-time products

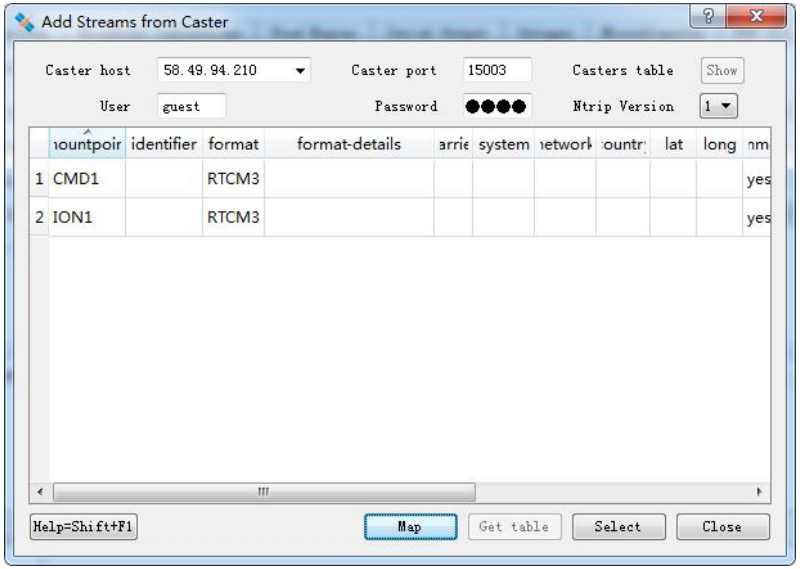
- SSR corrections (APC) for orbit and clock is broadcasted vis
  - IP/Port: 58.49.94.210:15003
  - User: guest
  - Password: guest



Real-time products

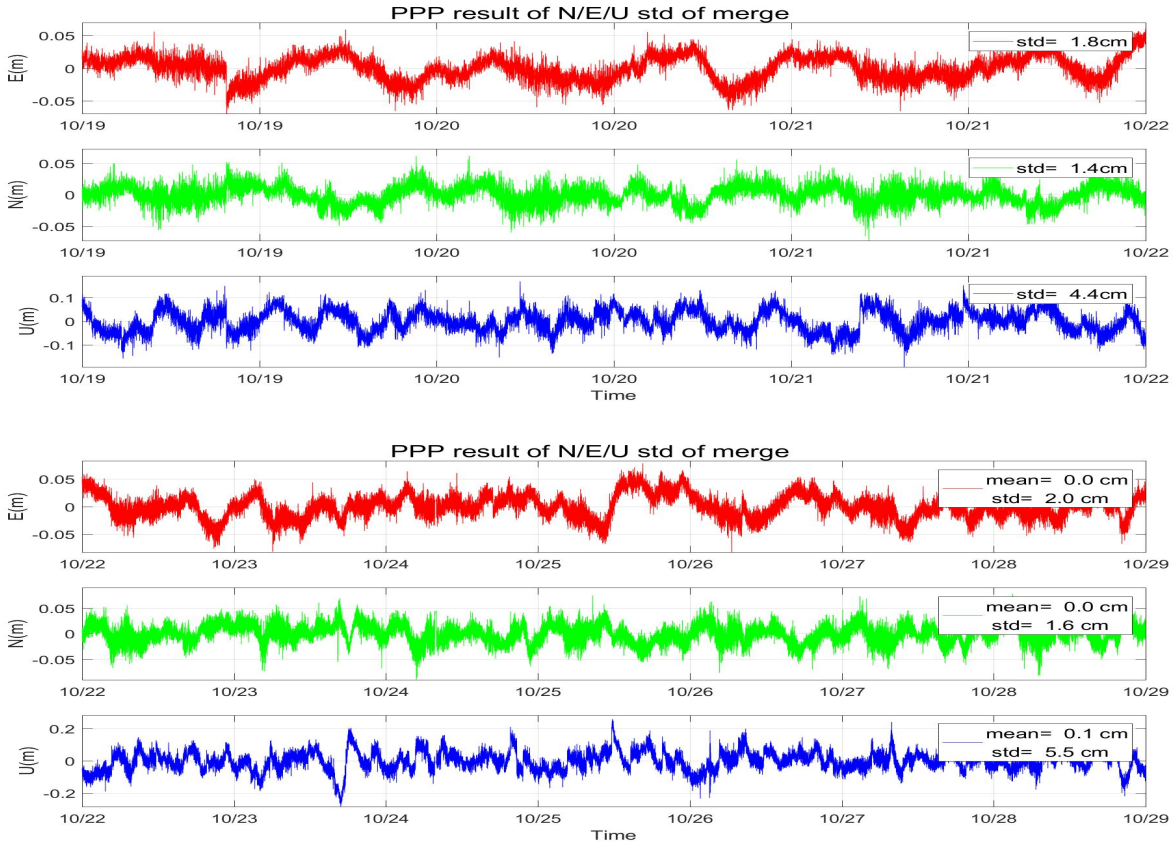
- SSR corrections (APC) for orbit and clock is broadcasted vis
  - IP/Port: 58.49.94.210:15003
  - User: guest
  - Password: guest
- IOD (Issue of Data) calculation
  - GPS: IODE
  - GLONASS: NINT(SOD/900)+1
  - Galileo: NINT(SOD/600)+1
  - BDS: NINT(SOD/1800)+1

Second of Day (SOD) is in GPS Time



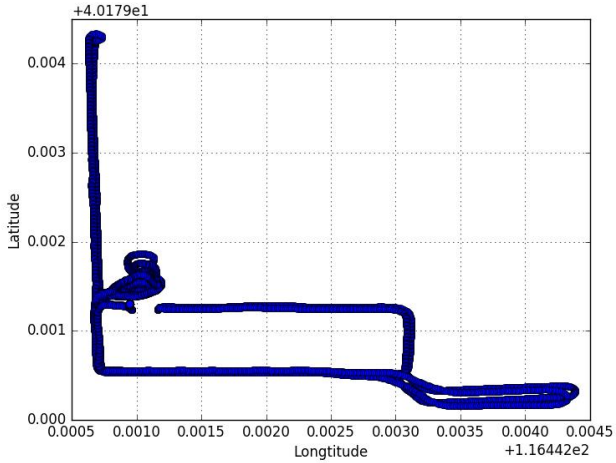
Validation

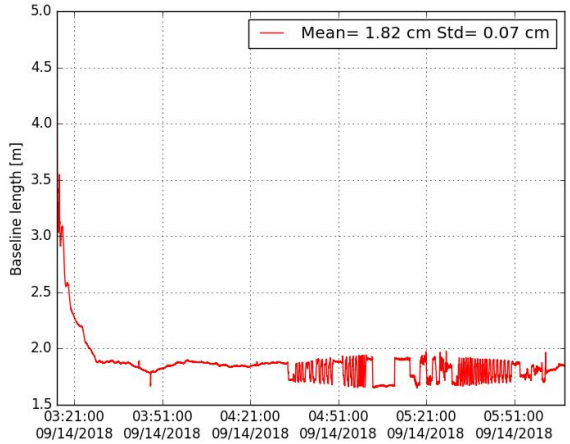
- Static station in Wuhan



Validation


1.8 m
LOVOL


+4.0179e1
0.004
0.003
0.002
0.001
0.000
Latitude
0.0005
0.0010
0.0015
0.0020
0.0025
0.0030
0.0035
0.0040
0.0045
Longtitude
+1.16442e2


Mean= 1.82 cm Std= 0.07 cm
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
Baseline length [m]
03:21:00
09/14/2018
03:51:00
09/14/2018
04:21:00
09/14/2018
04:51:00
09/14/2018
05:21:00
09/14/2018
05:51:00
09/14/2018

Summary and outlook

- WUM product keep to incorporate the new satellites, models or algorithem
  - BDS-3 and QZSS will be supported
  - Yaw attitude model for Galileo, BDS-2/BDS-3
- New hourly ultra-rapid orbits has been released with better quality (stability, accuracy), thanks to the improved computation efficiency by using block elimination
- With blocked QR factorization for SRIF, real-time clock with good performance by using IF observations is determined within limted time
- The real-time products are ready for evaluation and use

Thanks for your attentain !