

BDS Real-time Precise Products from WHU and its application in NBASS

Shi C., Lou YD., Li M., Gu SF., Zhang WX.,
Zheng F., Li XJ., Song WW., Dai XL., Yi WT.

GNSS Research Center of Wuhan University, GRC

IGS Workshop 2017

July 3-7, 2017, Paris, France

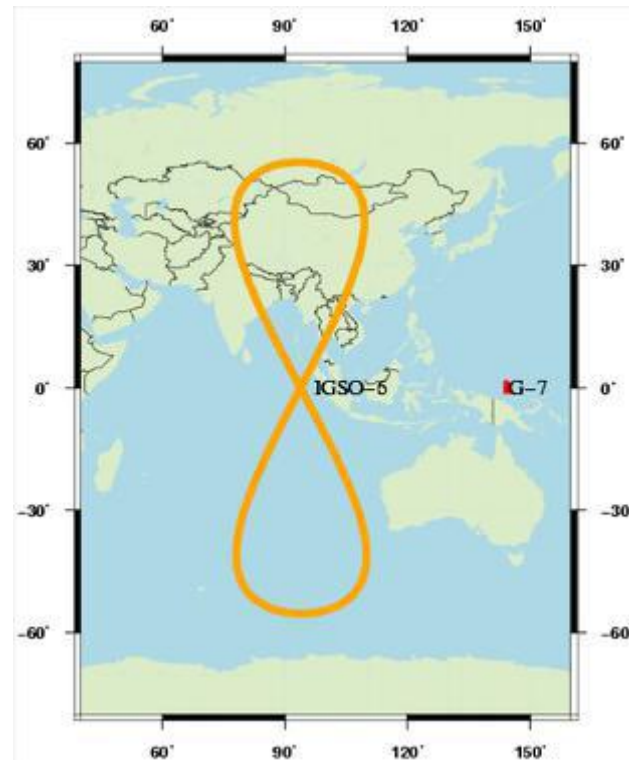
Outline

- Overview
- BDS Real Time Precise Products
- Application of Real-time PPP
- Summary

The Current Status of BDS

□ BDS-2

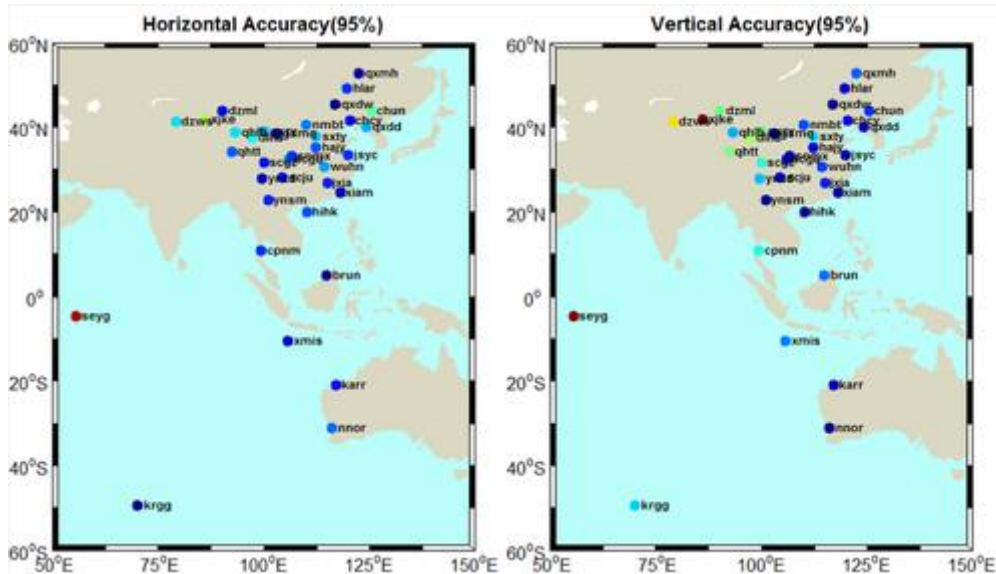
Common Name	SVN	Int. Sat. ID	Status	PRN	Notes
BEIDOU IGSO 6	C017	2016-021A	Operational	C15/C13	~95° E; launched 2016/03/29; PRN switch from C15 to C13 on 2016/10/11
BEIDOU G7	C018	2016-037A	N/A	C17	launched 2016/06/12



The Current Status of BDS

□ BDS-2

Common Name	SVN	Int. Sat. ID	Status	PRN	Notes
BEIDOU IGSO 6	C017	2016-021A	Operational	C15/C13	~95° E; launched 2016/03/29; PRN switch from C15 to C13 on 2016/10/11
BEIDOU G7	C018	2016-037A	N/A	C17	launched 2016/06/12

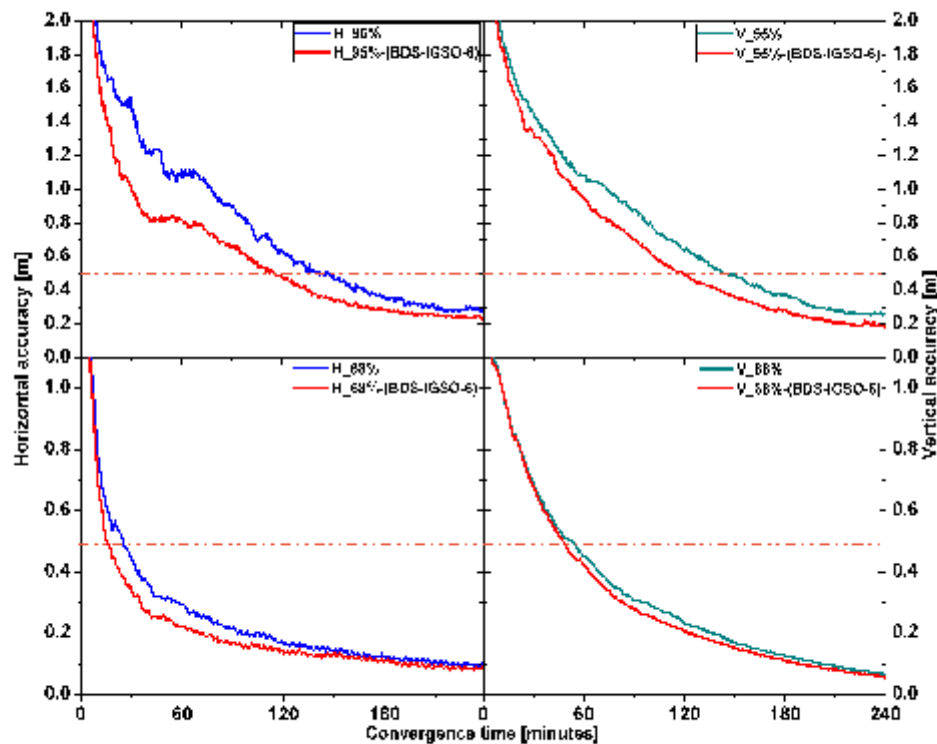


SPP	Horizontal	Vertical	
Accuracy (95%)	without IGSO-6	3.54m	6.09m
	With IGSO-6	3.34m	5.83m
Improvement	5.6%	4.3%	

The Current Status of BDS

□ BDS-2

Common Name	SVN	Int. Sat. ID	Status	PRN	Notes
BEIDOU IGSO 6	C017	2016-021A	Operational	C15/C13	~95° E; launched 2016/03/29; PRN switch from C15 to C13 on 2016/10/11
BEIDOU G7	C018	2016-037A	N/A	C17	launched 2016/06/12



PPP		Horizontal	Vertical
Convergence time (95% < 0.5m)	without IGSO-6	142 min	146 min
	with IGSO-6	116 min	120 min
Improvement		18.3%	17.8%

The Current Status of BDS

□ BDS-2

Common Name	SVN	Int. Sat. ID	Status	PRN	Notes
BEIDOU IGSO 6	C017	2016-021A	Operational	C15/C13	~95° E; launched 2016/03/29; PRN switch from C15 to C13 on 2016/10/11
BEIDOU G7	C018	2016-037A	N/A	C17	launched 2016/06/12

□ BDS-3

Common Name	SVN	Int. Sat. ID	Status	PRN	Notes
BEIDOU I1-S	C101	2015-019A	Operational	C31	launched 2015/03/30
BEIDOU M1-S	C102	2015-037A	Operational	C33	Slot A06, launched 2015/07/30
BEIDOU M2-S	C103	2015-037B	Operational	C34	Slot A01, launched 2015/07/30
BEIDOU I2-S	C104	2015-053A	Operational	C32	launched 2015/09/29
BEIDOU M3-S	C105	2016-006A	N/A	C35	Slot B01; launched 2016/02/01

National BDS Augmentation Service System(NBASS)

□ Object

- Improving the **positioning performance** of the BDS
- Providing various precise location-based services

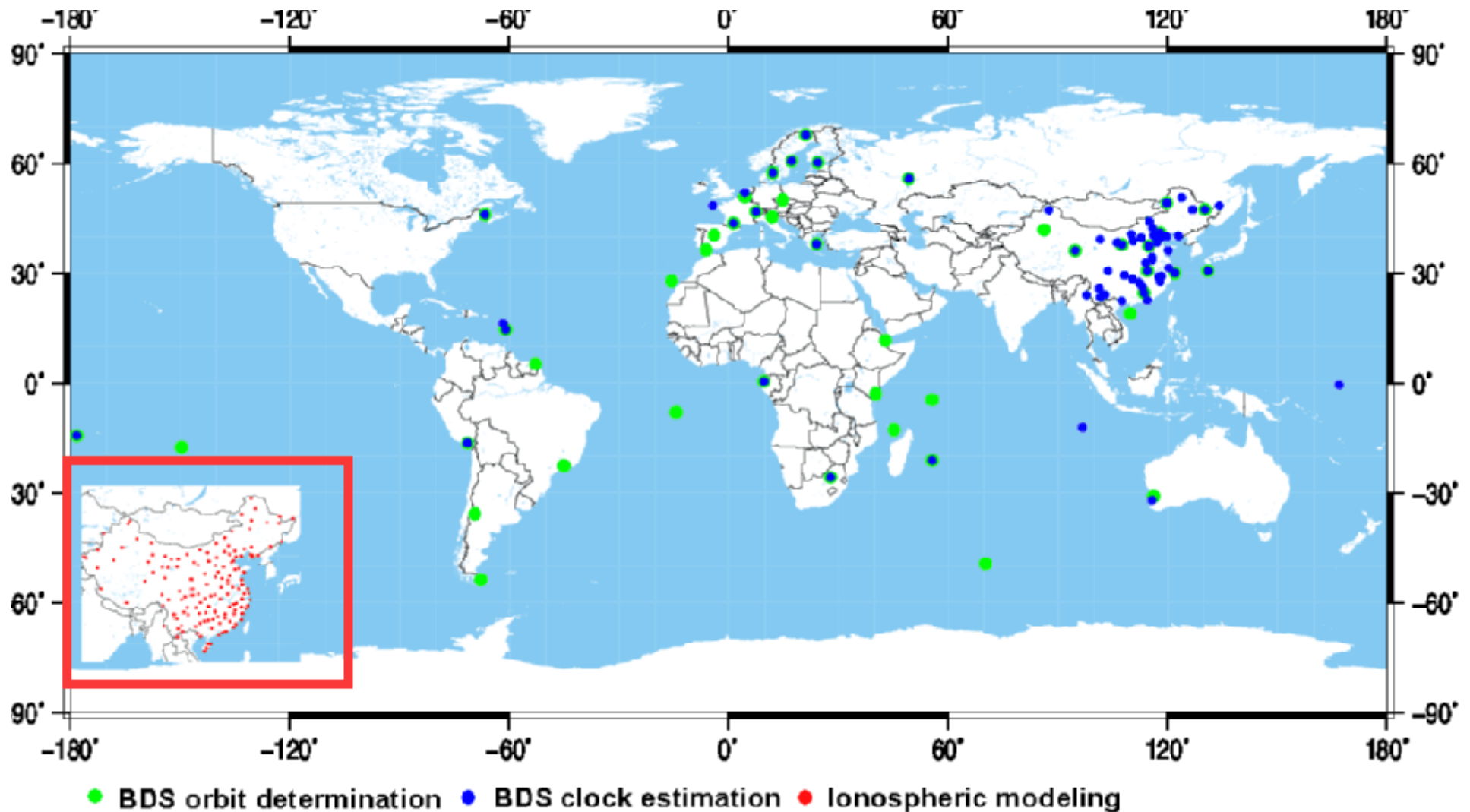
□ Infrastructure

- **150 BDS/GNSS reference stations** as Nationwide frame.
- **About 1200 BDS/GNSS** dense reference stations in special area.
- National data processing center, application service centers.

□ Augmented Satellite System

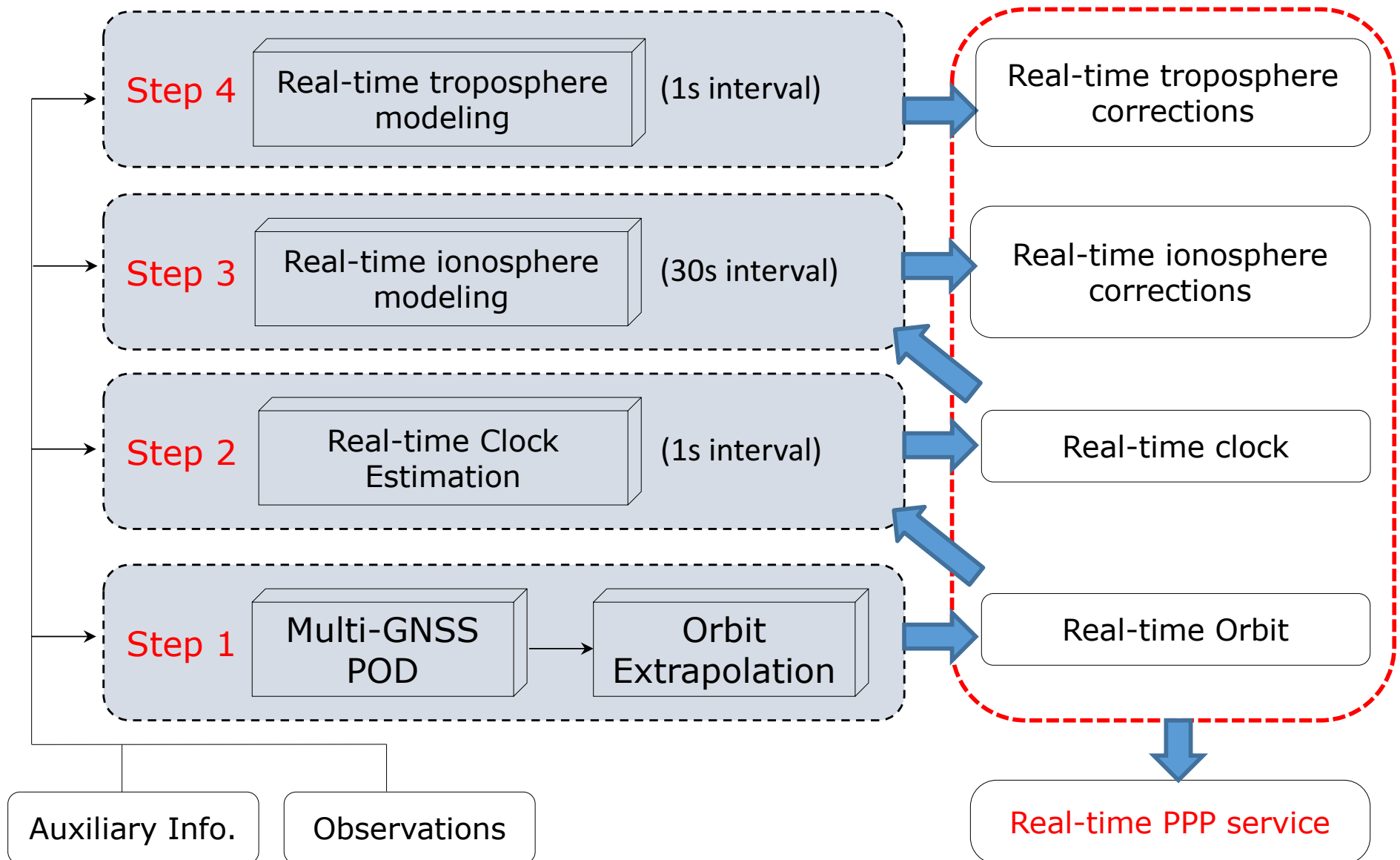
- **BDS, GPS, GLONASS, Galileo...**

Tracking Station Network for BDS RT-PPP Service



~72 stations for BDS ORB , ~92 stations for BDS CLK , ~150 stations for regional products

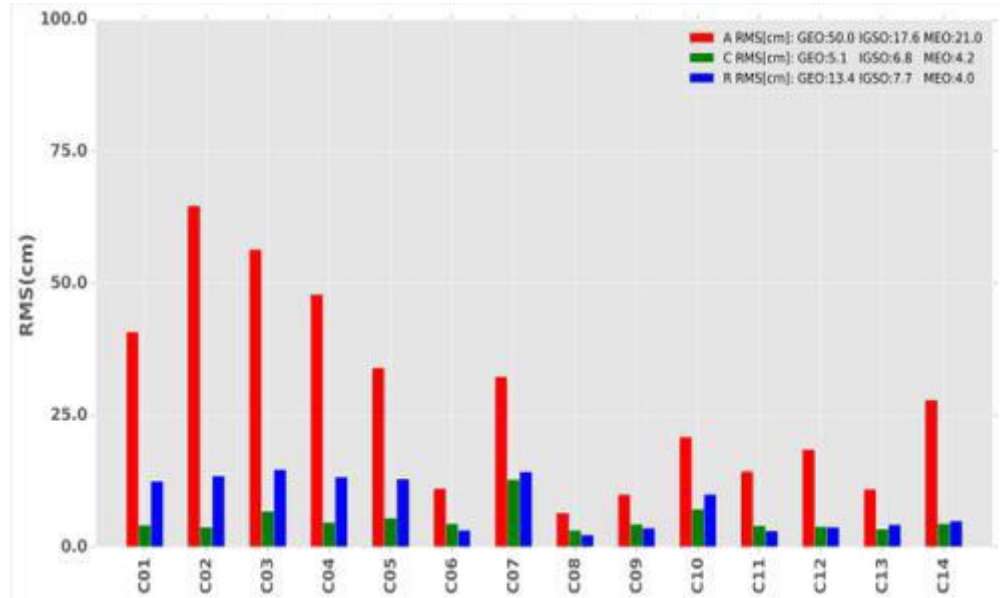
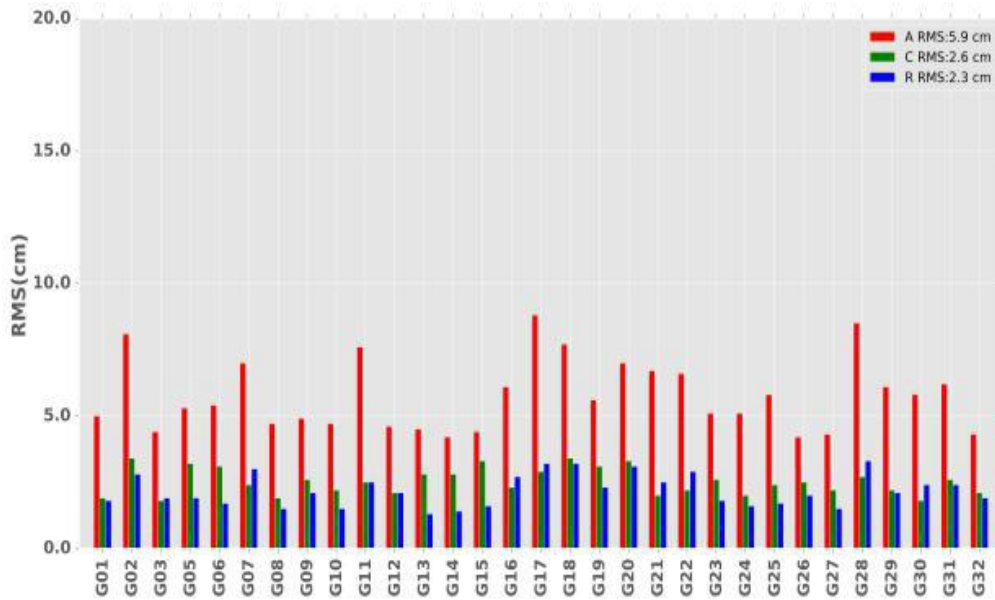
Principle of processing system



Outline

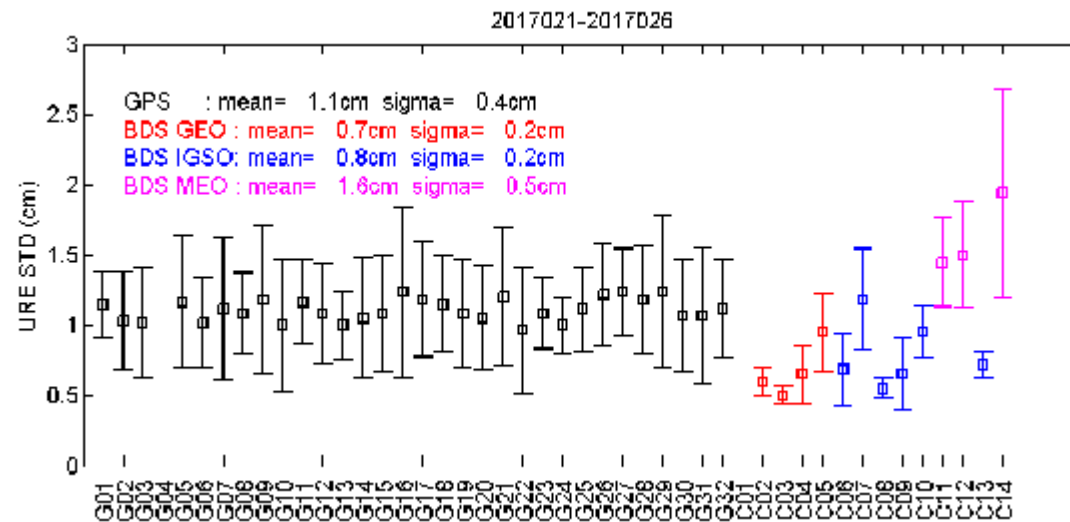
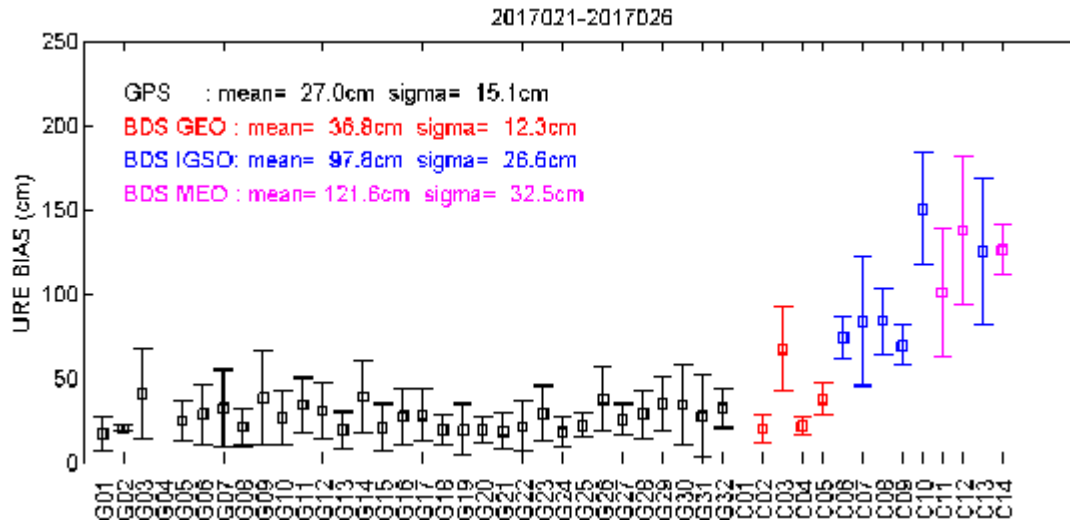
- Overview
- BDS Real Time Precise Products
- Application of Real-time PPP
- Summary

Real-Time Satellite Orbit



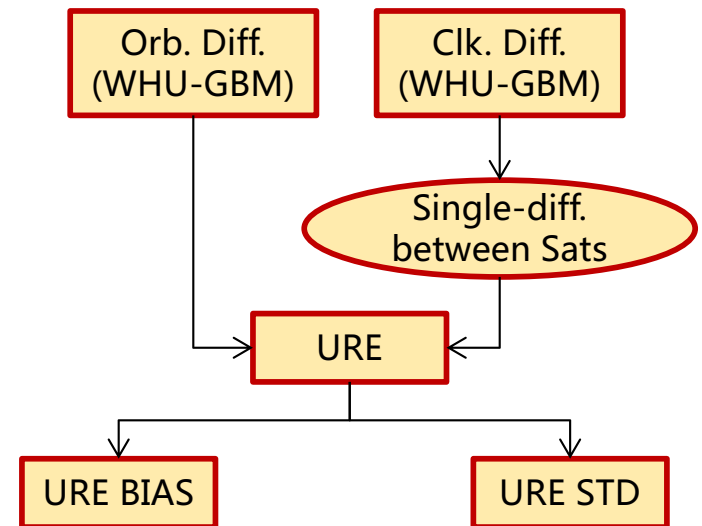
RMS (cm)	GEO	IGSO	MEO	GPS
A	50.0	17.6	21.0	5.9
C	5.1	6.8	4.2	2.6
R	13.5	7.7	4.0	2.3

Real-Time Precise Satellite Clock (URE)



$$URE = \sqrt{\alpha \cdot (dA^2 + dC^2) + \beta (dClk - dR)^2}$$

$$\begin{cases} \alpha = 0.01846081, \beta = 0.96308408 & \text{MEO} \\ \alpha = 0.0078296, \beta = 0.99214524 & \text{GEO/IGSO} \end{cases}$$

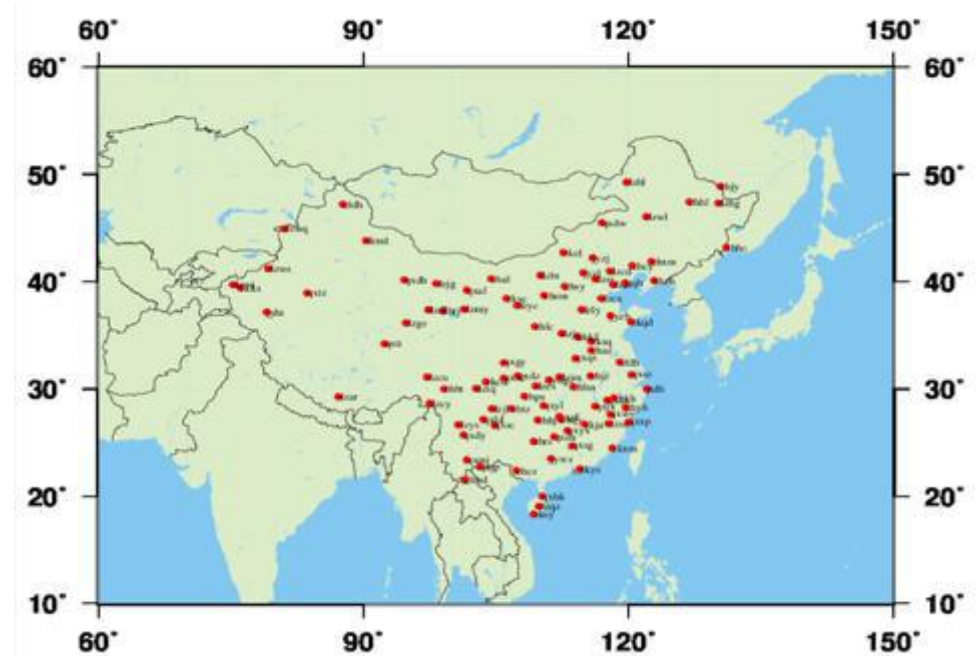


- Affect SPP accuracy
- Affect PPP accuracy
- Affect PPP convergence time

Real-Time CIM (China Ionosphere Map)

Strategy

Item	Value
Stations	~100
Interval	30 second
Coverage	E70~140, N10~60
Format	SSR
Observable	Carrier-phase smoothed pseudo-range GF
Modeling	5 degree SHF



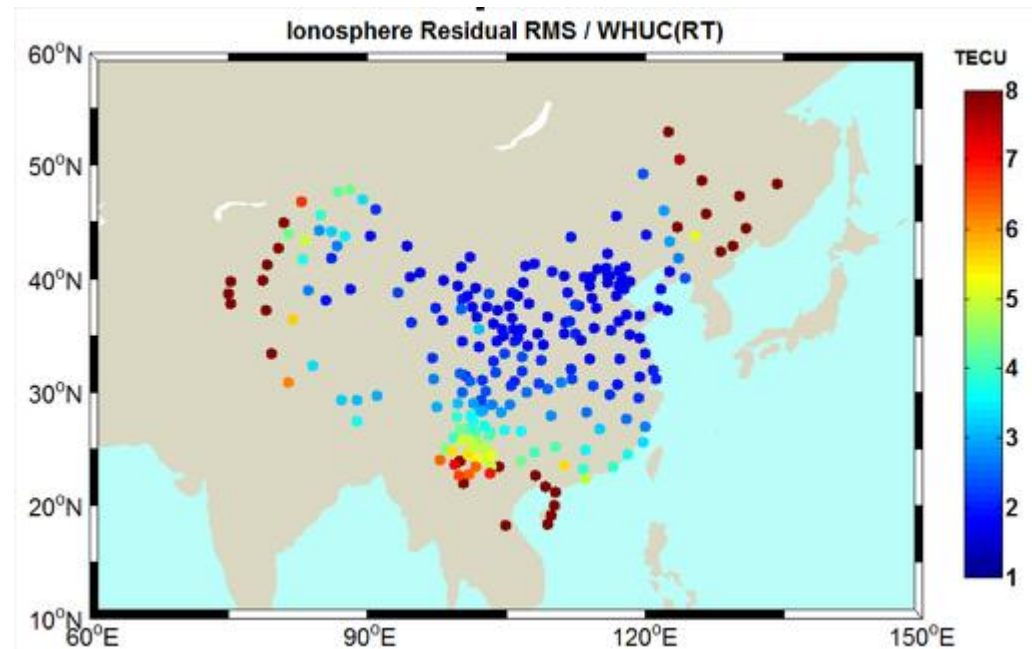
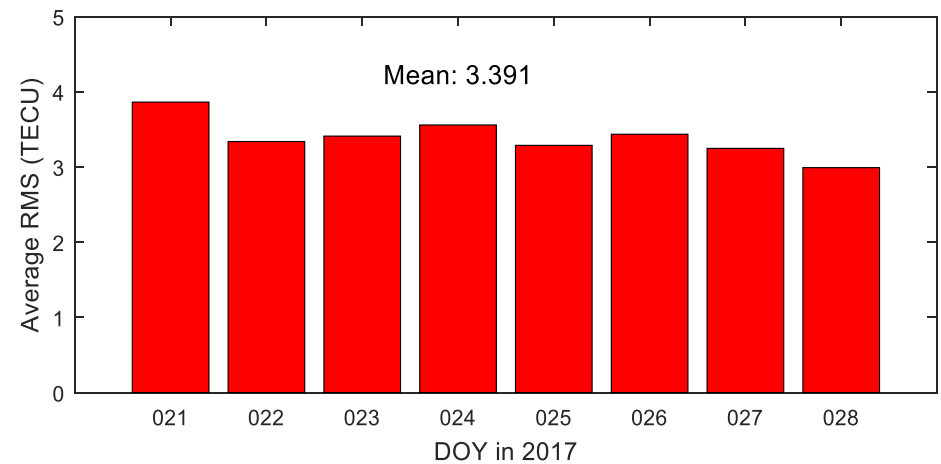
Real-Time CIM (China Ionosphere Map)

Strategy

Item	Value
Stations	~100
Interval	30 second
Coverage	E70~140, N10~60
Format	SSR
Observable	Carrier-phase smoothed pseudo-range GF
Modeling	5 degree SHF

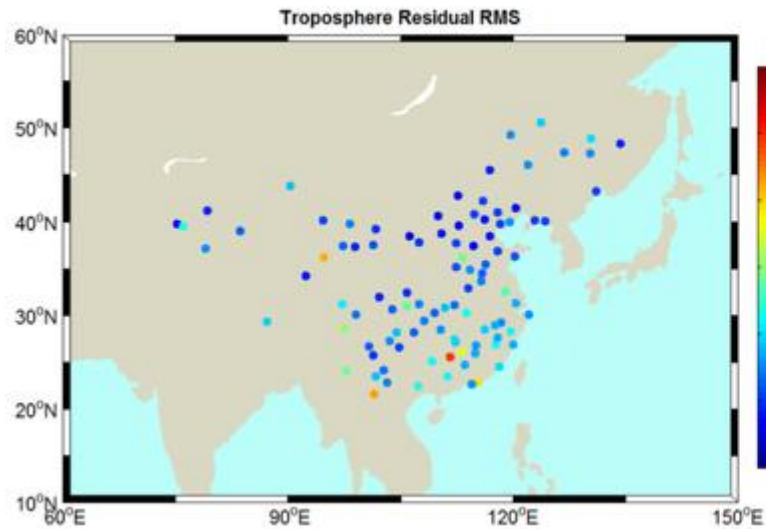
Assessment

Item	Value
Time	DOY 021~028, 2017
Station	~200
Reference	VTEC generated by PPP
RMS	3.4 TECU

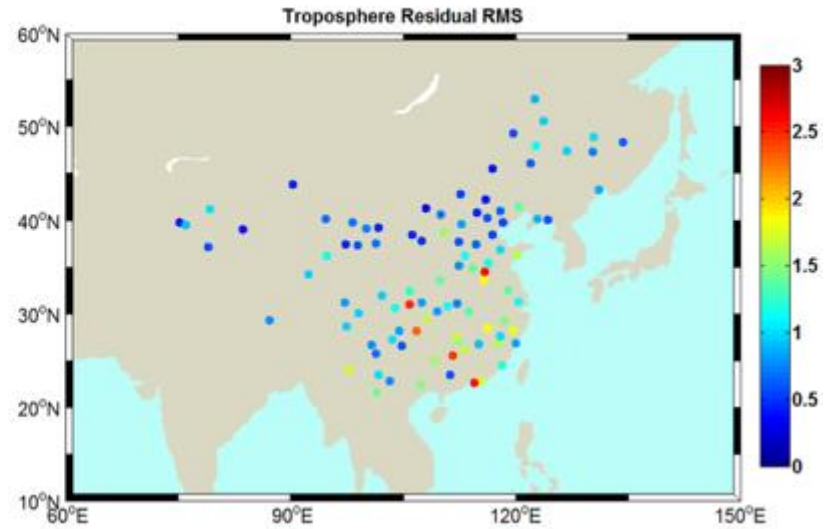


Initial result of Real-time Tropospheric Grid Point model (TGP)

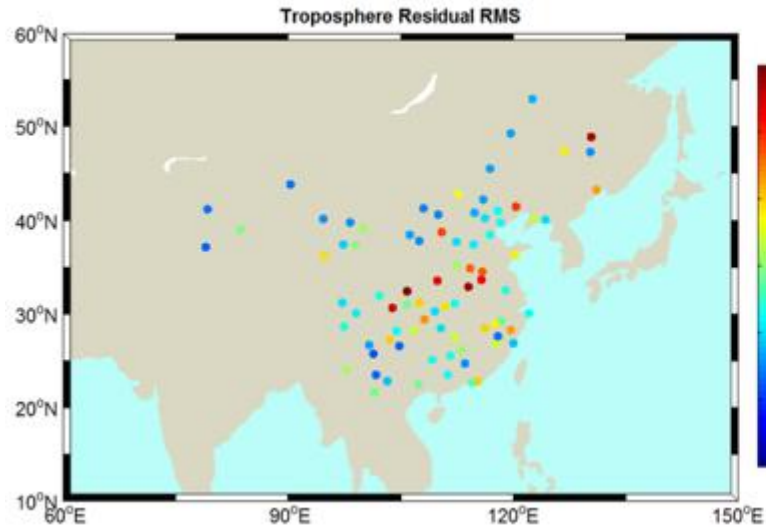
20160122-20160128



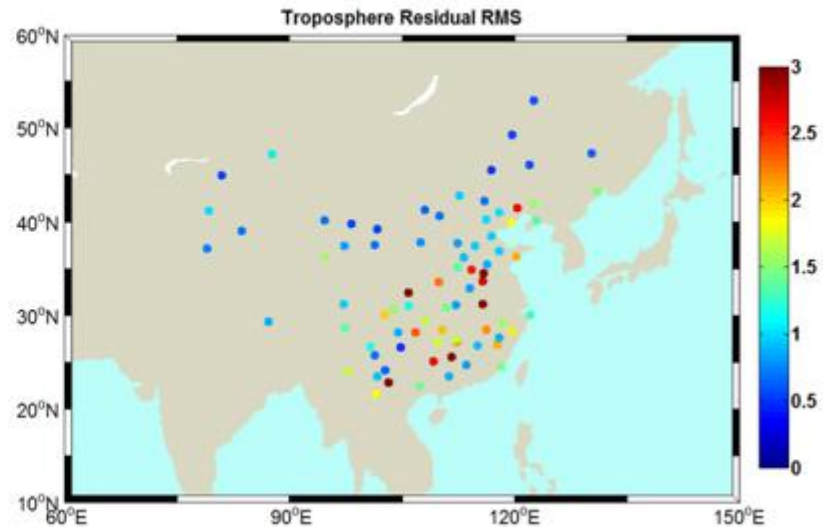
20160401-20160407



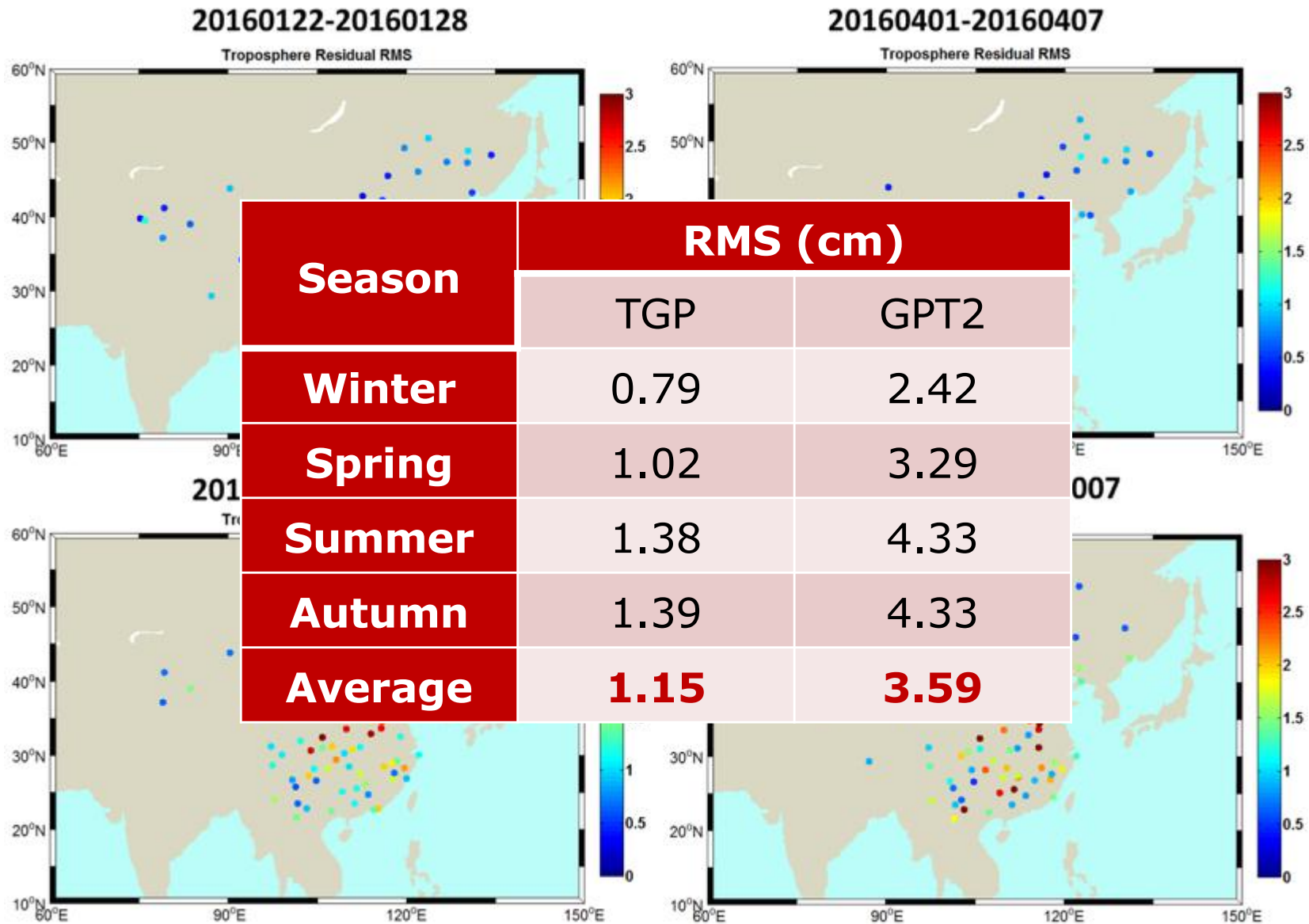
20160717-20160723



20161001-20161007



Initial result of Real-time Tropospheric Grid Point model (TGP)



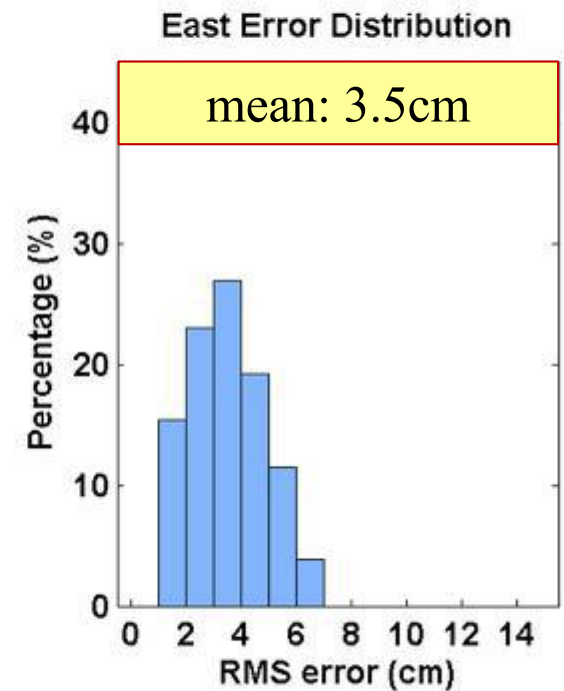
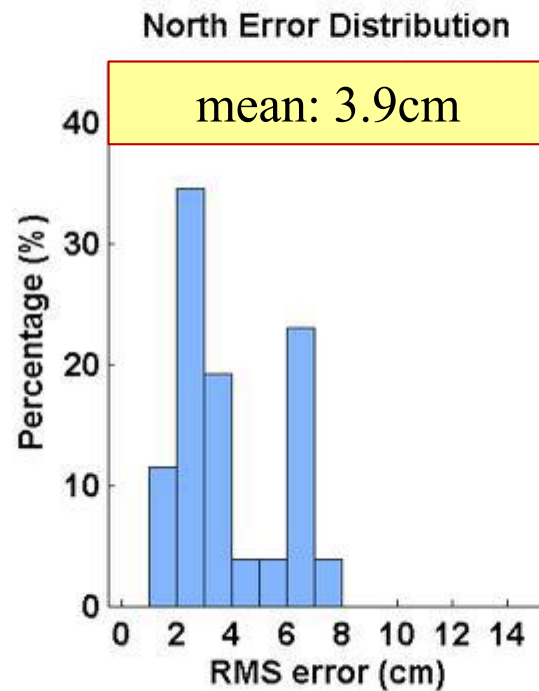
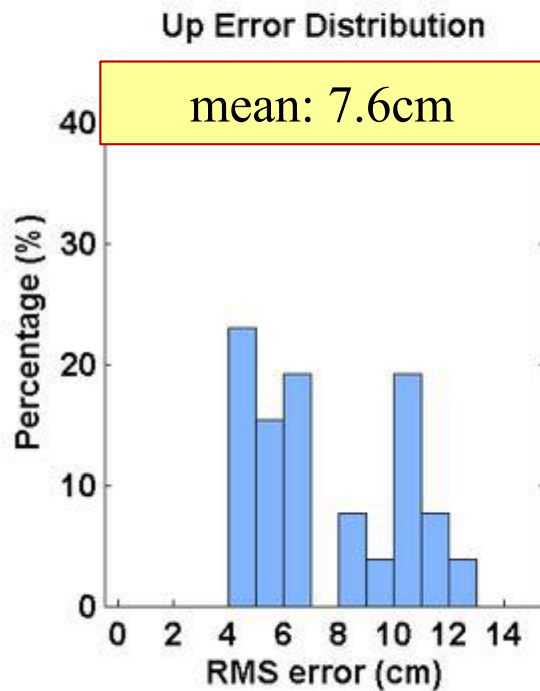
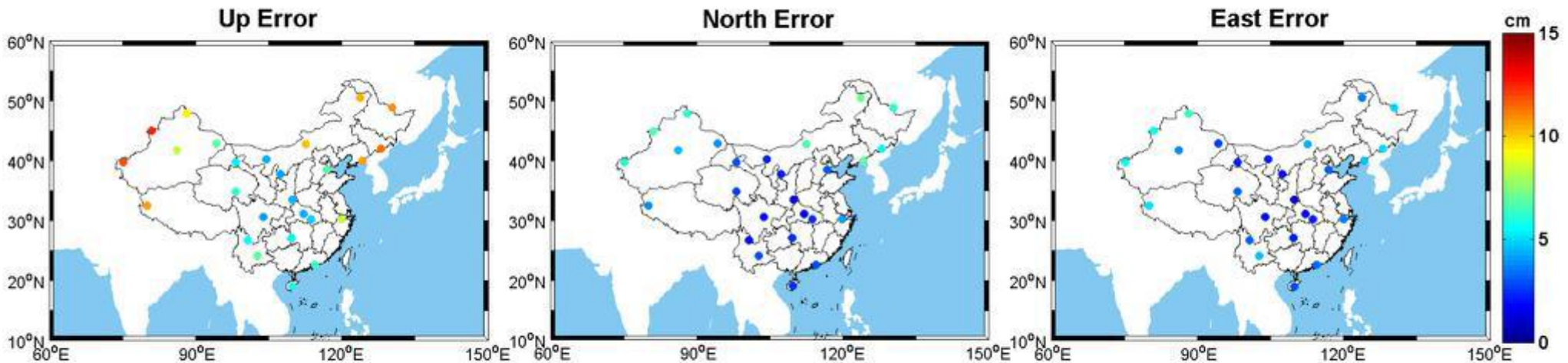
Outline

- Overview
- BDS Real Time Precise Products
- Application of Real-time PPP
- Summary

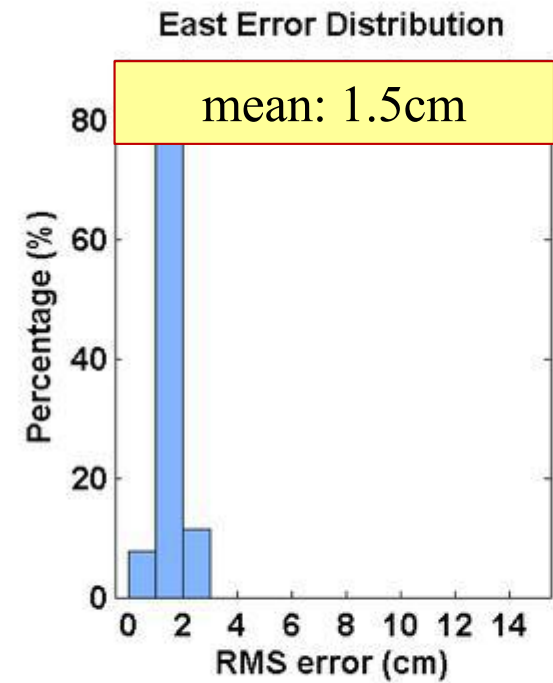
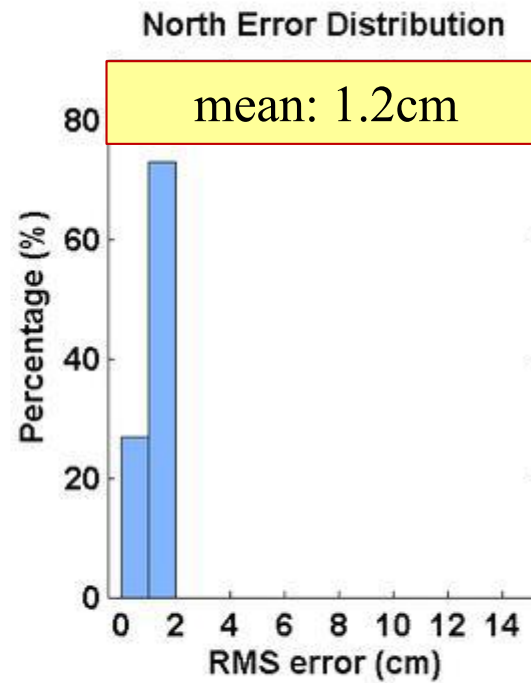
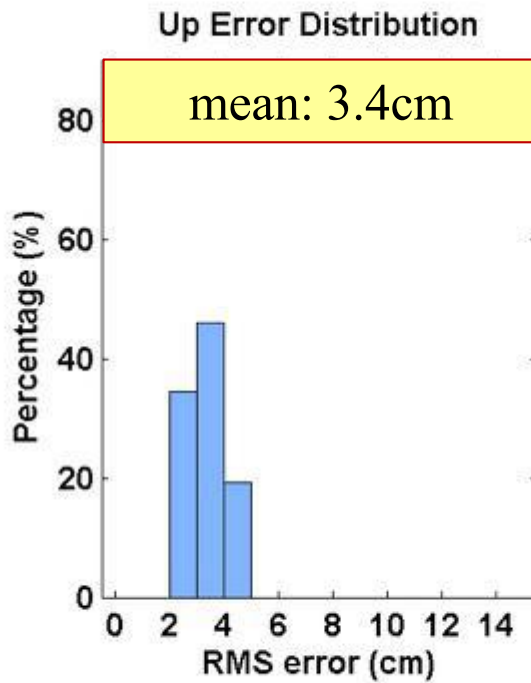
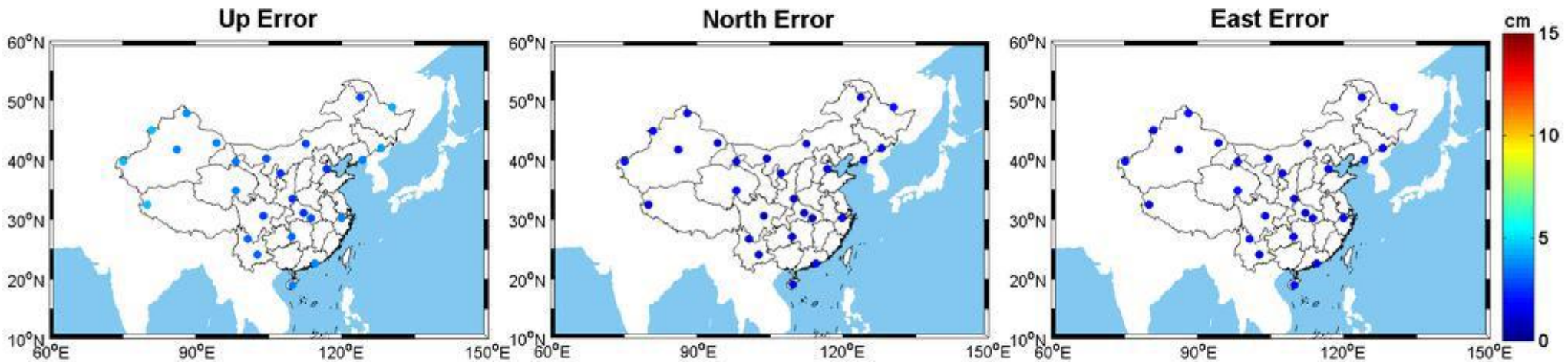
Details of the Real-Time experiment

- Stations: 26, distributed over China
- Session time: 20170121-20170128
- Accuracy
 - DF-PPP/SF-PPP/SF-SPP
- Convergence
 - DF-PPP/SF-PPP/DF-PPP with TGP

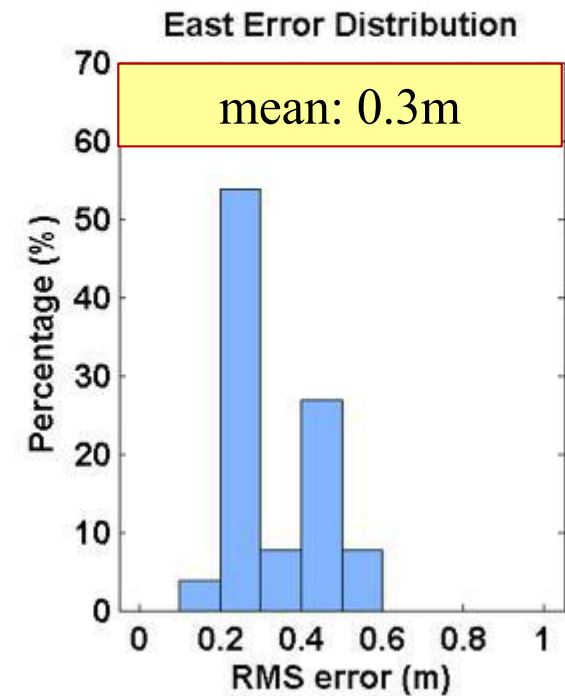
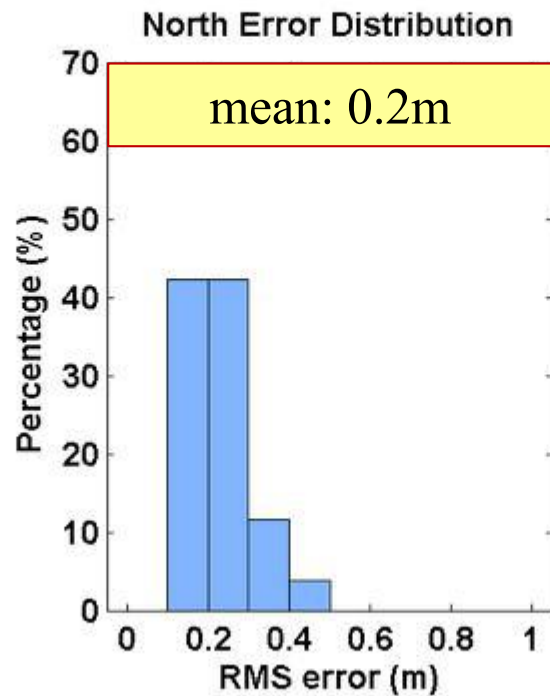
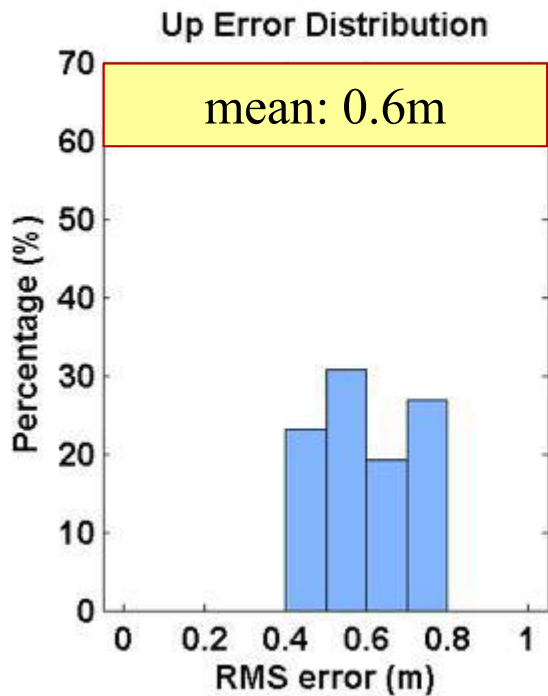
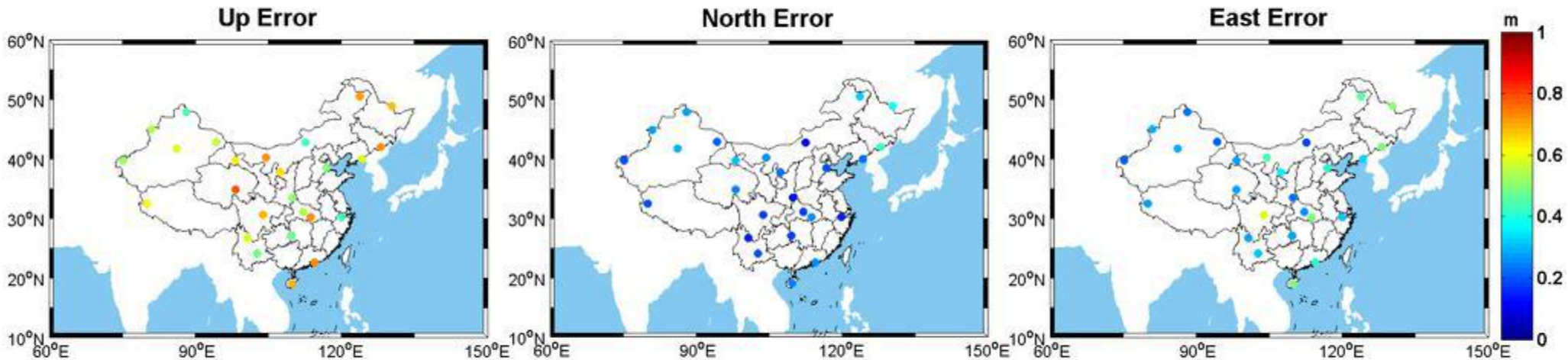
Real-time BDS DF-PPP Accuracy



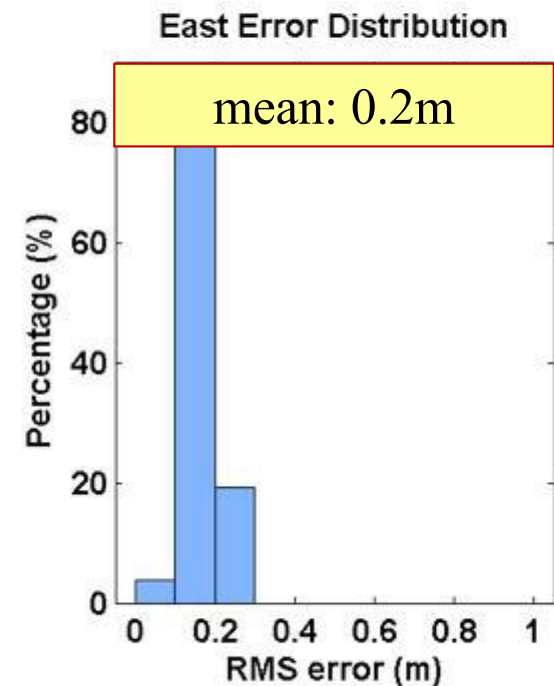
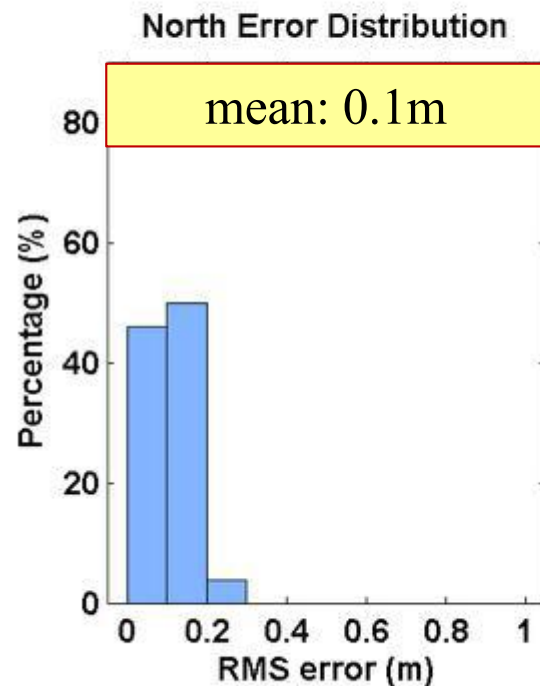
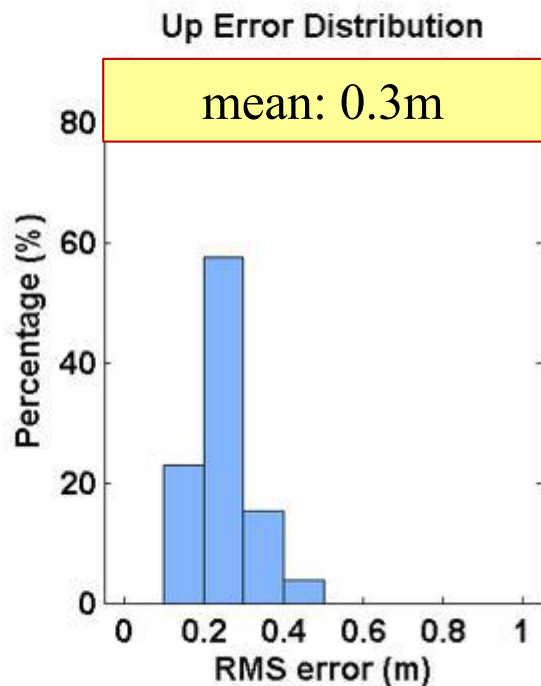
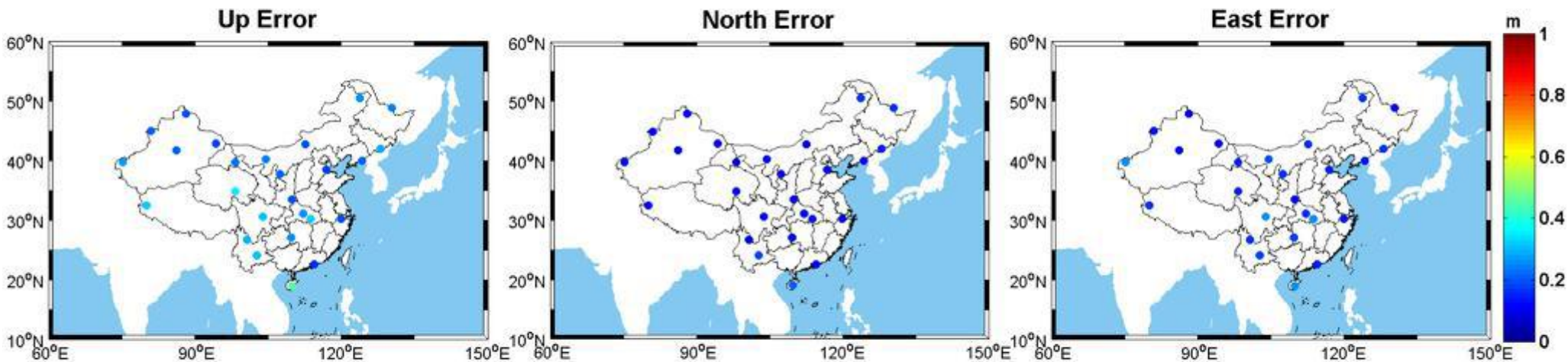
Real-time BDS+GPS DF-PPP Accuracy



Real-time BDS SF-PPP Accuracy

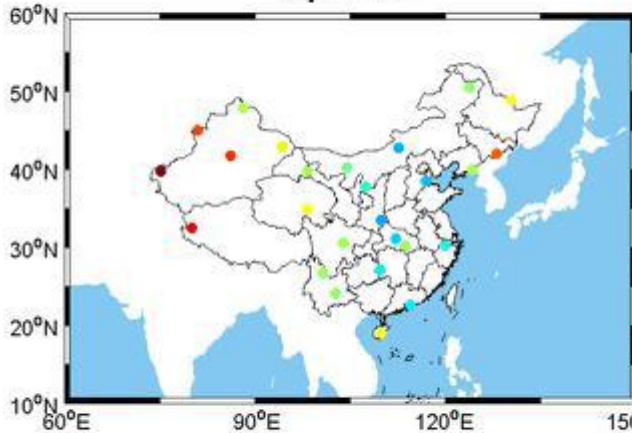


Real-time BDS+GPS SF-PPP Accuracy

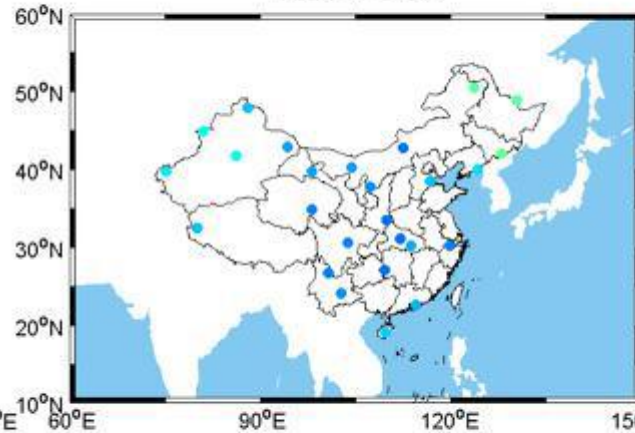


Real-time BDS SF-SPP Accuracy

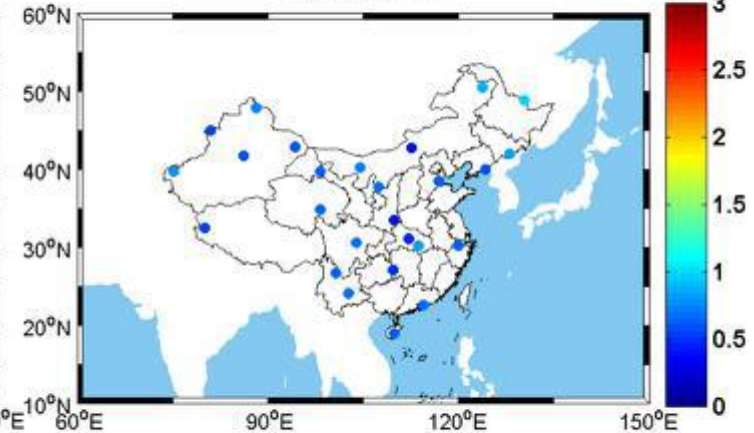
Up Error



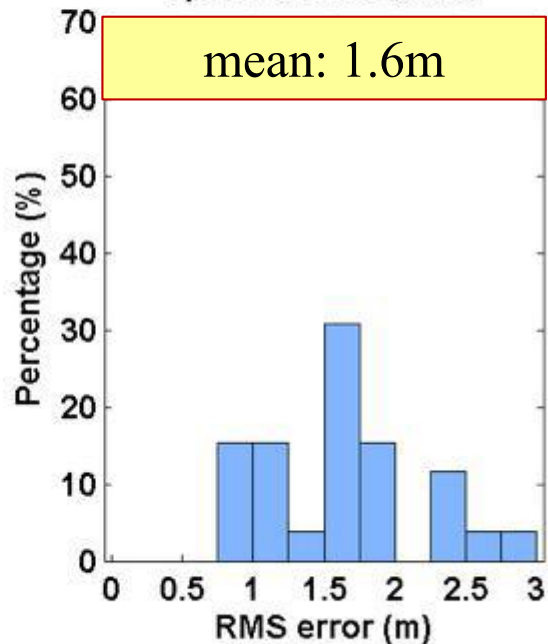
North Error



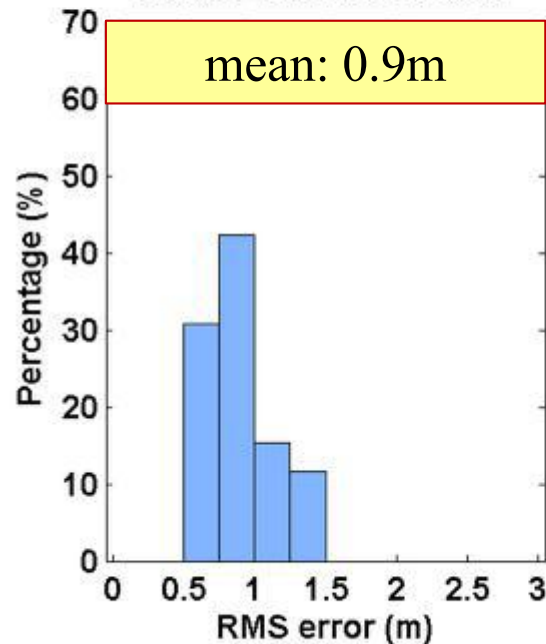
East Error



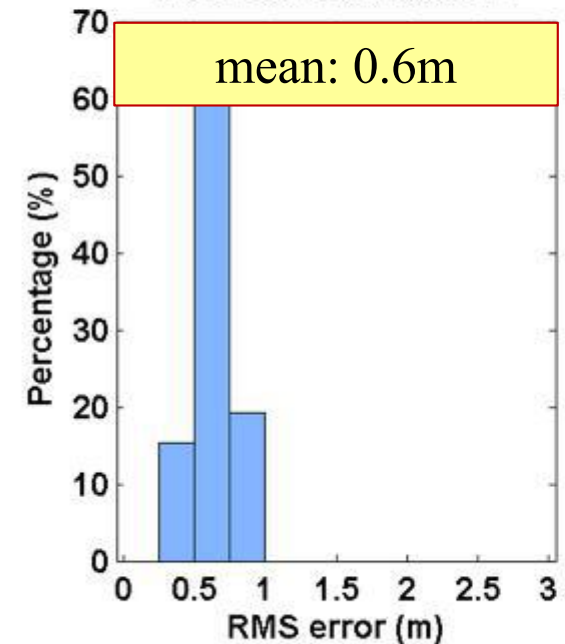
Up Error Distribution



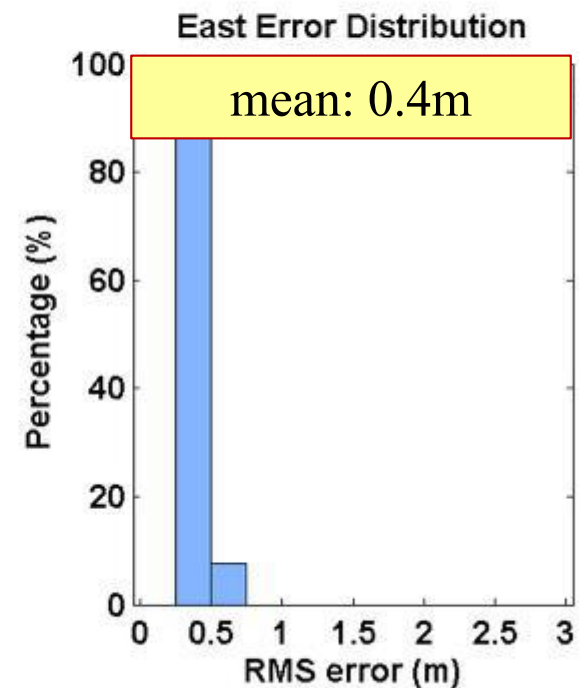
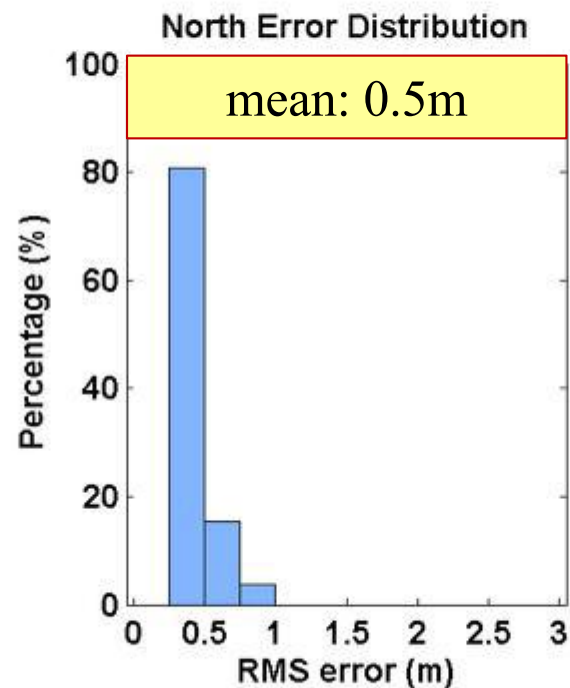
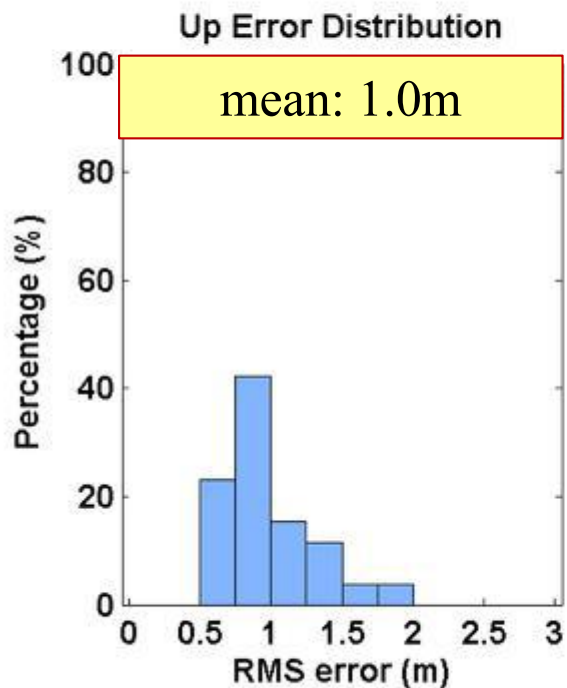
North Error Distribution



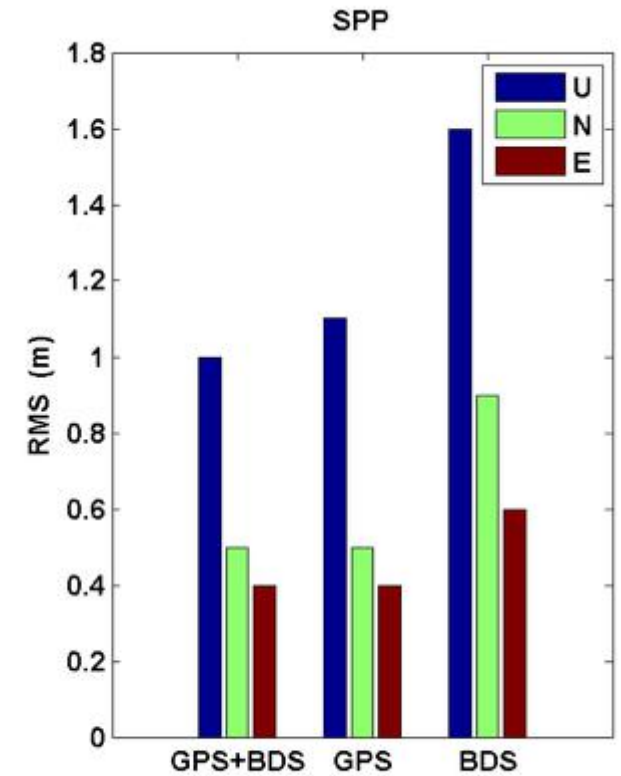
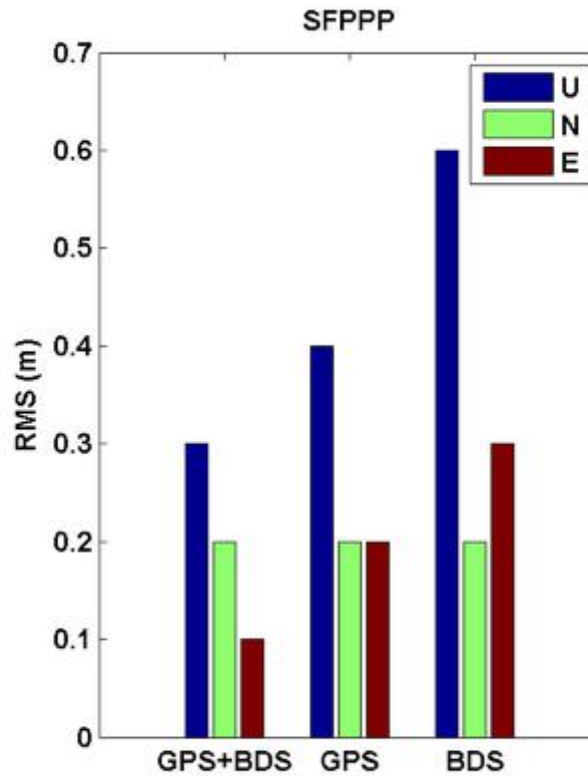
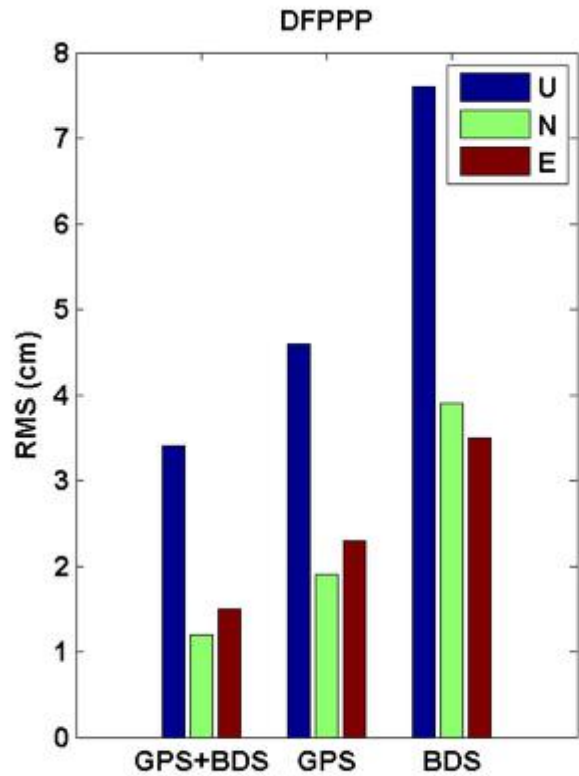
East Error Distribution



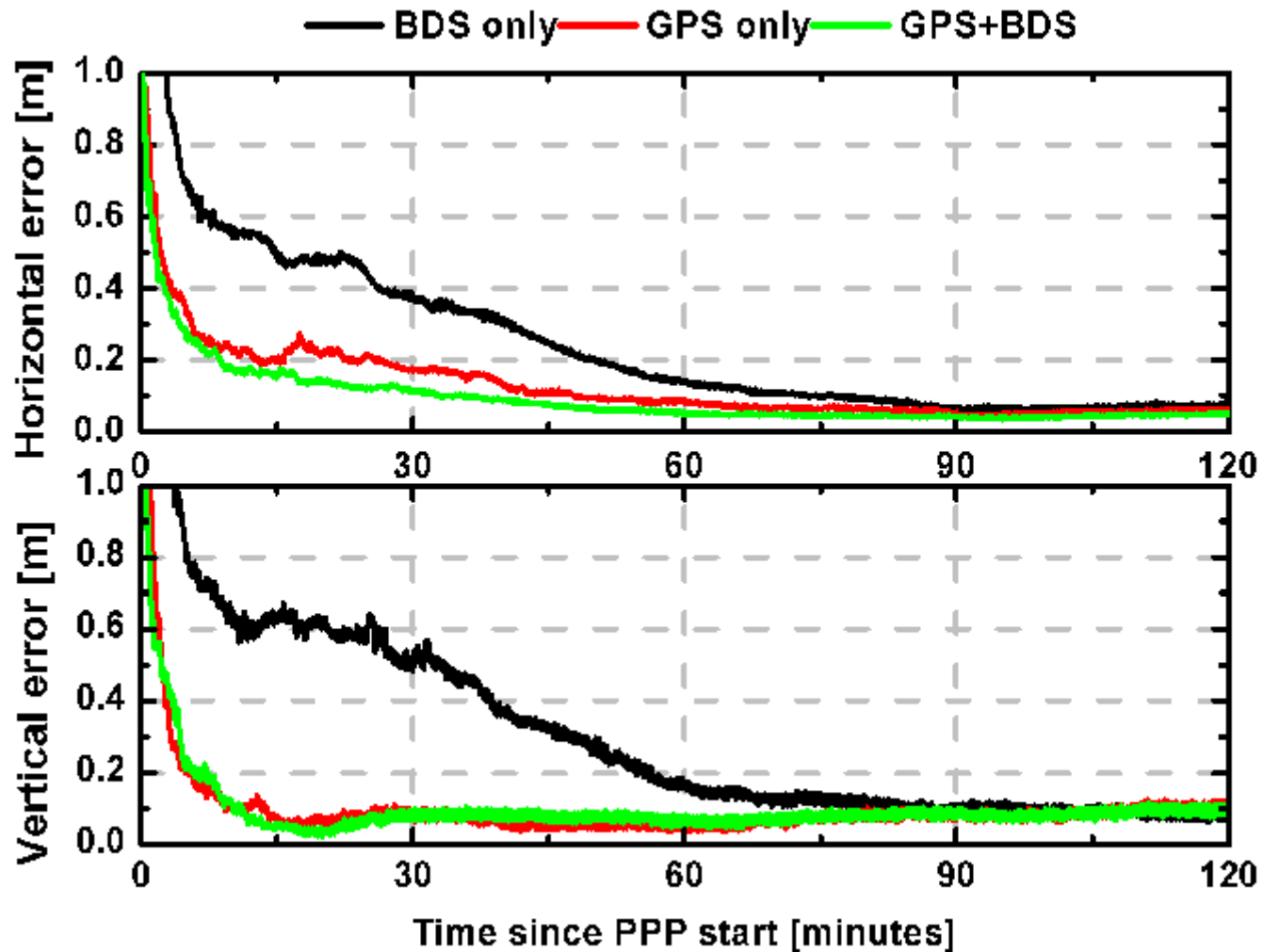
Real-time BDS+GPS SF-SPP Accuracy



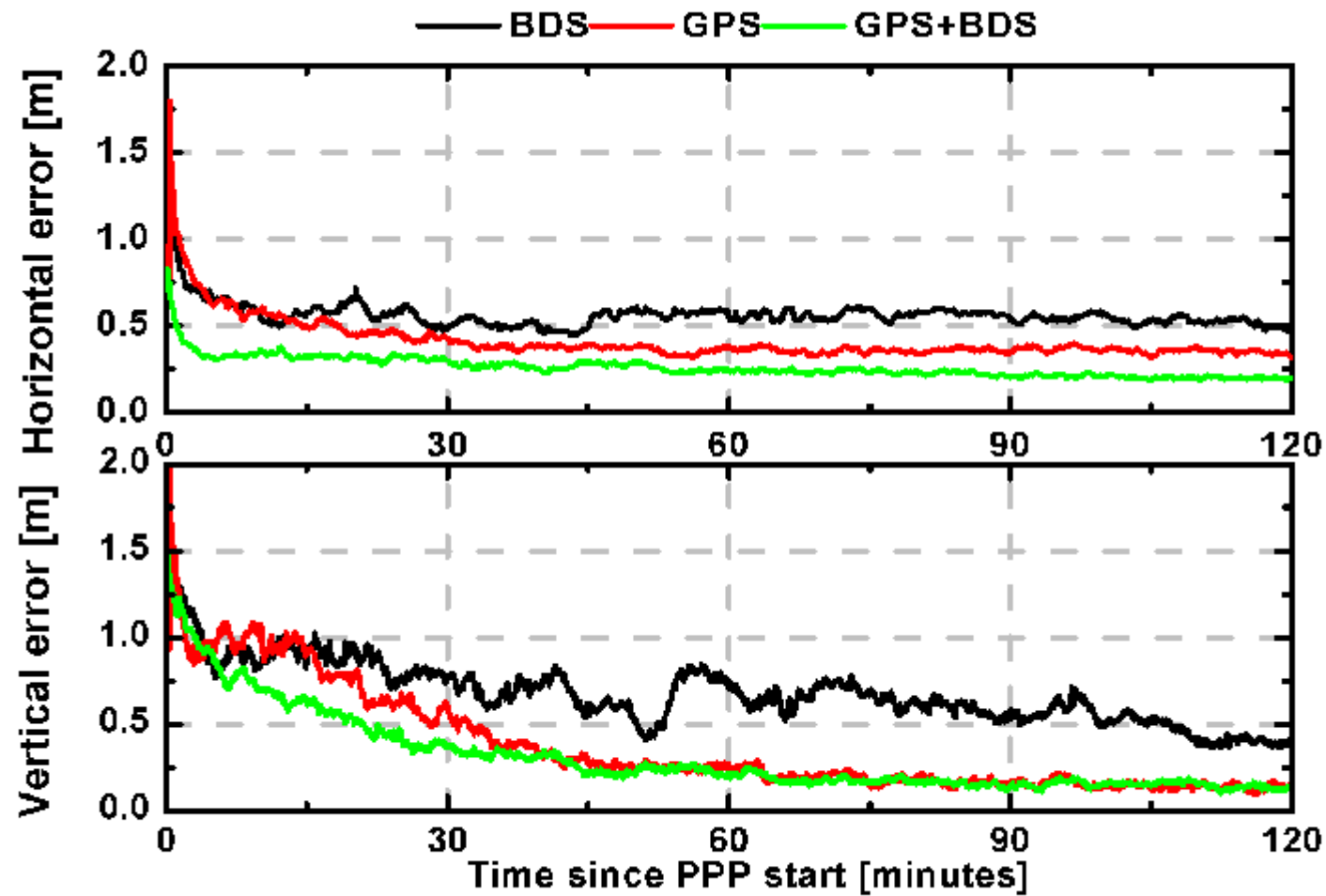
Result Analysis



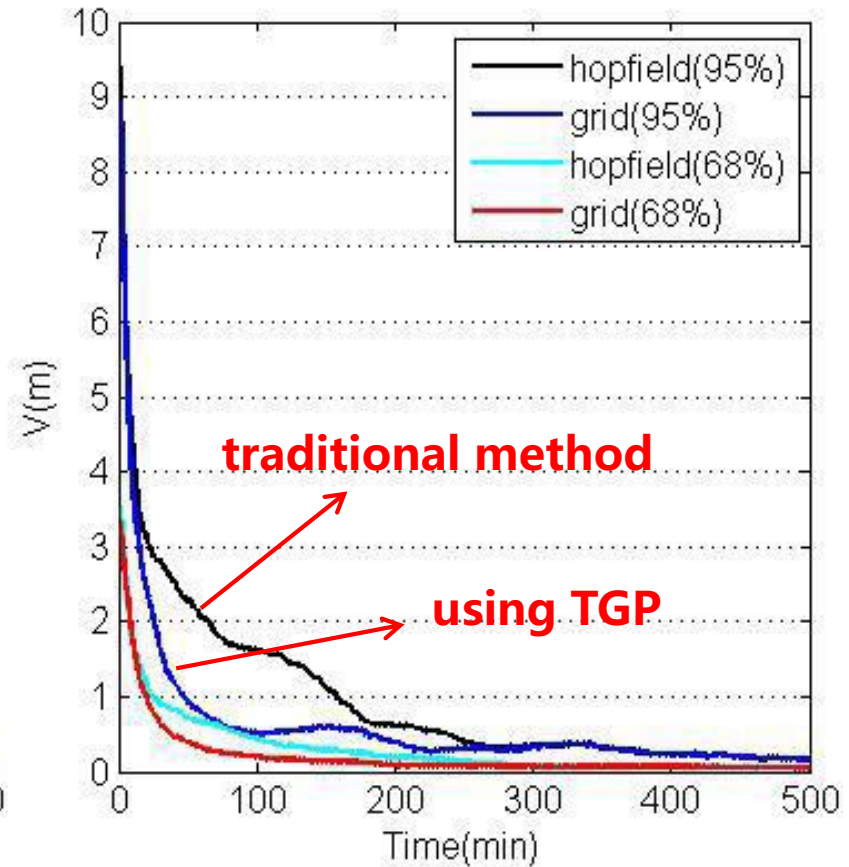
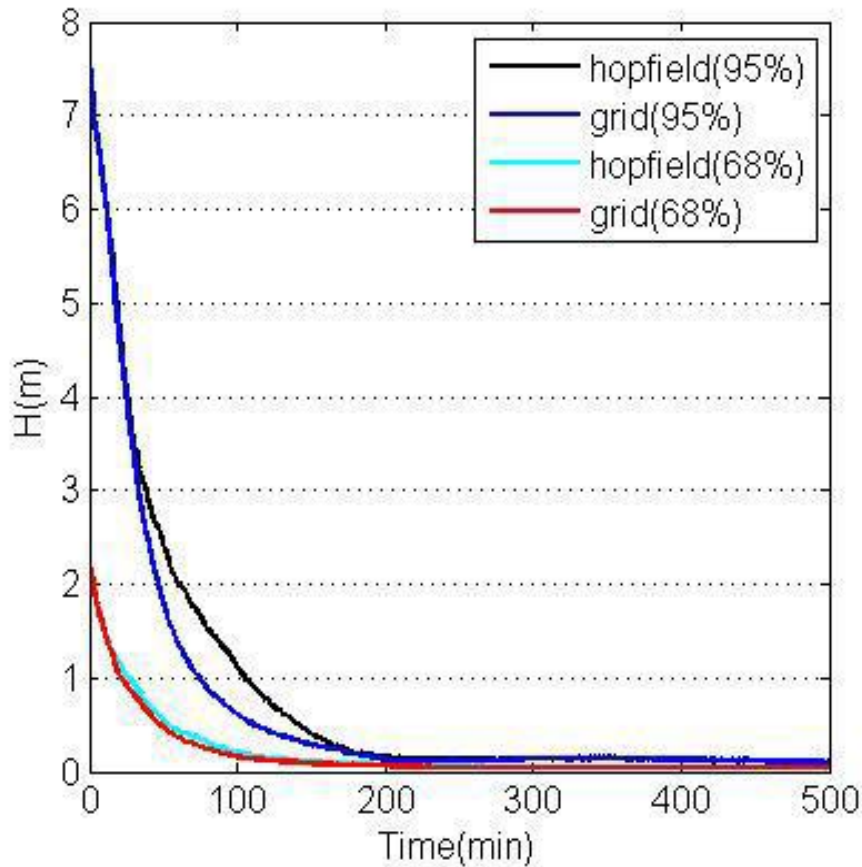
DF-PPP Convergence time



SF-PPP Convergence time



BDS DF-PPP Convergence time with TGP



Outline

- Overview
- BDS Real Time Precise Products
- Application of Real-time PPP
- Summary

Summary

□ BDS Real-time Precise Products:

- Real-time Orbit : GEO 15cm(R) ; IGSO/MEO 10cm(R) , 30cm(3D)
- URE (Clock) : BIAS~1.0m , STD~2cm
- Real-time Ionosphere : ~3TECU , The precision of boundary area is a bit poor
- Real-time Troposphere : <1.5cm, Initial result

□ BDS Real-time PPP:

- DF-PPP : 10cm in horizontal, 20cm in vertical, convergence time ~60 mins
- DF-PPP : 0.6m in horizontal, 1.2m in vertical, convergence time ~5 mins
- SF-SPP : 2.0m in horizontal, 3.0cm in vertical, comparing with standard SPP, improvement is about 40% and ~50% in horizontal and vertical
- BDS positioning accuracy distribution with regional characteristics, its accuracy is worse than GPS in marginal area

□ The major Contribution of BDS/GPS Combination

- DF-PPP : ~20mins; SF-PPP : ~2mins

Thank You for Your attention!



shi@whu.edu.cn