武漢大學
Wuhan University

Status and Issues of DBDS

Dr. Hui Liu
Wuhan University

Stanford PNT 2014 Symposium
30 October, 2014

Outline

- **Status of BDS**
- Status of Differential BDS (DBDS)
- Some Issues about DBDS
- Conclusions

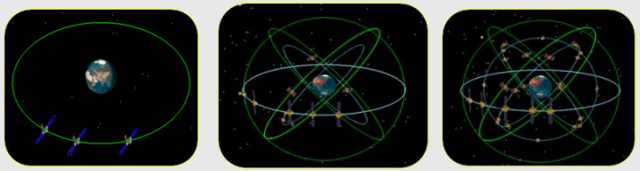
BDS Overview

- **System development**
  - Phase III
- **System Service**
  - Regional, passive service
- **System Performance**
  - Standard service for B1I:About 10 m
- **Hot points**
  - Infrastructure: NRTK,GBAS, SBAS,……
  - R&D: Chips, Receivers,Software……
  - Applications: Vehicle, Agriculture, Surveying,…

System Architecture

Space constellation

- 5 GEO
- 27 MEO
- 3 IGSO



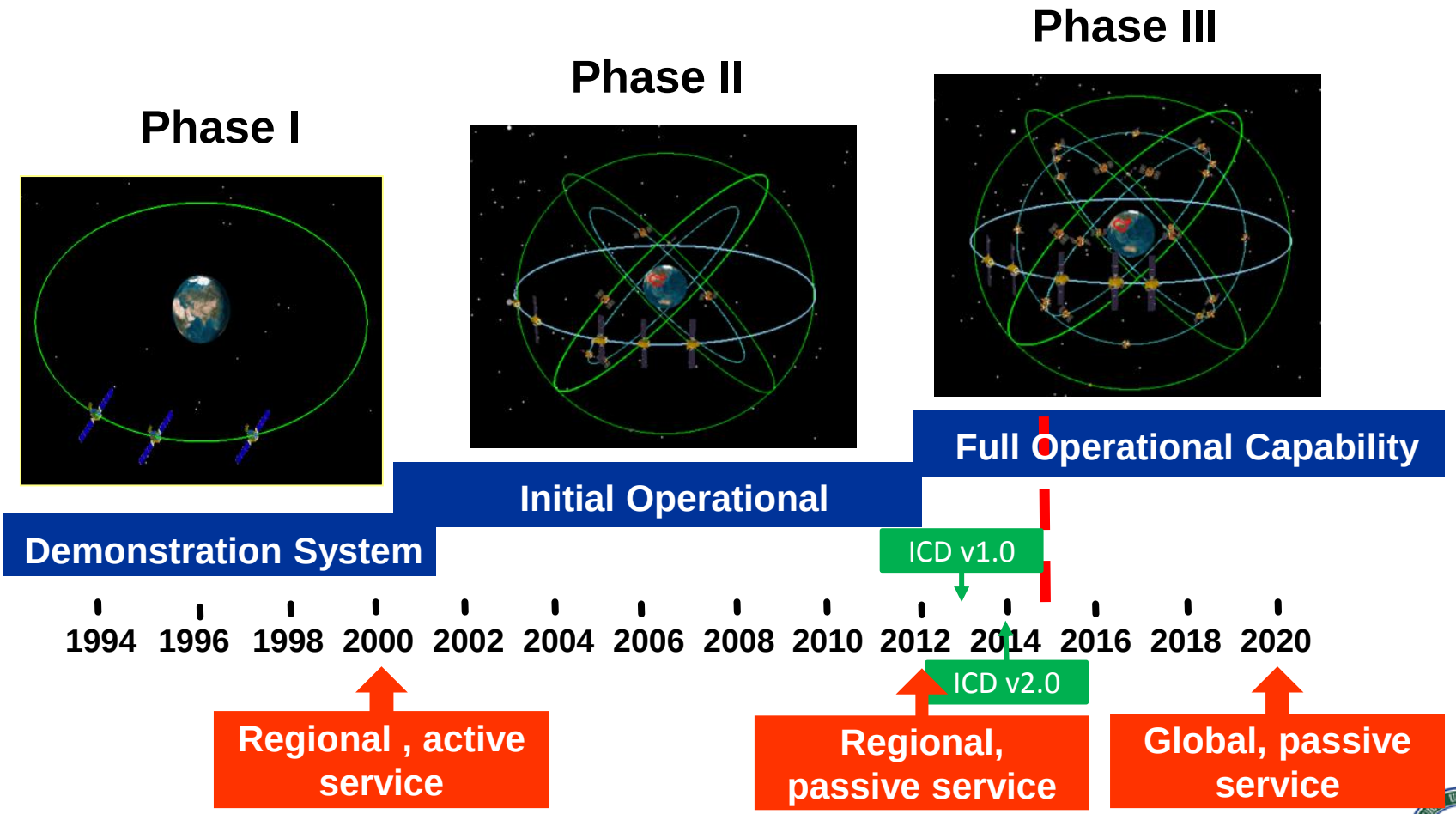
Ground control segment

- Master Control Stations (MCS)
- Uplink Stations(US)
- Monitoring Stations(MS)

User terminals

- BeiDou user terminals
- Terminals compatible with other GNSS

Development Sections

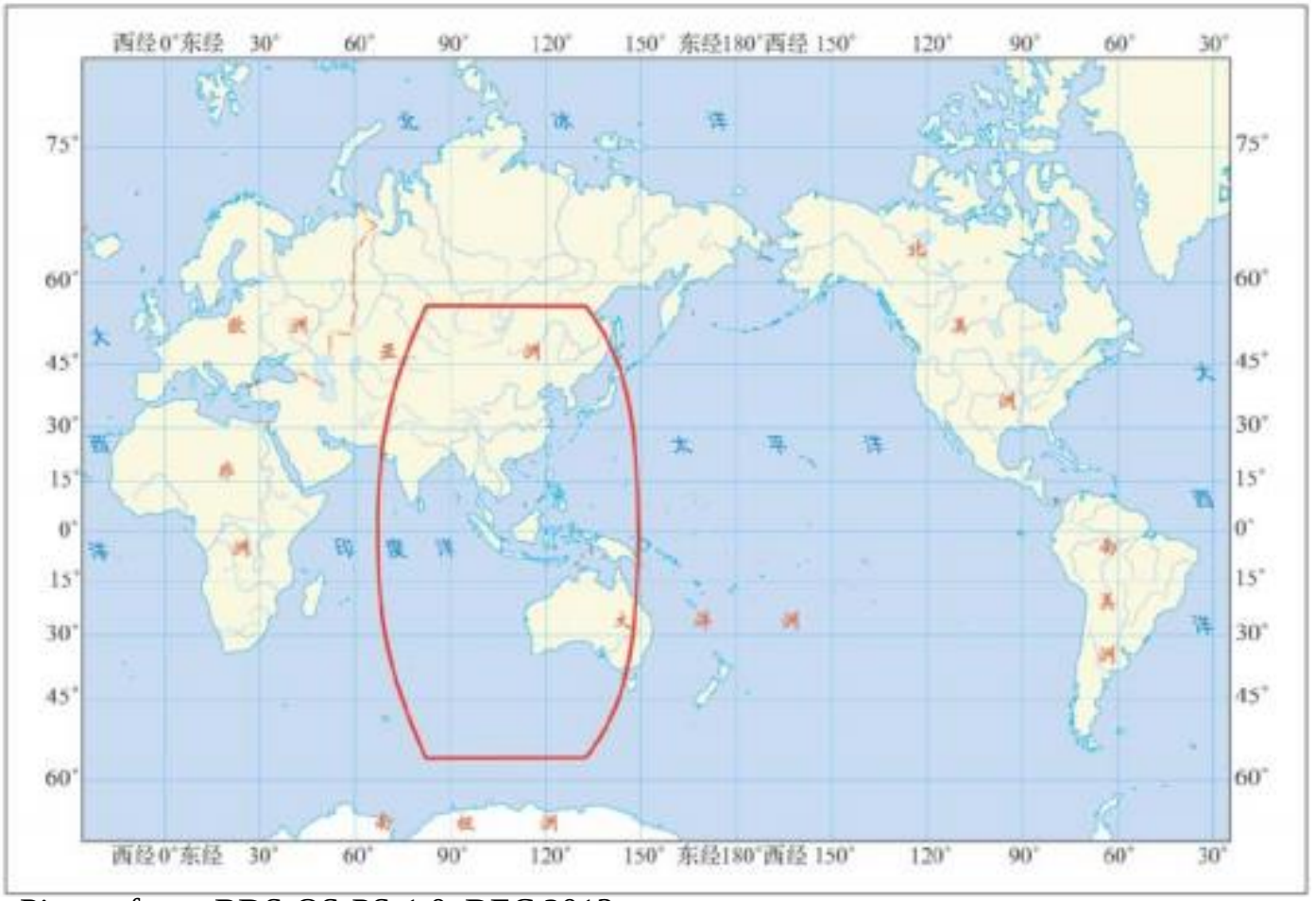


BDS Satellites

Satellites	Launching date	Carrier rocket	Orbit	Status
Experiment 1	2000.10.31	CZ-3A	GEO	not working
Experiment 2	2000.12.21	CZ-3A	GEO	not working
Experiment 3	2003.05.25	CZ-3A	GEO	online
Experiment 4	2007.02.03	CZ-3A	GEO	offline
1	2007.04.14	CZ-3A	MEO	online
2	2009.04.15	CZ-3C	GEO	offline
3	2010.01.17	CZ-3C	GEO	online
4	2010.06.02	CZ-3C	GEO	online
5	2010.08.01	CZ-3A	IGSO	online
6	2010.11.01	CZ-3C	GEO	online
7	2010.12.18	CZ-3A	IGSO	online
8	2011.04.10	CZ-3A	IGSO	online
9	2011.07.27	CZ-3A	IGSO	online
10	2011.12.02	CZ-3A	IGSO	online
11	2012.02.25	CZ-3C	GEO	online
12,13	2012.04.30	CZ-3B	MEO	online
14,15	2012.09.19	CZ-3B	MEO	online
16	2012.10.25	CZ-3C	GEO	online

System Service

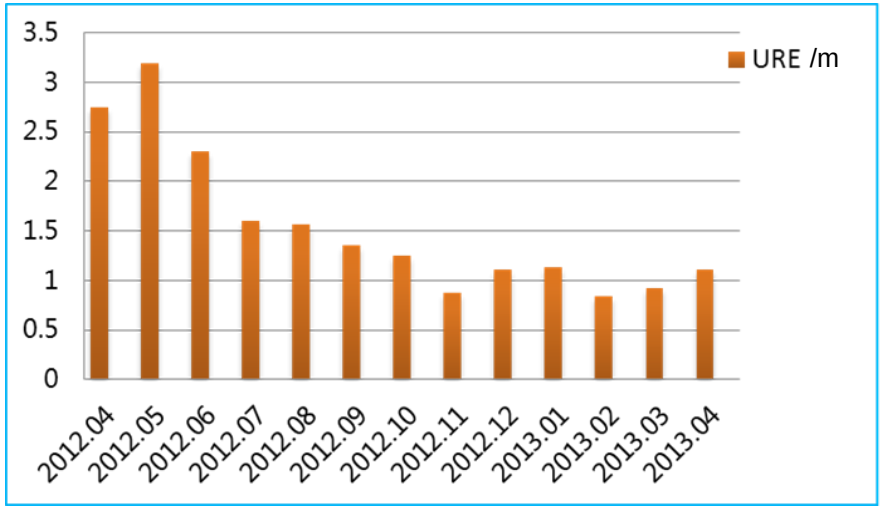
- **Regional service officially launched**



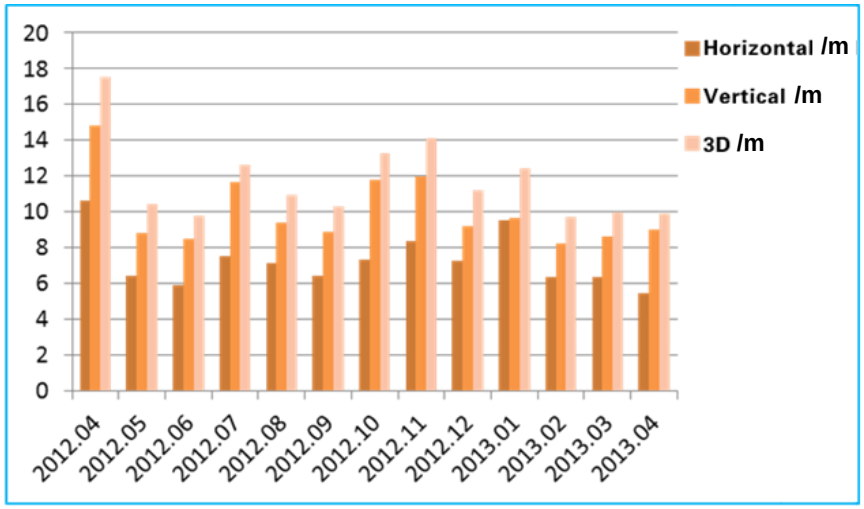
Picture from BDS-OS-PS-1.0 ,DEC 2013

System Performance

- **Service performance test and assessment**
  - BeiDou System is under continuous and stable operation
  - Service performances fulfill the design needs



SIS URE



Positioning accuracy (95%)

System Development Status

- **System applications**

System Development Status

I. Chips and terminals

System Development Status

- Mass market applications

Contents

- Status of BDS
- **Status of Differential BDS (DBDS)**
  - **Concept**
  - **The development of DBDS in China**
  - **The performance tests of DBDS**
  - **DBDS standard**
- Some Issues about DBDS
- Conclusions

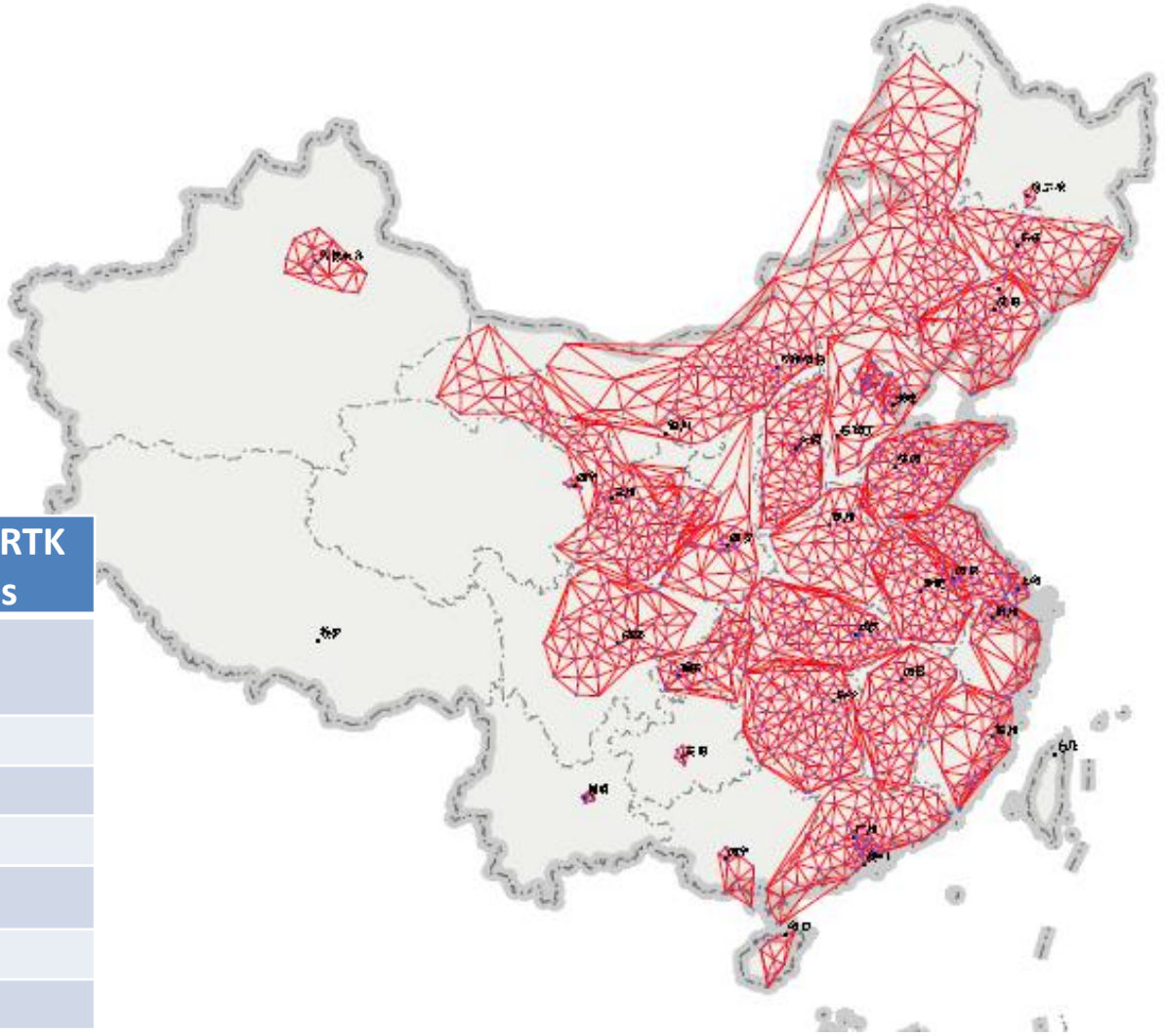
Concept

- **The DGNSS services in the framework of RTCM SC104**

Technical	Platform	Protocols
Code differential (CDGNSS) 0.3m~2m	RBN-DGNSS	RTCM 10402.X
Phase differential (RTK/NRTK) 0.02m~0.10m	NRTK system	RTCM 10403.X, Ntrip, RSIM,etc.
State Space Representation (SSR) 0.1m~1.0m	GBAS, SBAS	RTCM 10403.X RTCA159

Reference Stations and NRTK system in China

Data to the end of 2013

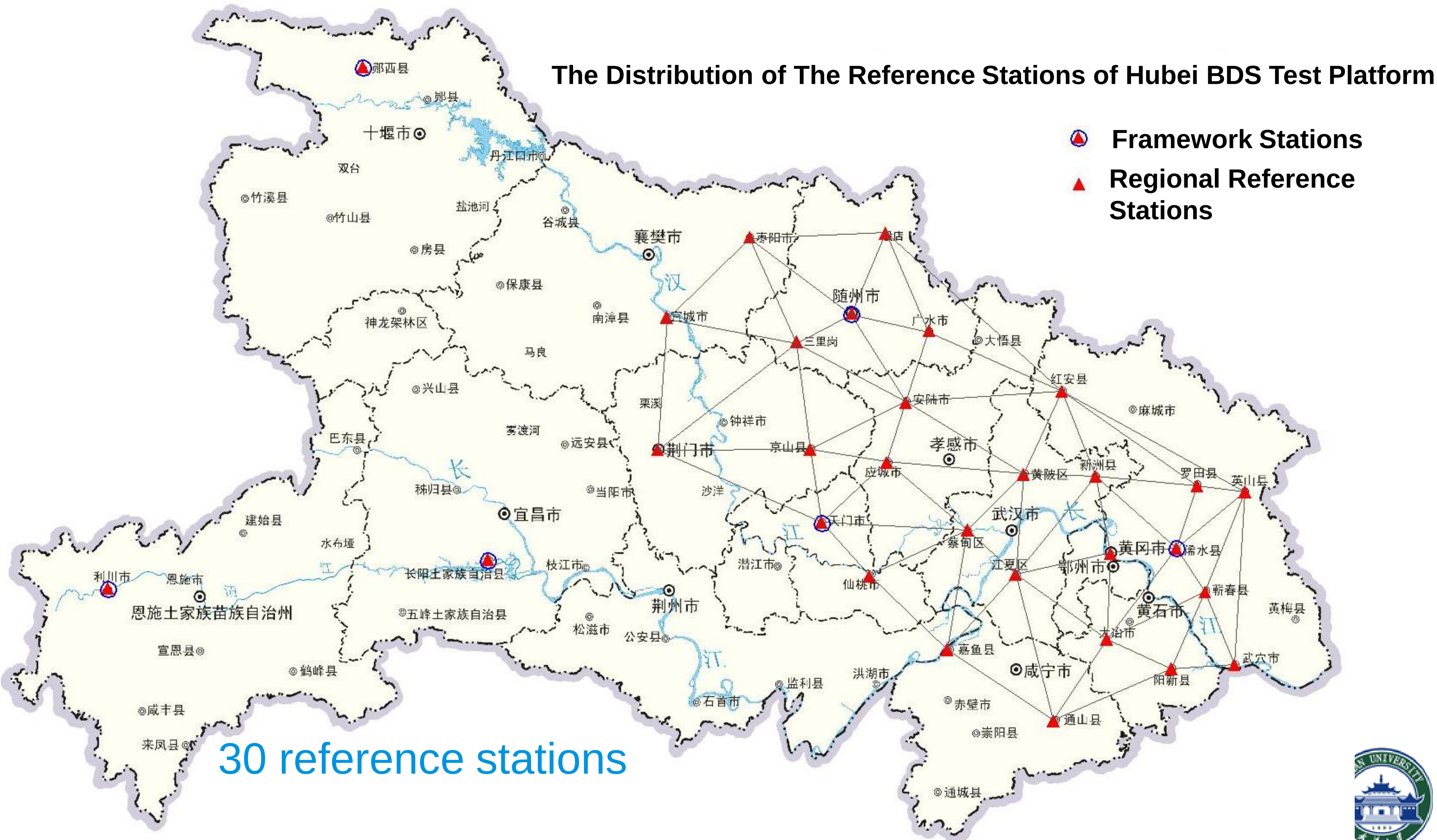


	Num of Stations	Num of NRTK systems
Provincial, urban	~1500	>50
NASMG	~350	--
CEA	~300	--
CMA	~300	
Others	~200	~10
Industry	~500	>50
Total	~3200	>110

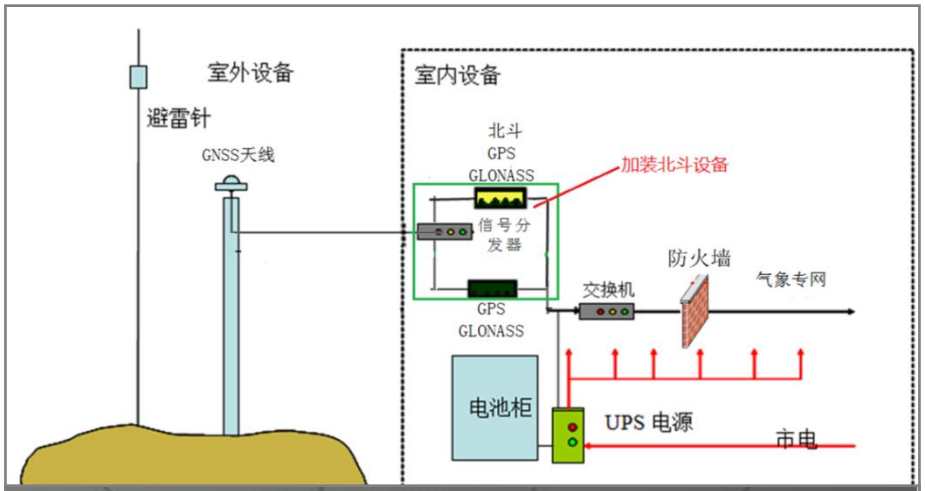
The development of DBDS in China

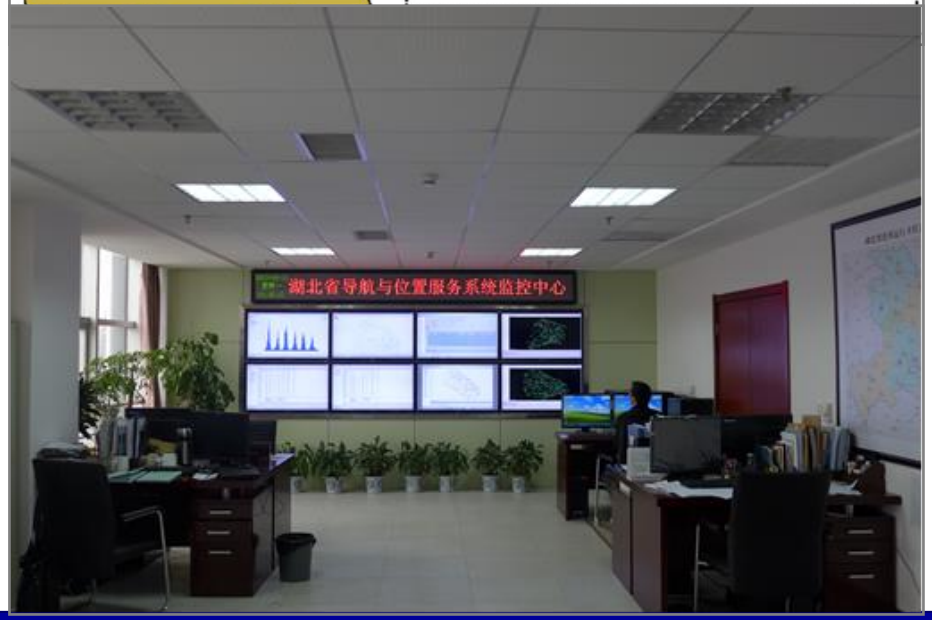
- Hubei DBDS Test platform
- The performance testing
- DBDS standard in the framework of RTCM SC104

Hubei DBDS Test Platform



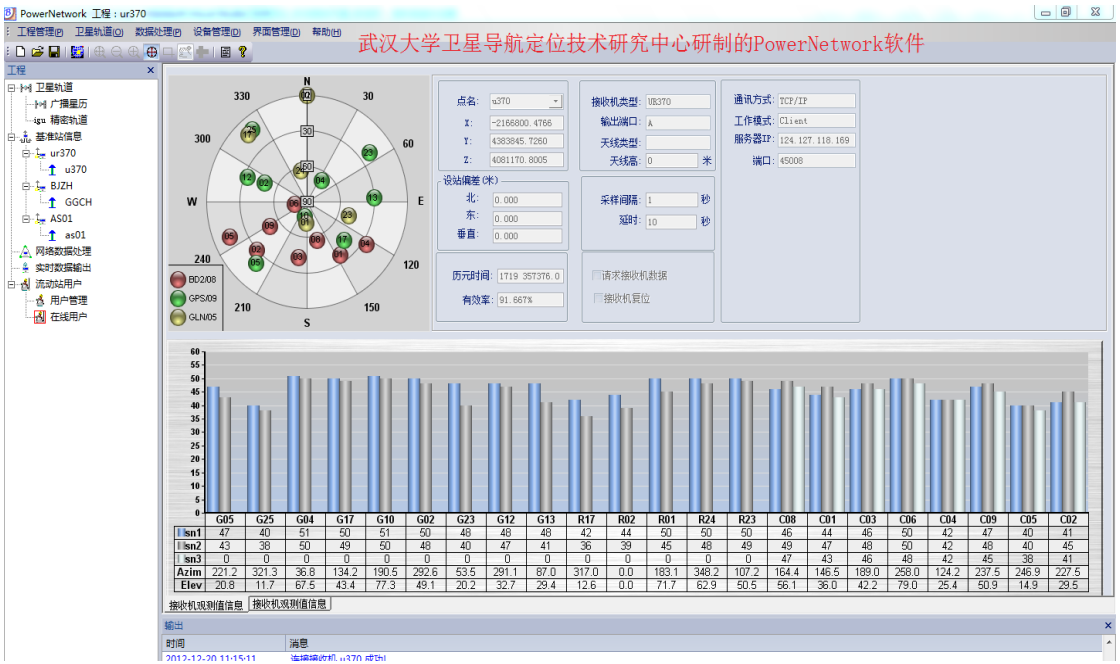
Stations and Data Center





Software

- **Functions**
  - Reference Stations management
  - Data processing for DBDS/NRTK/PPP
  - User management
- **Systems and signals**
  - BDS B1,B2,B3
  - GPS L1,L2
  - GLONASS L1,L2



GNSS Receiver—BDS/GPS OEM

	Specification
Freq	Beidou B1/B2 + GPS L1/L2
Positioning Mode	Support point positioning using Beidou only, GPS only, and Beidou/GPS
BDS	Support Beidou B1/B2，Support Beidou point positioning, differential Beidou, and high precision relative positioning
Differential Corrections	CMR,CMR+,RTCM2.x,RTCM3.x
RTK Positioning	Support instant RTK and long range RTK
RTK accuracy	Horizontal: 1cm+1ppm Vertical：2cm+1ppm
Power	1.6W
WAAS	Support WAAS and PPP

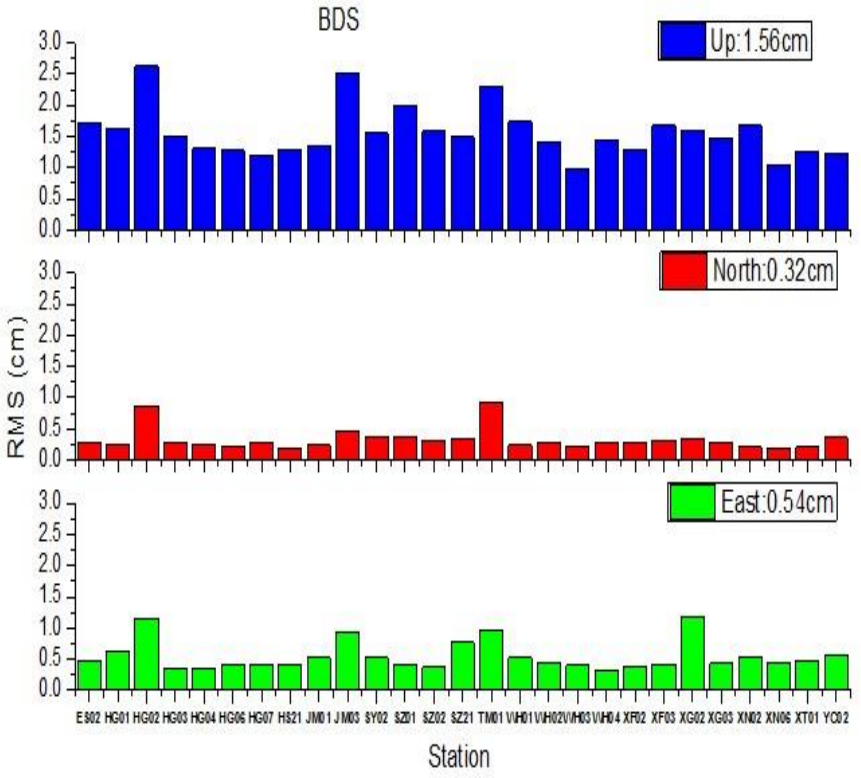
User Terminals

- RTK Rover
- GIS data collector

Performance Test—post processing

- **Reference stations coordinates**
  - CGCS2000(BDS data only)
  - RMS H:0.006m, V: 0.015m(95%)

ECEF RMS		Baseline Repeative
	RMS	Fixed +Scale
X	0.007m	6.7mm+2.8×10^{-8}
Y	0.010m	10.0 mm +1.6×10^{-8}
Z	0.006m	5.8mm +3.0×10^{-8}



Performance Test— CDBDS

- **Dynamic testing**
  - 1Hz position output
  - RMS: H:67m ， V:1.5m(95%)

Mode	BDS L1
Points Number	1344
1 Sigma	0.67m
95%	1.44m
Points number	BDS L1

2014/11/5

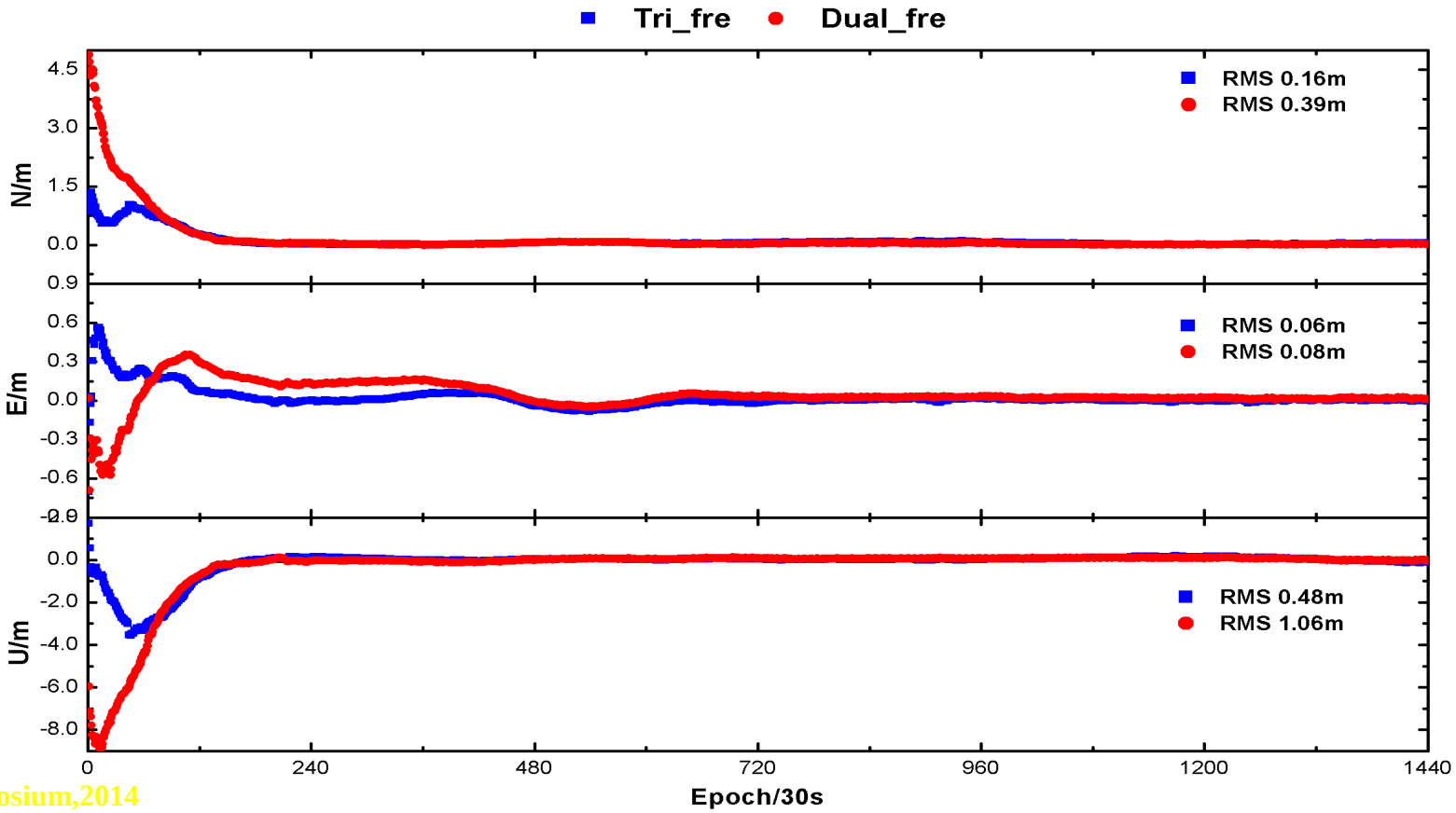
Performance Test —BDS NRTK

- **Stationary positioning tests**
  - BDS2 B1/B2
  - BDS3 B1/B2/B3
  - GPS L1/L2

Mode	Fixed Rate	Initial Time/s	Average STD/m		Average RMS/m	
			H	V	H	V
GPS+BDS3	100%	**5.76**	**0.004**	**0.018**	0.010	0.036
GPS+BDS2	80%	27.46	0.003	0.015	0.011	0.042
BDS3	83%	**16.40**	**0.007**	**0.020**	0.013	0.052
BDS2	40%	50.78	0.003	0.015	0.014	0.045
GPS	44%	40.28	0.006	0.021	0.012	0.048

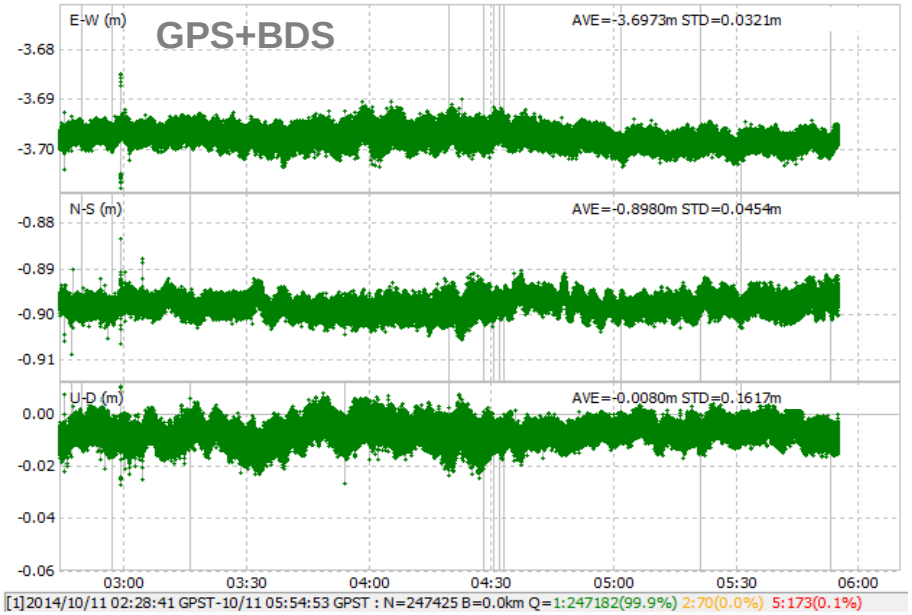
Performance Test— BDS PPP

- **Stationary Test**
  - B1/B2/B3 3D RMS H: 0.18m V:0.48m
  - B1/B2 3D RMS H: 0.40m V:1.06m



Performance Test—20Hz Stationary

- Stationary , 4m baseline BDS B1+GPS L1
- Single Epoch Resolution

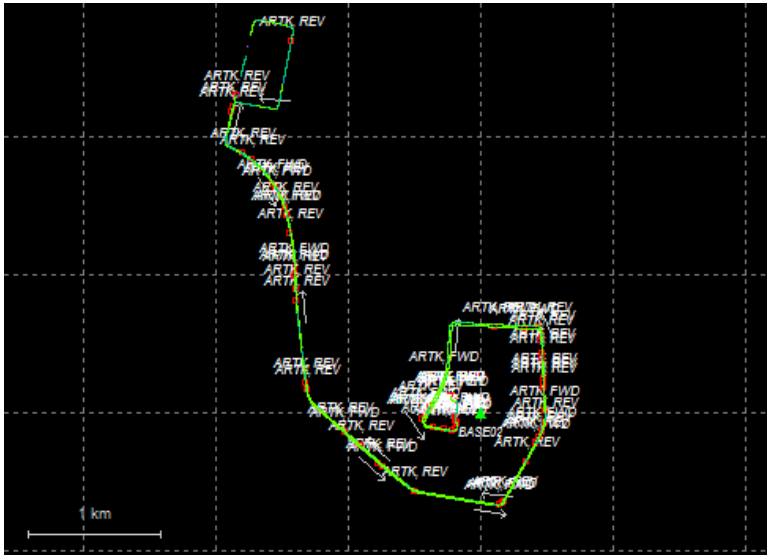


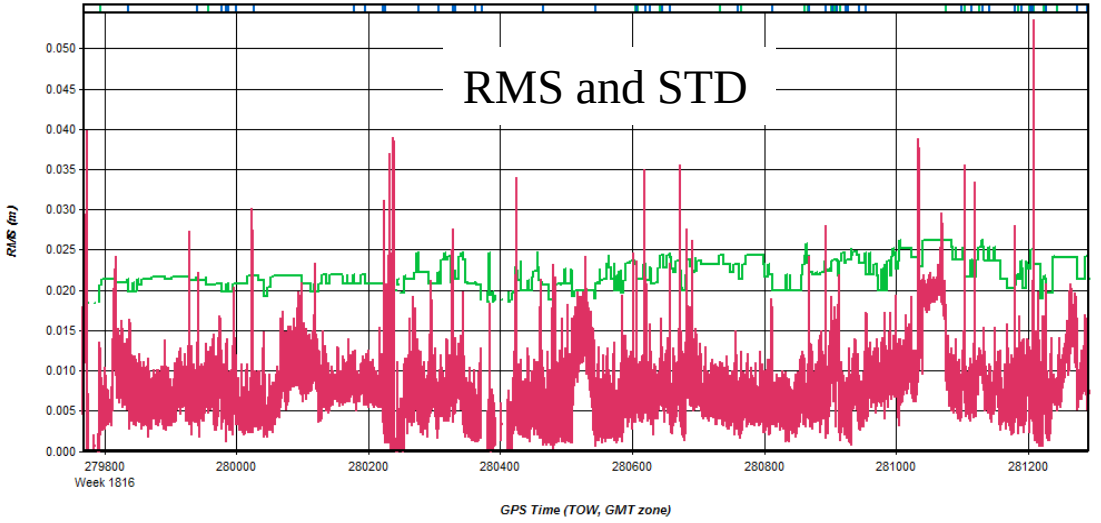
—The Ambiguities Fixing Rate of GPS/BDS improve nearly 20% than GPS.

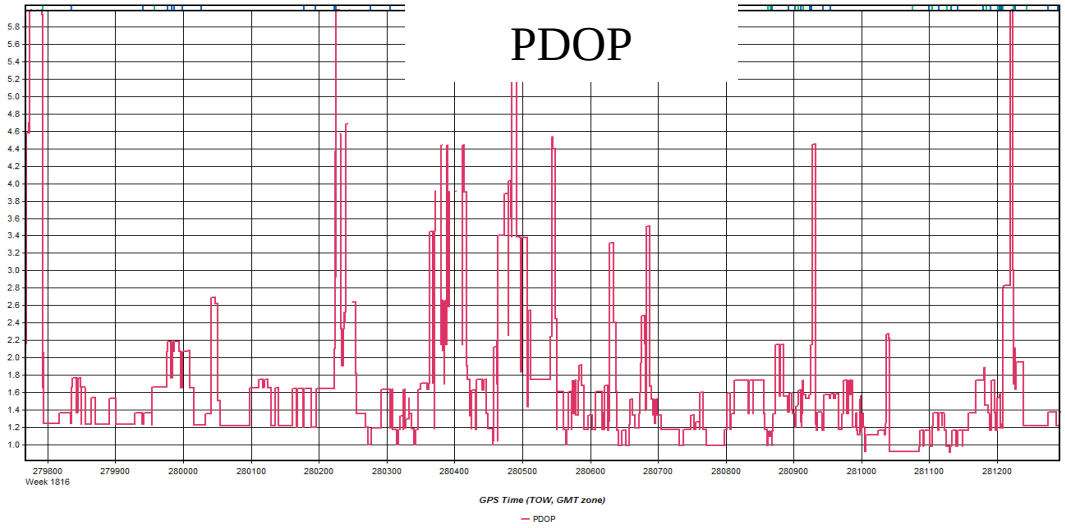
—The accuracy improved

Performance Test—20Hz dynamic

- **Dynamic test**
  - GPS+BDS
  - Post data processing
  - 6Km baseline
  - Baseline RMS 0.025m







DBDS standard

- **RTCM SC104 standards about GNSS**
  - RTCM 10402.x RTCM Recommended Standards for DGNSS
  - RTCM 10403.x, Differential GNSS
  - RTCM 10410.1, Standard for Networked Transport of RTCM via Internet Protocol (Ntrip)
  - RTCM 10401.2, Standard for Differential Navstar GPS Reference Stations and Integrity Monitors (RSIM)
- **Missions**
  - Add BDS and other systems messages to extend standards
  - The compatibility testing
  - New protocal developed for multi-system
- **Status**
  - BDS WG has been formed since 2013 in RTCM SC104
  - 4 BDS standard proposals have been submitted

Contents

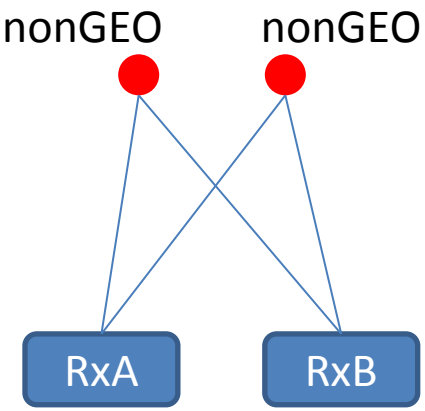
- Status of BDS
- Status of Differential BDS (DBDS)
- **Some Issues about DBDS**
  - **1.BDS Inter-Satellite-Type Biases**
  - **2.BDS RTCM IODE**
- Conclusions

1.BDS Inter-Satellite-Type Biases

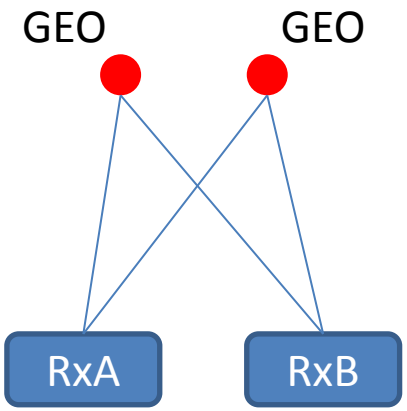
- **Background**
  - The 20-bits Neumann-Hoffman code is modulated on the D1 navigation message and is broadcast by the BDS MEO MEO/IGSO satellites. There is no NH code modulated in D2 message for GEO satellites. (see BDS-SIS-ICD-2.0 **5.2.1)**
- **Issues**
  - It was found that there would be a half circle carrier phase bias of GEO satellites between two boards if IGSO/MEO satellite is chosen as a reference satellite, and vice versa
- **Status**
  - Testing results from Jean-Marie Sleewaegen's team[1] and BDS WG
  - After the study, BDS WG release the report at the plenary meeting ,Sept.2014."Implementation Issues on BDS NH Code"

1.BeiDou Inter-Satellite-Type Biases

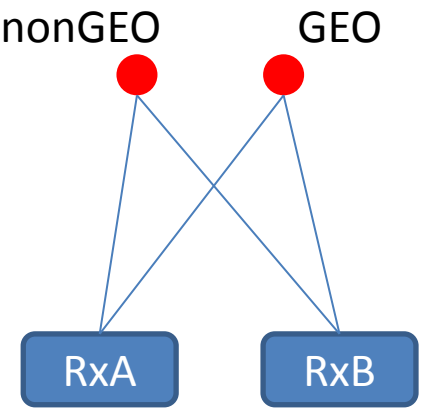
Test of BeiDou short baseline RTK with mixed receivers:



OK



OK



½-cycle biases

1.Test Result

Items	Date	Receiver Couple	Receiver Model	Freq.	IGSO −GEO	IGSO −MEO	GEO −MEO
Septentrio Jean-Marie Sleewaegen's team[2]	July 20-29,2013,	Trimble −Septentrio	Trimble NETR9 - Septentrio POLARx4 (before firmware is updated)	B1	0.0	0.0	0.0
				B2	−0.5	0.0	0.5
	July 20-29,2013,	Trimble − Trimble	Trimble NETR9 - Trimble NETR9	B1	0.0	0.0	0.0
				B2	0.0	0.0	0.0
	July 20-29,2013,	Trimble – Javad	Trimble NETR9 - Javad TRE_G3T DELTA	B1	−0.5	0.0	0.49
				B2	0.0	0.0	0.0
	Sept.23-29,2013	Javad – Septentrio	Javad TRE G3TH DELTA - Septentrio ASTERX3 (before firmware is	B1	0.5	0.0	−0.5
	Dec. 17-26, 2013,	Trimble −Septentrio	Trimble NETR9 - Septentrio POLARx4 (after firmware is updated)	B1	−0.5	0.0	0.5
				B2	0.0	0.0	0.0
BDS WG	June 9-13, 2014	Trimble – ComNav Tech	Trimble BD970 - ComNav K508	B1	−0.5	0.0	0.5
				B2	0.0	0.0	0.0
	June 9-13, 2014,	NovAtel – ComNav Tech	NovAtel OEM628 - ComNav K508	B1	0.0	0.0	0.0
				B2	0.0	0.0	0.0
	June 9-13, 2014,	Trimble – NovAtel	Trimble BD970 - NovAtel OEM628	B1	−0.5	0.0	0.5
				B2	0.0	0.0	0.0

[2] N. Nadarajah, P. G. Teunissen, J.-M. Sleewaegen, and O. Montenbruck, "The mixed-receiver BeiDou inter-satellite-type bias and its impact on RTK positioning," *GPS Solutions,* pp. 1-12, 2014/06/28 2014.

1.Implementation Issues on BDS NH Code

- **Method A**:
  - Convert 0 to -1, 1 to +1.
  - The signal level sequence of the 20-bites NH code is [-1 -1 -1 -1 -1 1 -1 -1 1 1 -1 1 -1 1 -1 -1 1 1 1 -1]
- **Method B**:
  - Convert 0 to 1, 1 to -1, the same as GPS and Galileo.
  - The signal level sequence of BDS NH code turns to be [1, 1, 1, 1, 1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, -1, -1, -1, 1]
- The signal level of method A and method B is opposite, there is a half cycle bias (180 degree) of carrier phase
- **Method B is recommended.**

1.The Summary of NH Code Implementation from Different GNSS Manufacturers

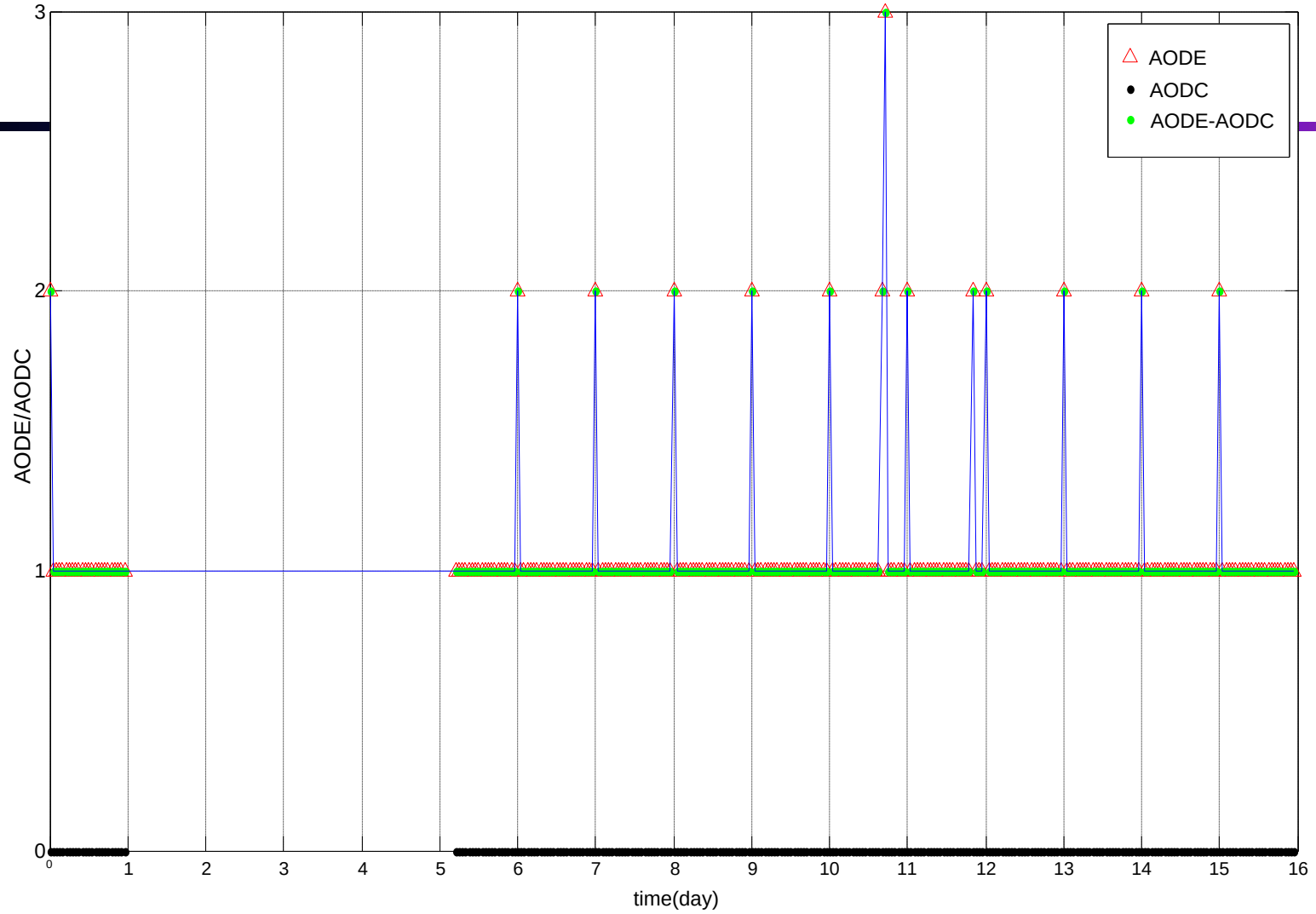
Manufacturers	NH Code Implementation Method	
	B1I	B2I
Trimble[1][3]	Method A	Method B
Javad[1][3]	Method B	Method B
Septentrio (before the end of 2013)[2]	Method A	Method A
Septentrio (nowadays)[2]	Method B	Method B
ComNav Tech	Method B	Method B
NovAtel	Method B	Method B
Unicore Communications, Inc.	Method B	Method B

Reference

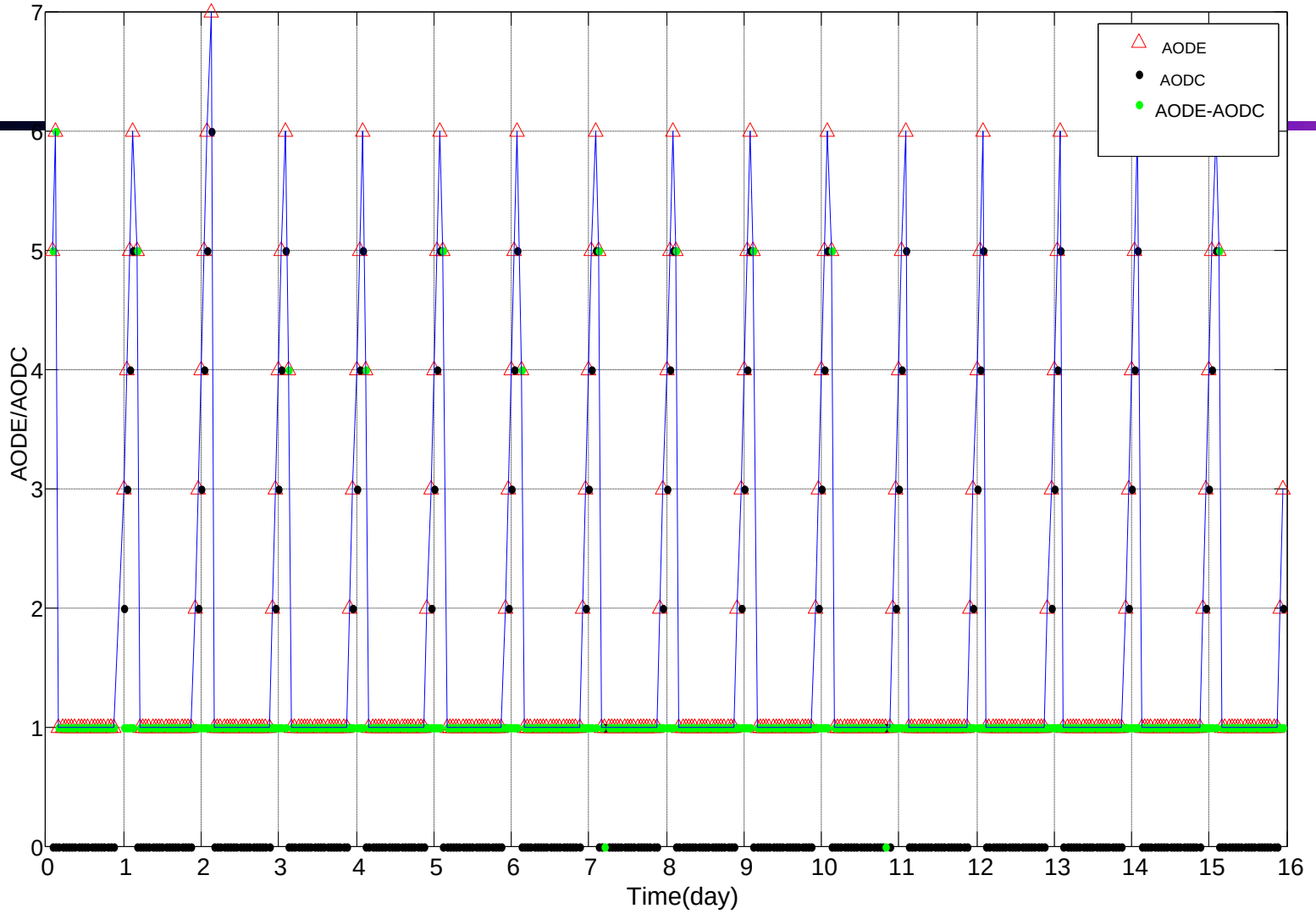
[1] N. Nadarajah, P. Teunissen, and N. Raziq, "BeiDou Inter-Satellite-Type Bias Evaluation and Calibration for Mixed Receiver Attitude Determination," *Sensors,* vol. 13, pp. 9435-9463, 2013.
[2] N. Nadarajah, P. G. Teunissen, J.-M. Sleewaegen, and O. Montenbruck, "The mixed-receiver BeiDou inter-satellite-type bias and its impact on RTK positioning," *GPS Solutions,* pp. 1-12, 2014/06/28 2014.
[3] BeiDou Inter-Satellite-Type Biases, N. Nadarajah etc.,RTCM SC-104 Conference, May,2014,Darmstadt

2.BDS RTCM IODE Status and Issues

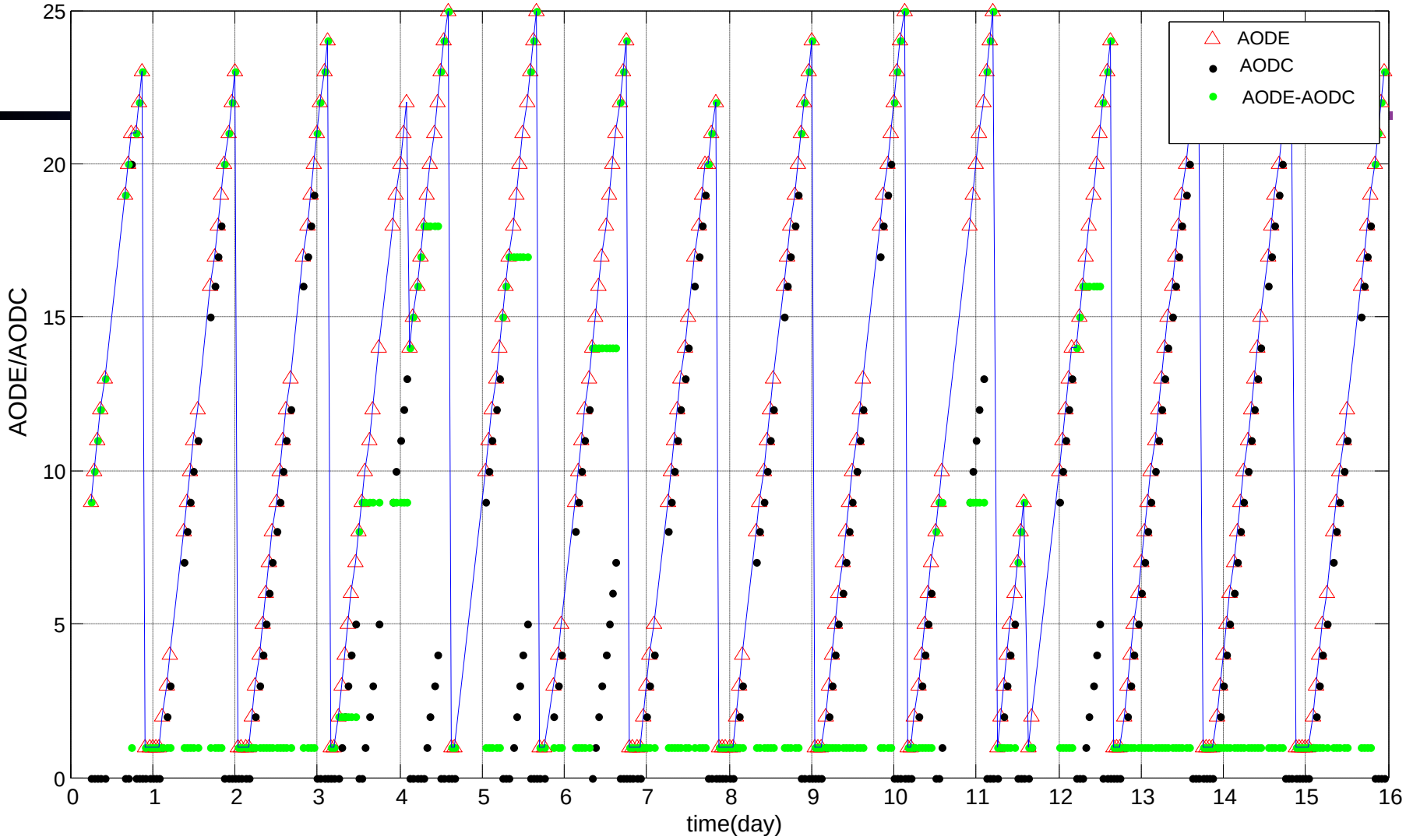
- **Issues:**
  - AODE/AODC and Toe only can identify the data set together
  - How to use the parameters in the BDS Navigation data to identify the BDS Navigation data sets in the framework of RTCM messages (8-bit)?
- **Status:**
  - The proposal from BDS WG that uses the combination of Toe and AODE(Jan,2014)
  - The proposal from Mr.Kendall that uses low 8-bits Toe in 32s rate (May, 2014)
  - The proposal from Geo++ that uses CRC24Q from18 parameters of BDS Navigation (107-2014-SC104-818.pdf, May, 2014)
  - Proposal from Frank Takac for NRTK
- **Still working on it**



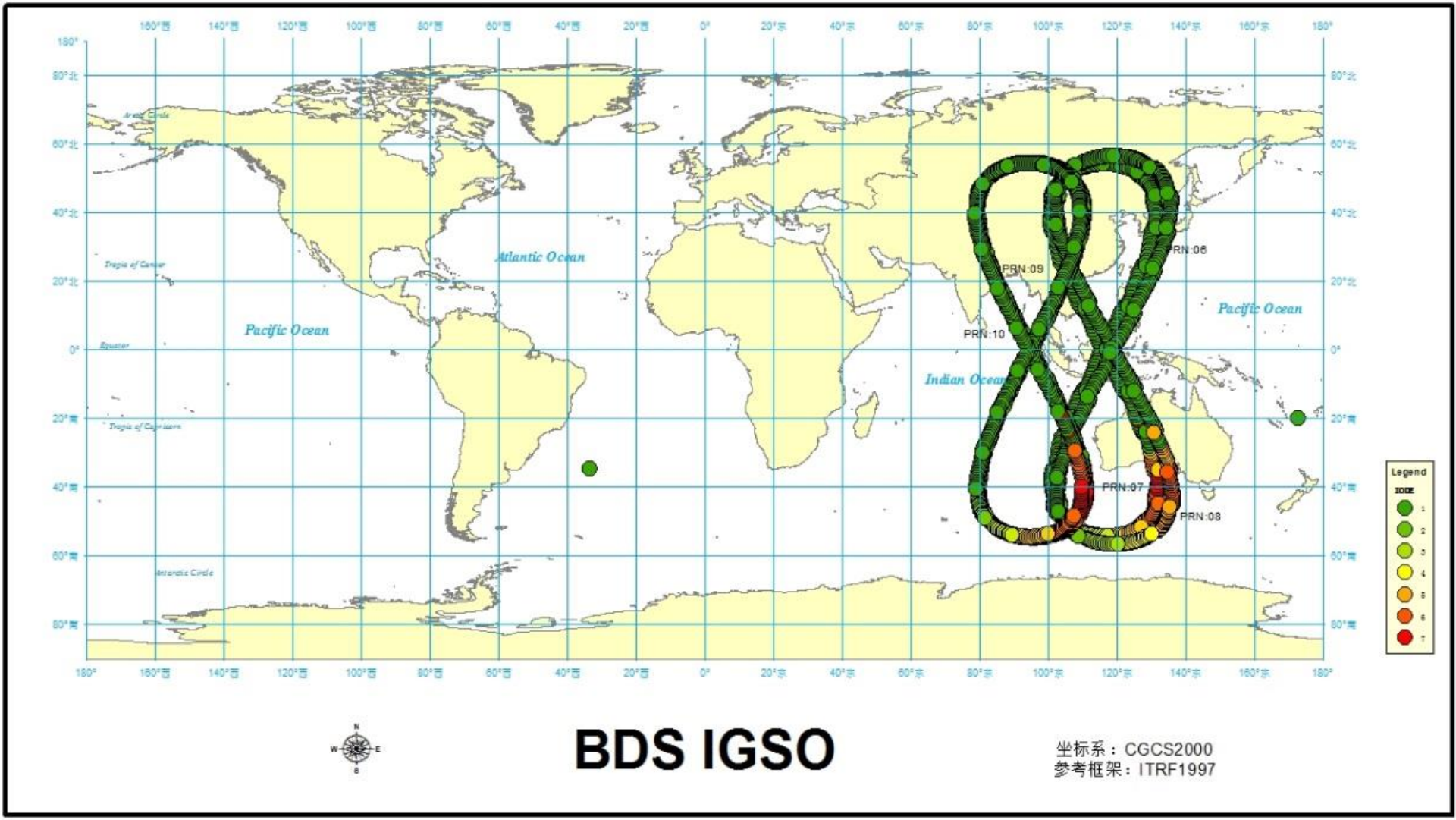
BDS GEO AODE/AODC vs Time
（PRN 04,2014,DOY 139-154）



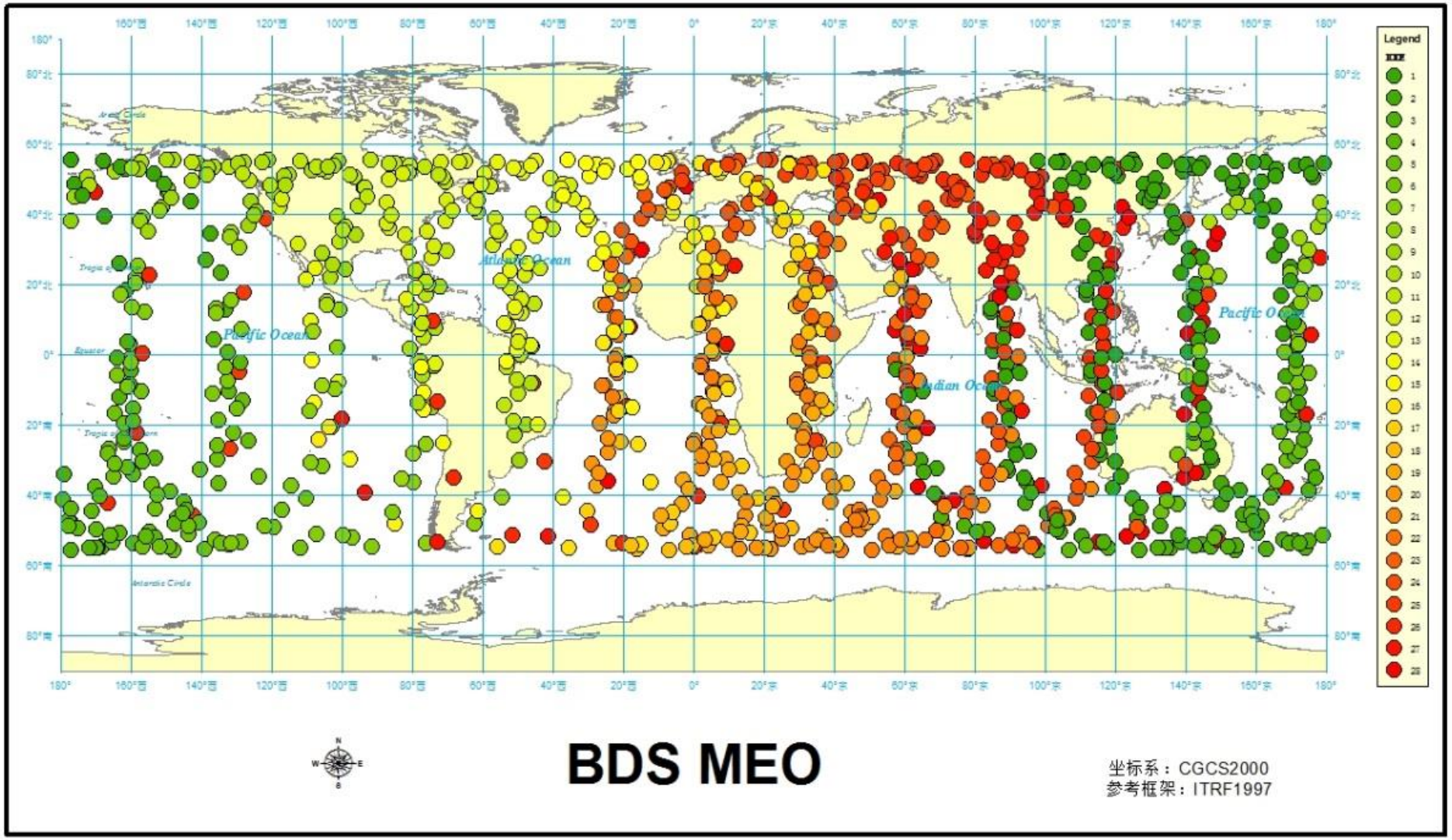
BDS IGSO AODE/AODC vs Time
（PRN 08,2014,DOY 139-154）



BDS MEO AODE/AODC vs Time
（PRN 14,2014,DOY 139-154）



BDS IGSO AODE vs SV track
（PRN 05-10,2014年,139-154）



BDS MEO AODE vs SV track（PRN 11-14,2014,DOY 139-154）

Contents

- Status of BDS
- Status of Differential BDS (DBDS)
- Some Issues about DBDS
- **Conclusions**

Conclusions

- BDS is still in developing, the signal system, service region, performance will be upgraded in phase III
- DBDS can improve the quality of PNT service significantly
- The infrastructure will be upgraded to support BDS/GPS
- Some proposals about DBDS standard have been submitted

Conclusions

- **DBDS standard in the framework of GNSS standard**
  - BDS AODE and AODC
  - BDS SSR standards
  - ……
- **NRTK/PPP algorithm of multi-system**
- **Integrity monitoring of NRTK**

Thank you!