

# Preliminary Results from MASS & BeiDou first Continuous Operating Reference System in Hubei Province

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GNSS Research Center

Wuhan University

# Outline

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- Introduction of PANDA software
  - MASS Using PANDA
  - COMPASS Precise Position Results
  - SUMMARY
-

# Positioning And Navigation Data Analyst

- To derive possible information from GNSS/SLR/VLBI/DORIS data
- Real-time Processing function from 2007
- Current Applications
  - POD of GNSS (GPS, GLONASS, COMPASS, GALILEO)
  - POD of LEOs (CHAMP, GRACE, COSMIC, JASON, HY-2A, ZY-3)
  - Ionosphere and Troposphere Modeling
  - Huge Network data processing
  - Real-time PPP, PPP-RTK
  - SINEX Combination

# Outline

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- Introduction of PANDA software
  - MASS Using PANDA
  - COMPASS Precise Position Results
  - Summary
-

# Prototype of Multi-Constellation Augmentation Service System(MASS) in China

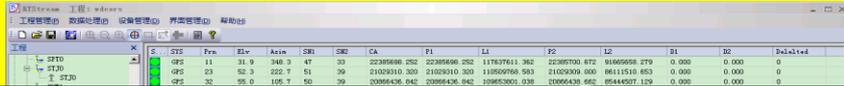
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## □ Goals

- Using GNSS data stream in China and global stations
  - Processing for Real-time GNSS orbit, Clock And atmosphere parameters
  - Products broadcast by sat. and Mobile internet
  - Augmentation with GPS/COMPASS in Wide-area, Dm level RT-PPP for double-frequency, Better than 1m accuracy for single-frequency
- Support by National High-tech R&D Program (863 Program) of China
-

# Wide-area Augmentation Processing Platform

## Data stream management



## Satellite Real-time Orbit Processing



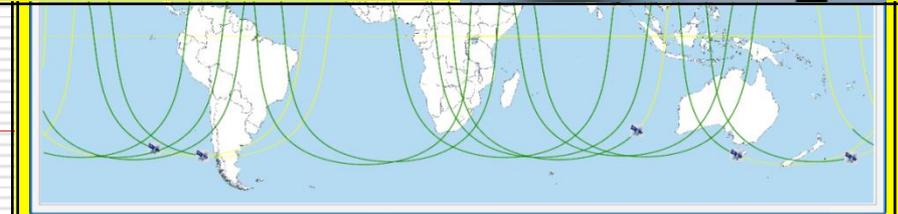
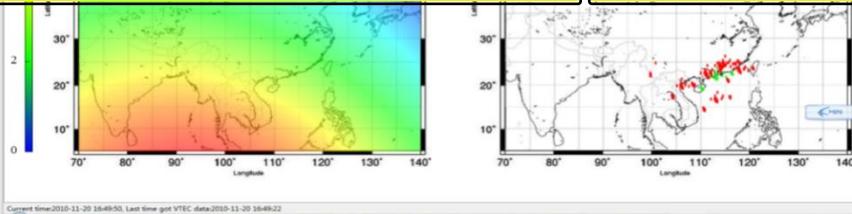
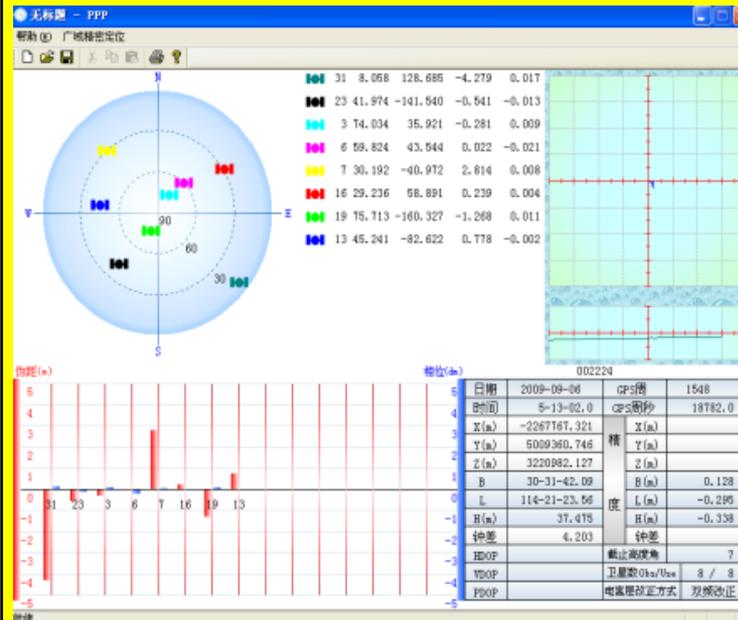
## Products Broadcast

Time: 2010-11-20 12:10:24.49  
No. Of Sat: 30

G02	-46.9100	51.8490	31.0400	50.3920
G03	33.4210	-10.0320	-62.8140	36.6670
G04	-73.9420	23.5530	9.3570	61.9600
G05	-14.8290	2.9110	83.9710	-51.3790
G06	1.5190	-26.5300	-92.7450	40.7100
G07	-61.2320	-44.3190	44.4050	85.6010
G08	-70.4250	-50.3780	-7.3230	4.5600
G09	32.1410	1.9760	-19.6720	25.1960
G10	-51.0600	10.1420	97.0750	-63.0440
G11	-40.1050	-66.1330	-88.0840	-40.7880
G12	14.5950	27.0360	1.4450	-51.5750
G13	-60.8250	-70.0770	71.6950	7.3730
G14	68.8930	-99.8590	-89.5690	85.5610
G15	53.5720	18.6520	-30.0680	-65.9650
G16	36.8700	-0.5390	73.3770	-17.5300
G17	-79.5780	11.1300	-28.4760	66.0990
G18	47.6010	81.7080	-24.3880	8.7420
G19	98.6980	-52.3520	-71.2950	-90.3720
G20	-21.8590	-6.4810	97.3290	36.9250
G21	29.1090	68.5870	16.1780	-73.5640
G22	93.8150	-88.1610	-14.5200	49.2290
G23	-29.4630	-99.8200	43.5330	14.5490
G24	-73.8220	-91.8230	-1.1140	47.6650
G25	92.8720	33.0780	53.8320	-50.8630
G26	-53.5260	66.5600	-15.8020	-6.2150
G27	3.4300	70.5310	-30.9150	49.2360
G28	-81.7390	-29.3930	-69.5150	94.2040
G29	82.3890	48.6600	45.4180	2.0320
G30	43.7260	-56.5810	67.3620	7.9130
G31	70.4370	-44.3140	66.9310	44.6470

start

## Terminal Real-time Precise Point Positioning



# Monitoring and Control System

### Net Viewer - 360极速浏览器

172.16.105.101

武汉大学GNSS中心机房环境

## DVR/DVS V2.2 build 20081029

3F IT Floor

- 01-Camera 01
- 02-Camera 02
- 03-Camera 03
- 04-Camera 04

2011年10月27日 15:52:22

2011年10月27日 15:52:23

Camera 01

Camera 02

2011年10月27日 15:52:22

2011年10月27日 15:52:22

无视频信号

无视频信号

Camera 03

Camera 04

### RTStream 工程: wdcrs

工程管理 数据管理 设备管理 报警管理 帮助

基站站址图

- ▲ AZIS
- ▲ AZIS
- ▲ AJAC
- ▲ AJAC
- ▲ ALER
- ▲ ALER
- ▲ ALGO
- ▲ ALIC
- ▲ ARLI
- ▲ ABLL
- ▲ AIKC
- ▲ AIKC
- ▲ AZTU
- ▲ BAKH
- ▲ BAKH
- ▲ BOB1
- ▲ BOB1
- ▲ BRAC
- ▲ BRBT
- ▲ BRBT
- ▲ BRST
- ▲ BRST
- ▲ BRIS
- ▲ BRIS
- ▲ BRUC
- ▲ BRUC
- ▲ CAZC
- ▲ CAZC
- ▲ CAS1
- ▲ CAS1
- ▲ CBK1
- ▲ CBK1
- ▲ CMB
- ▲ CMB
- ▲ CMB

点名: AZIS

I: 491.8552, 73823

T: 5945922, 6749

Z: 995363, 3393

接收机类型: RTK 3.1

输出端口: A

天线类型: 0 米

采样间隔: 1 秒

串口: 10 秒

历元时间: 1868, 138538.0

有效率: 81.500%

基站编定(件)

北: 0.000

东: 0.000

垂直: 0.000

请求接收机数据

接收机位置

通讯方式: RTKIP

工作模式: Client

服务器IP: 58.49.58.149

端口: 2101

用户名: ydchina

数据源: A1230

	G03	G06	G14	G16	G19	G21	G22	G32	R04	R05	R06	R18	R19
Jan1	49	50	46	45	41	40	45	40	36	47	43	49	47
Jan2	36	37	37	26	22	16	28	19	39	45	38	45	45
Azim	311.0	315.3	89.7	241.5	327.2	76.9	7.8	253.8	12.2	305.0	0.0	138.8	19.5
Elev	59.7	72.9	68.2	31.7	26.0	22.3	38.7	21.3	19.8	48.4	0.0	43.6	72.0

接收机观测值信息

输出

时间 消息

2011-10-31 22:27:07 接收机 RTK 网络中断

2011-10-31 22:27:40 接收机 RTK 网络中断

2011-10-31 22:27:40 接收机 RTK 网络中断

### 武汉大学GNSS中心机房环境监控系统

设备监控 报警管理

#### 系统状态: 运行良好

#### 三楼层机房UPS

设备名称	当前状态/值	正常值
电池状态	正常	
电池温度	18°C	
电池时间	538Min	
电池电压报警阈值	0	
电池电压	222	
环流报警	0	
输入电流	3	
输入线电压	正常(227V)	170~260
输入最大线电压	236V	
输入最小线电压	221V	
输入频率	50Hz	
输出频率	3	
基本输出状态	正常	2
输出电压	219V	
输出频率	50Hz	
输出负载	44%	
输出电流	27A	
A相输入电压	正常(233V)	170~260
B相输入电压	正常(231V)	170~260
C相输入电压	正常(221V)	170~260
A相输入电流	0A	
B相输入电流	0A	
C相输入电流	0A	
A相输出电压	正常(219V)	170~260
B相输出电压	正常(219V)	170~260
C相输出电压	正常(219V)	170~260
A相输出电流	0A	
B相输出电流	0A	
C相输出电流	0A	

### R1 PPP

no data-20

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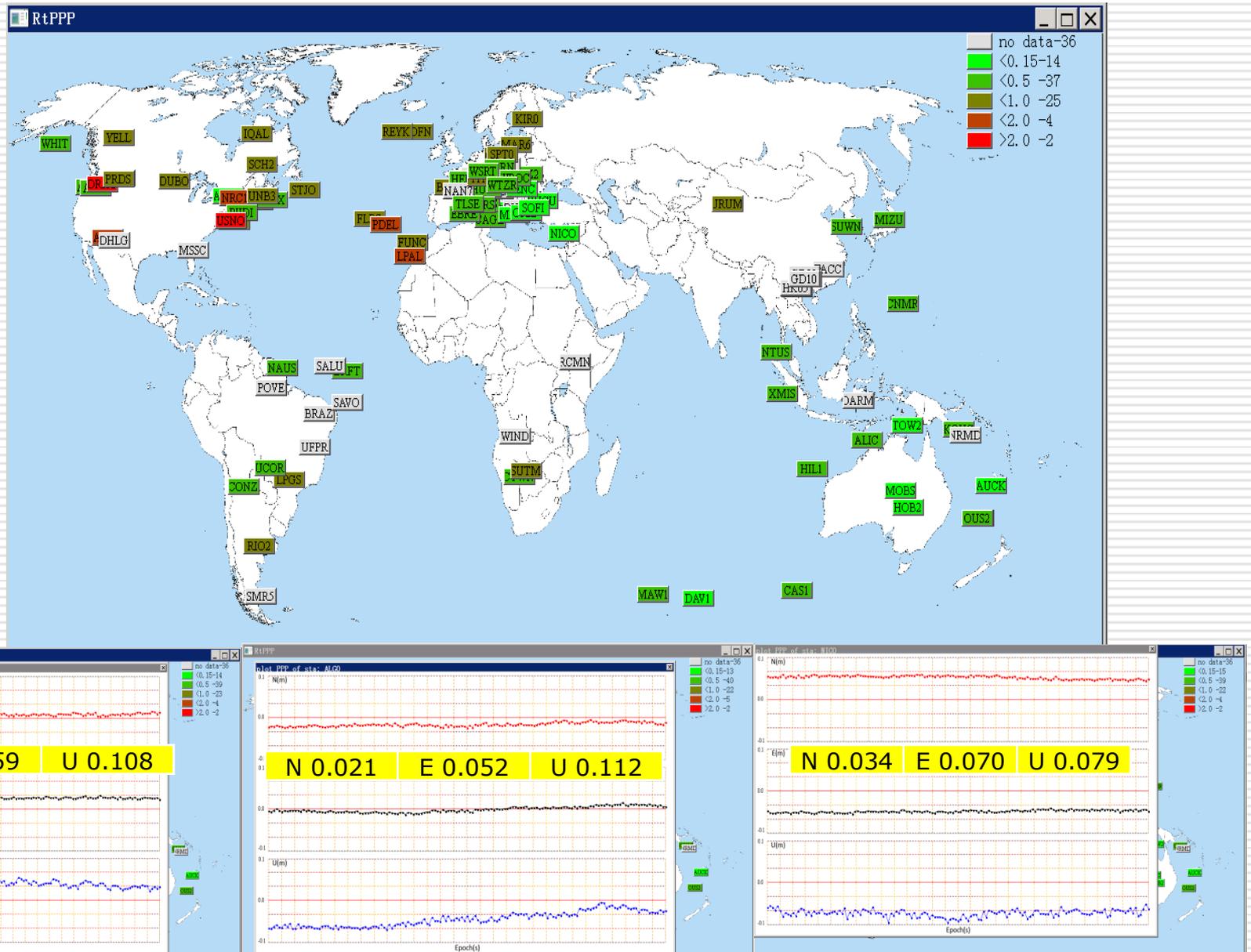
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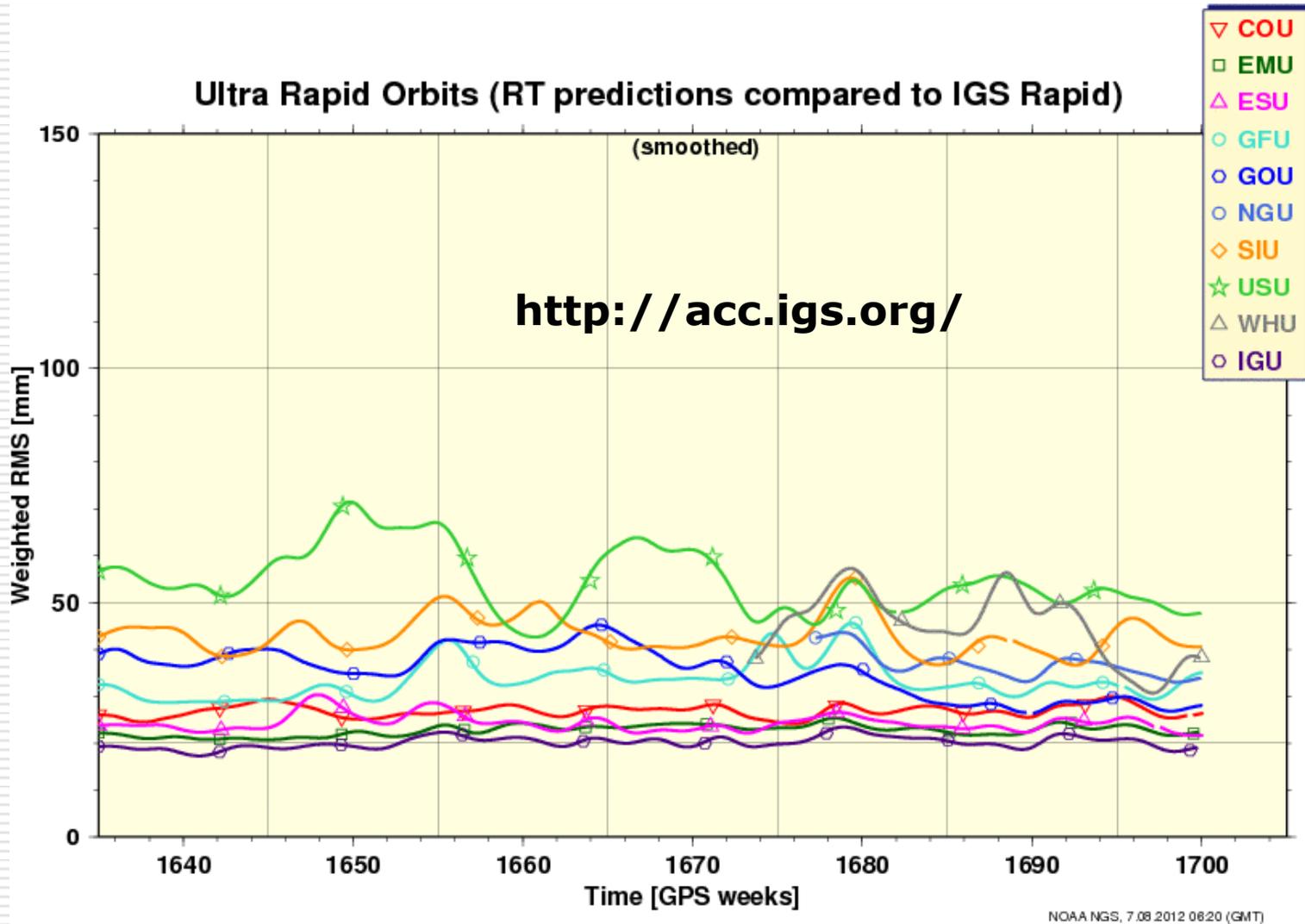
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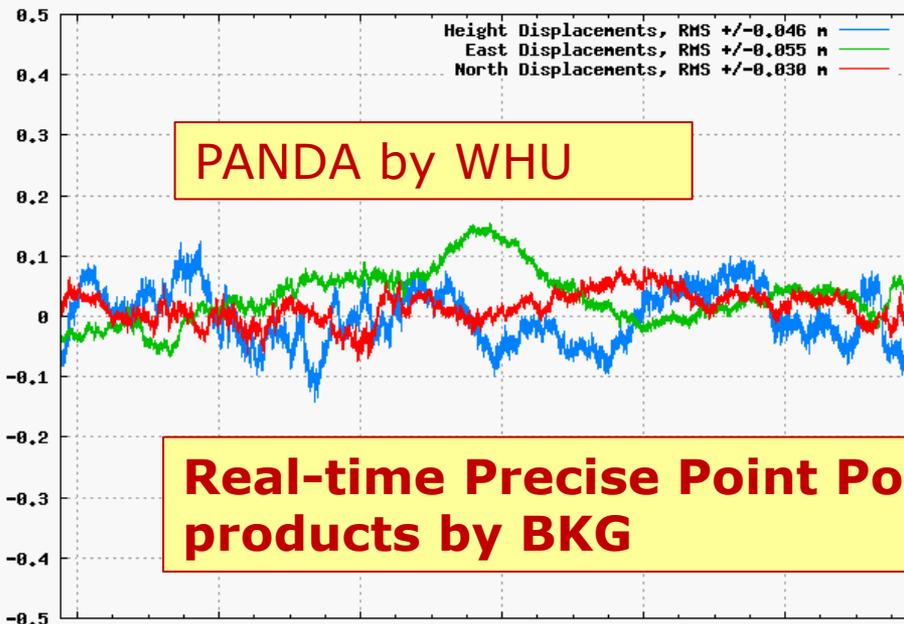
# Global Real-Time Precise Positioning Monitoring



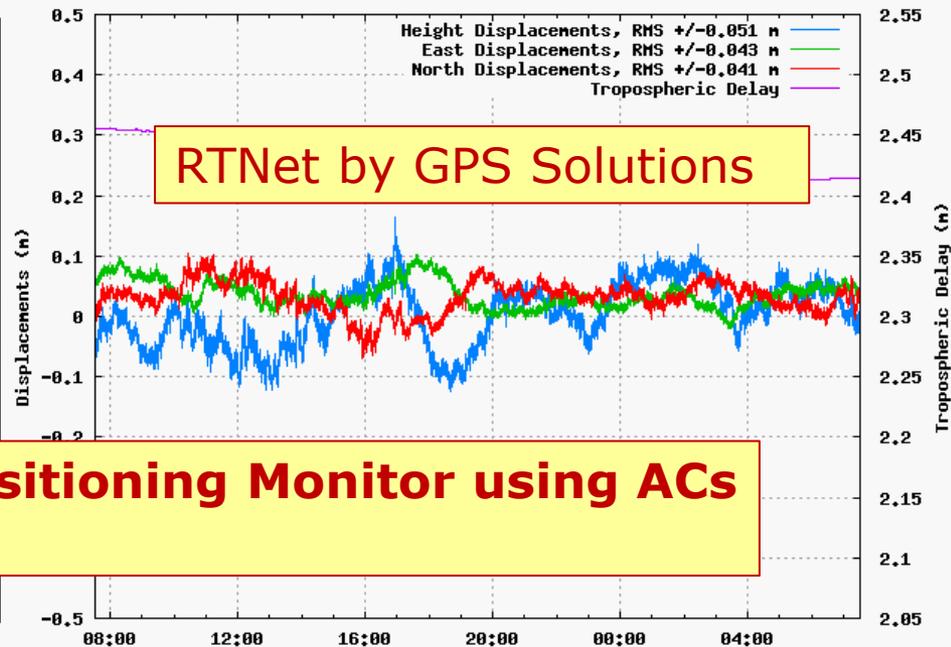
# Ultra-rapid orbit Quality by PANDA



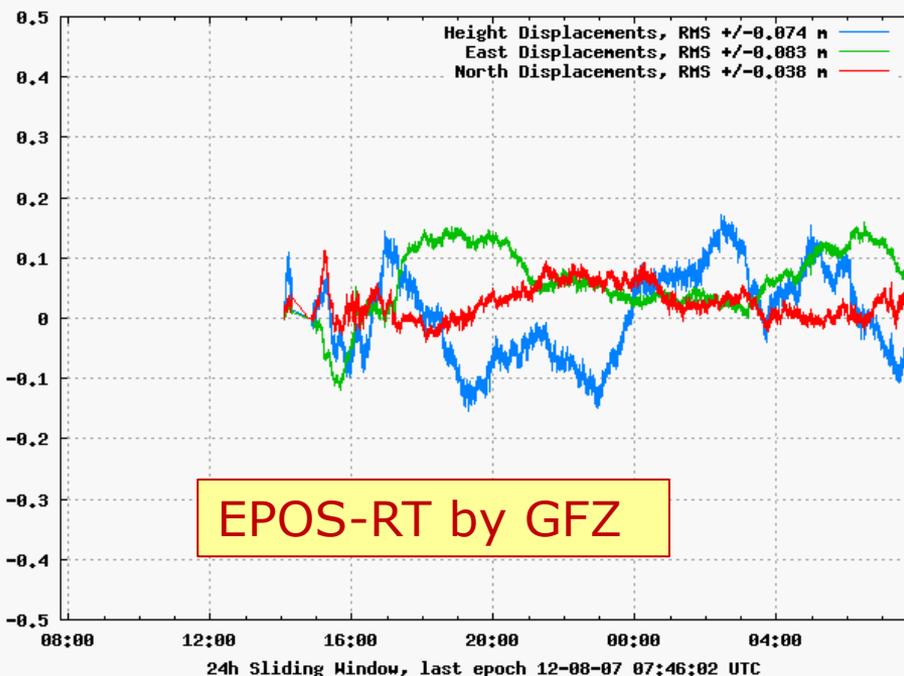
Realtime PPP results for FFHJ1, Monitor Scenario 3 - (C) BKG



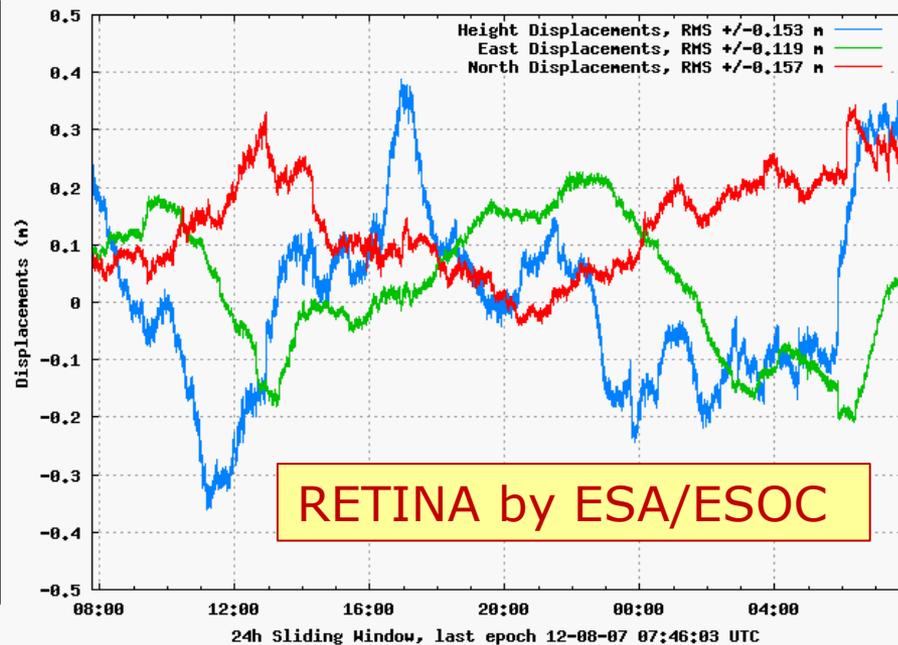
Realtime PPP results for FFHJ1, Monitor Scenario 5 - (C) BKG



Realtime PPP results for FFHJ1, Monitor Scenario 4 - (C) BKG



Realtime PPP results for FFHJ1, Monitor Scenario 7 - (C) BKG

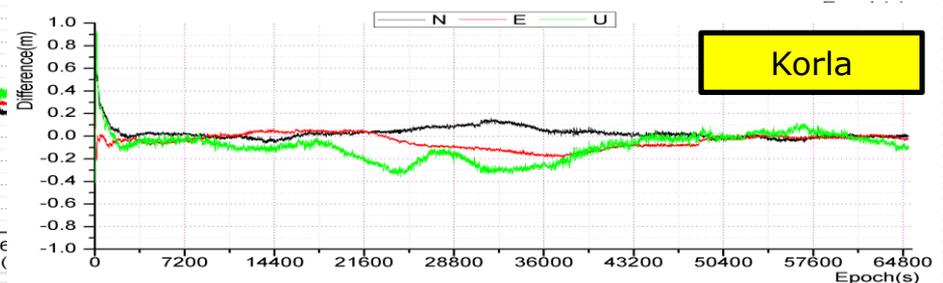
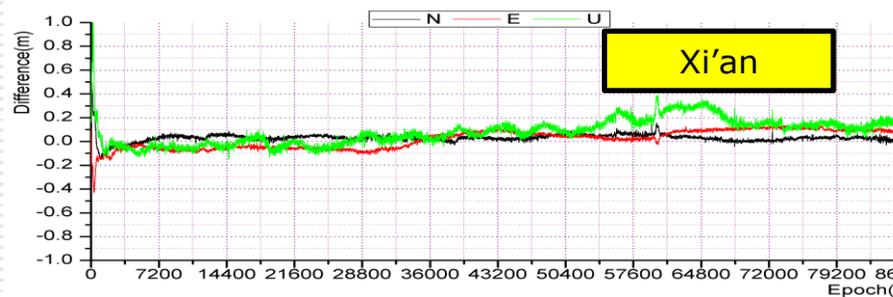
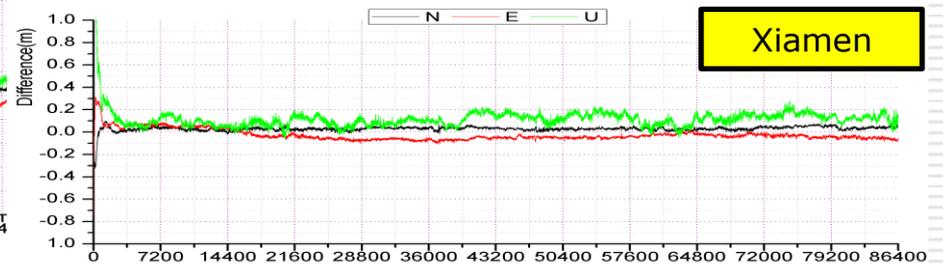
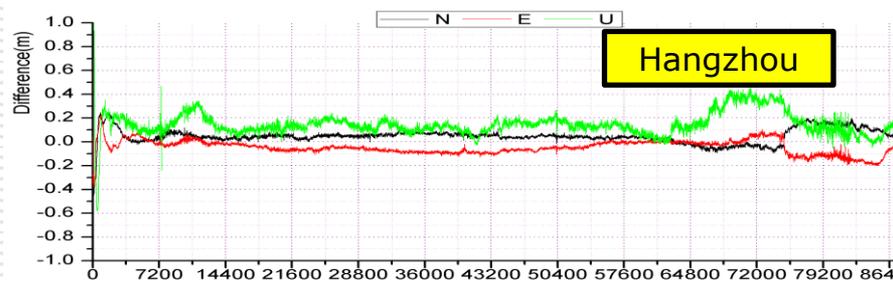
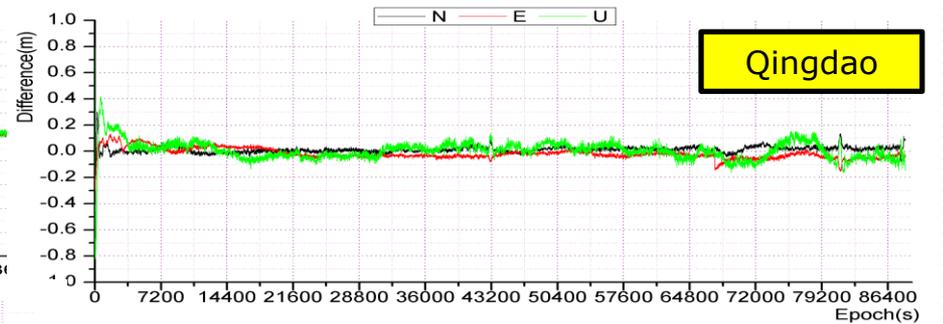
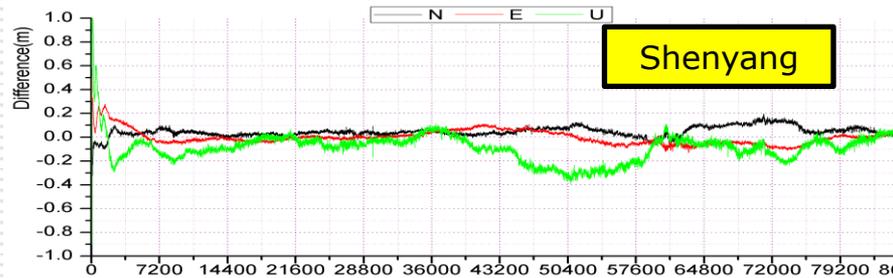
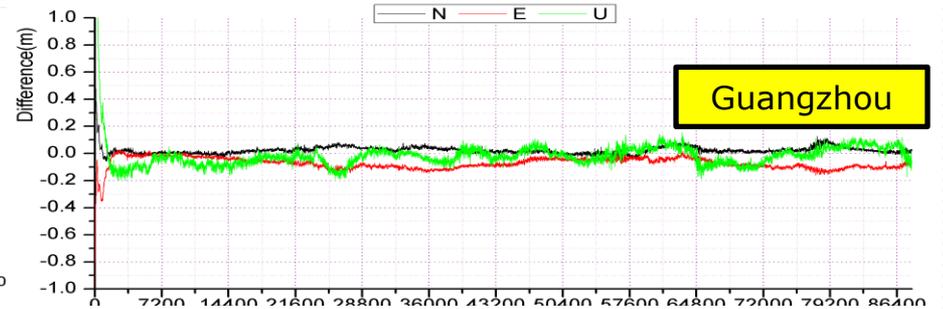
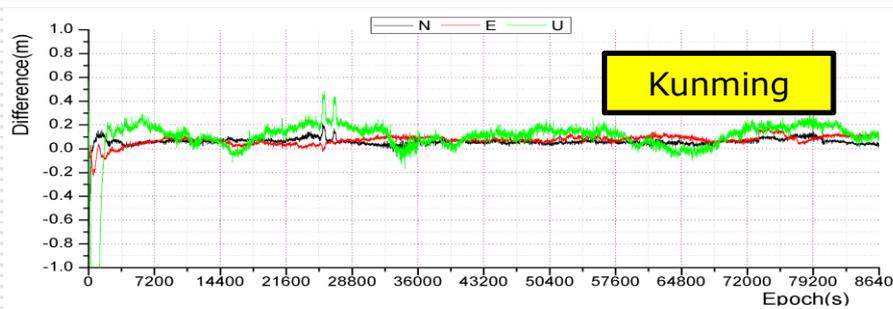


# Accuracy tests of MASS in China

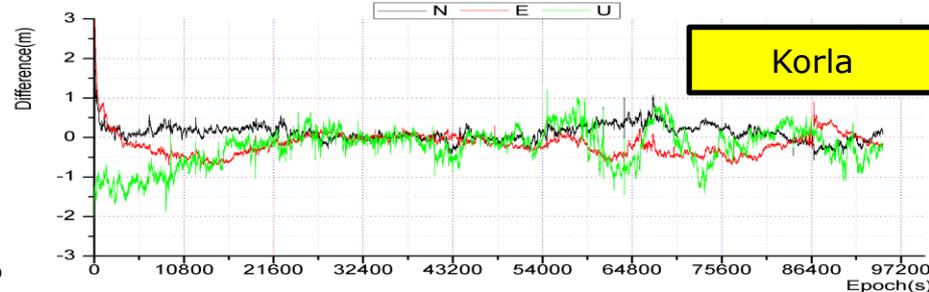
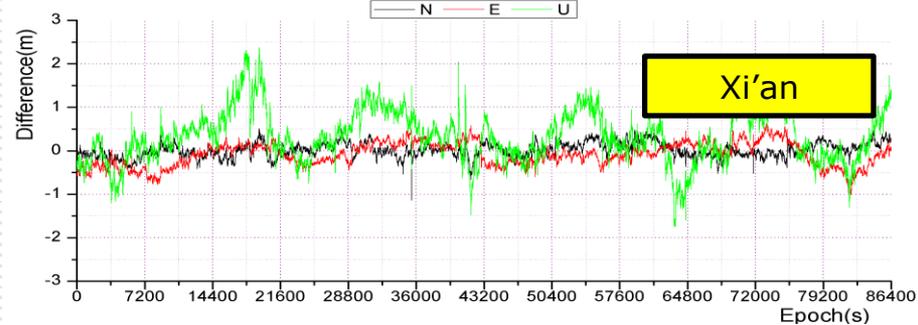
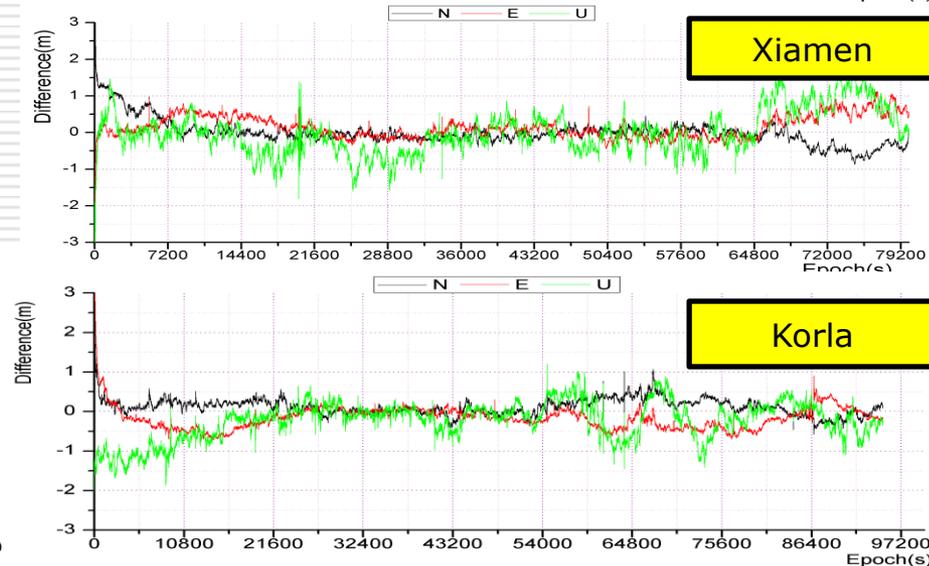
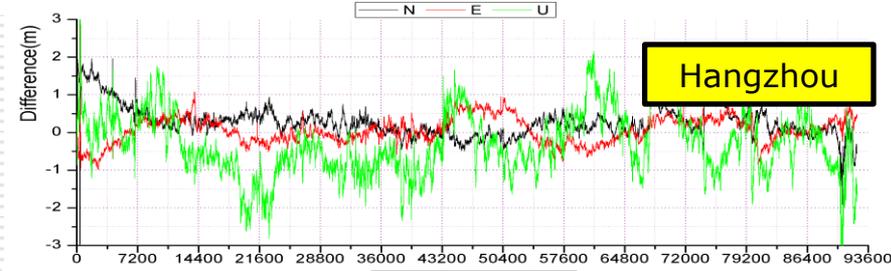
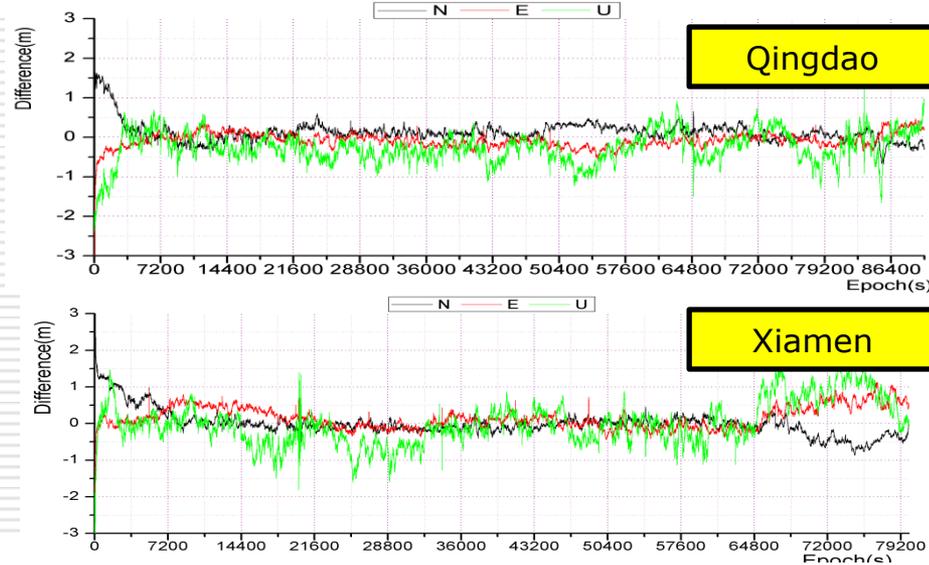
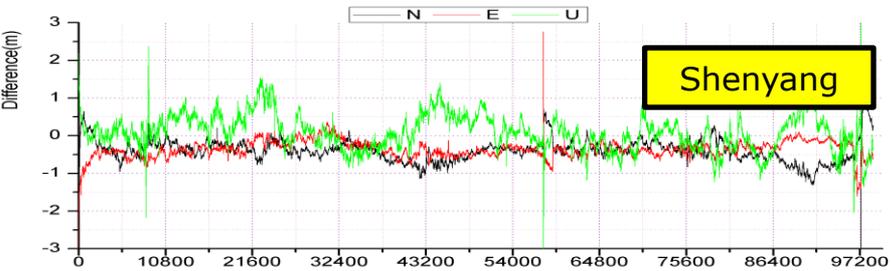
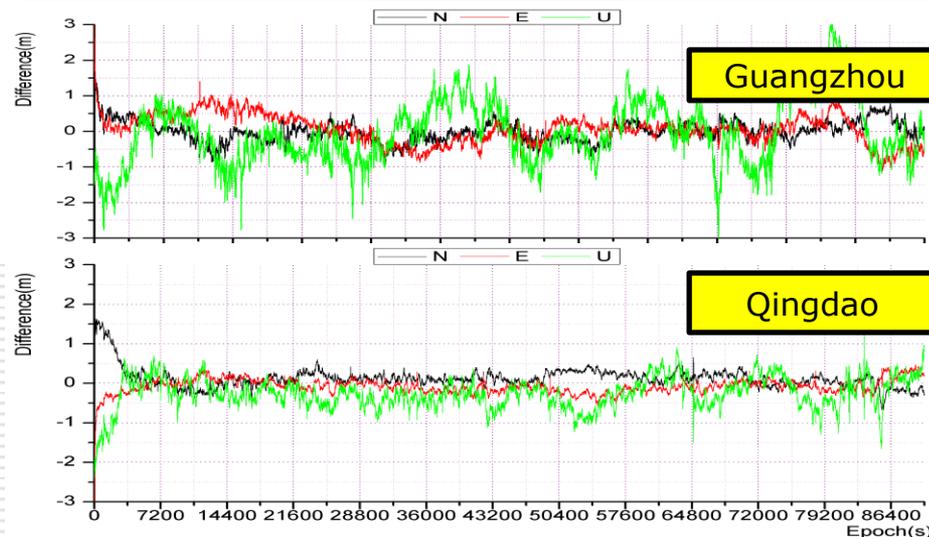
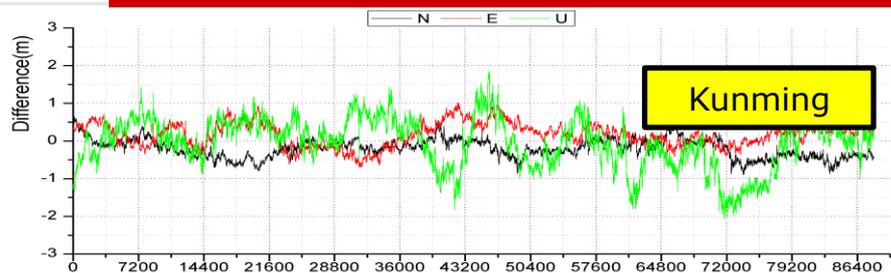


June 25 ~ July 11,  
2011, 24-hour test

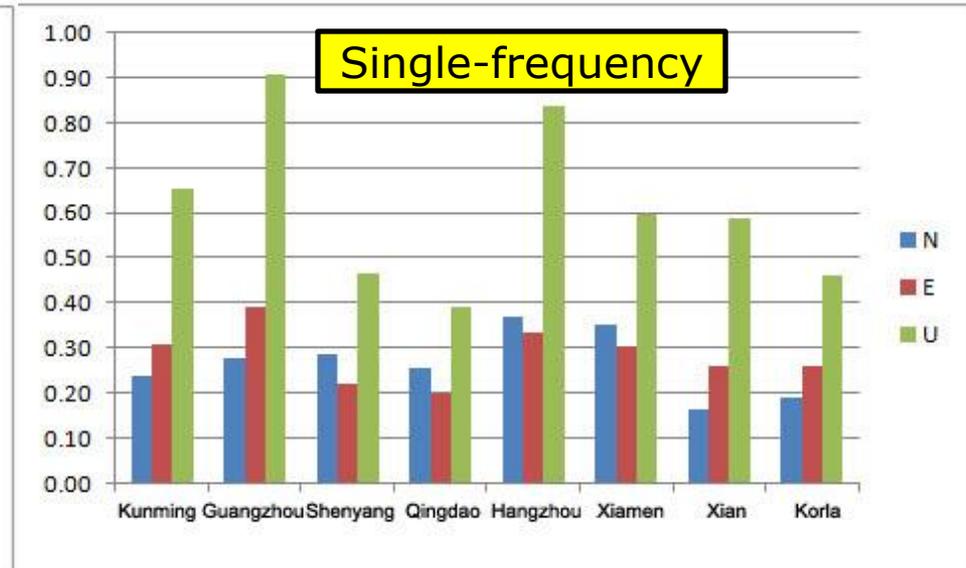
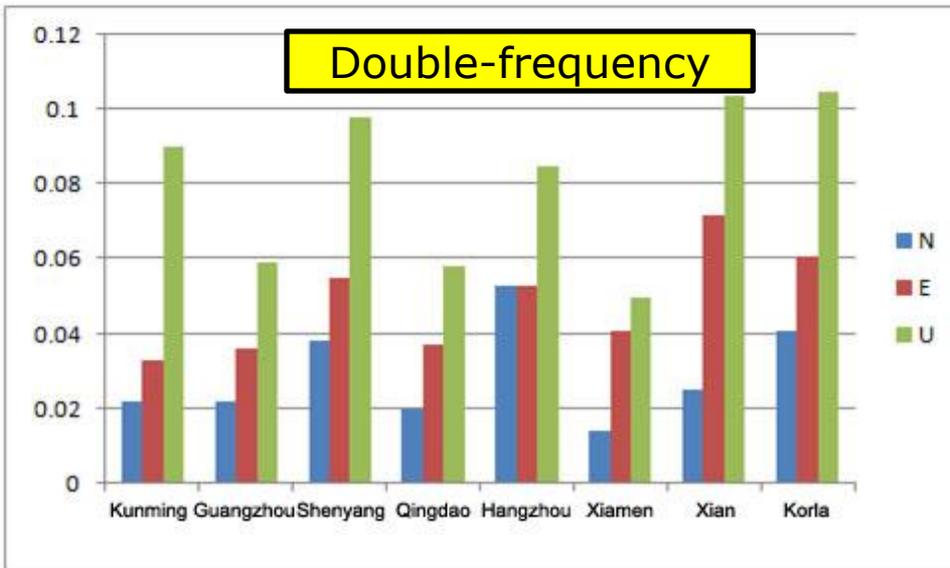
# The time series of double-frequency test results



# The time series of single-frequency test results

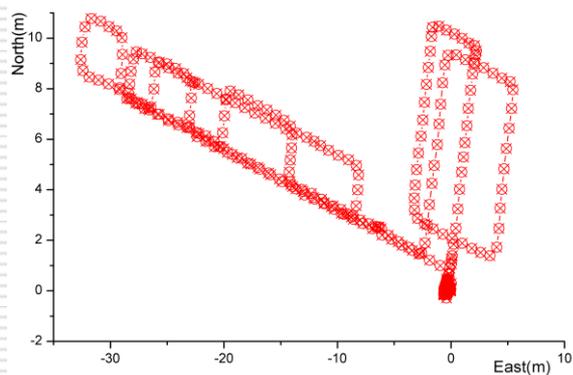


# Test Result Statistics

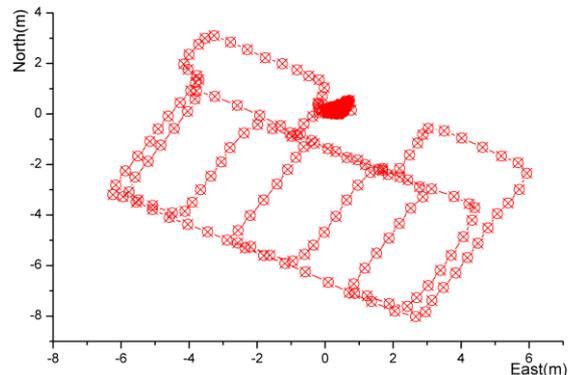


RMS (m)	N	E	U
<b>Double-frequency</b>	0.029	0.049	0.081
<b>Single-frequency</b>	0.268	0.286	0.614

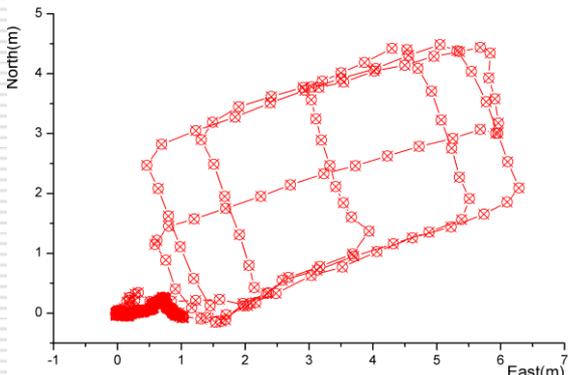
# Kinematic RT-PPP (double-frequency)



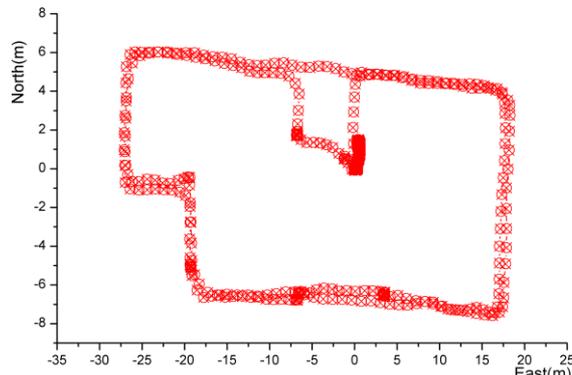
**Guangzhou**



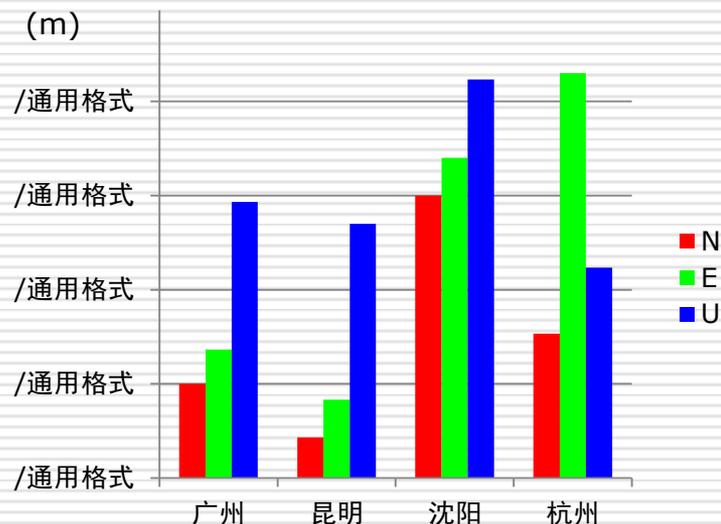
**Shenyang**



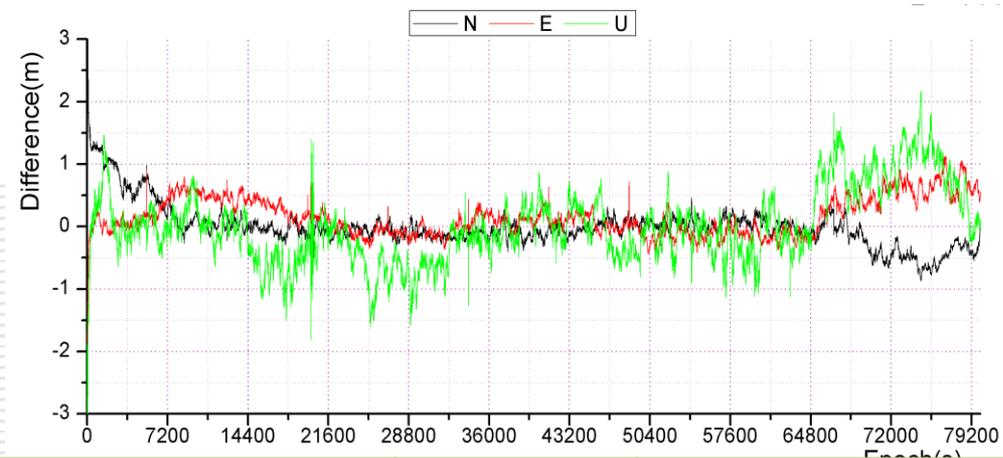
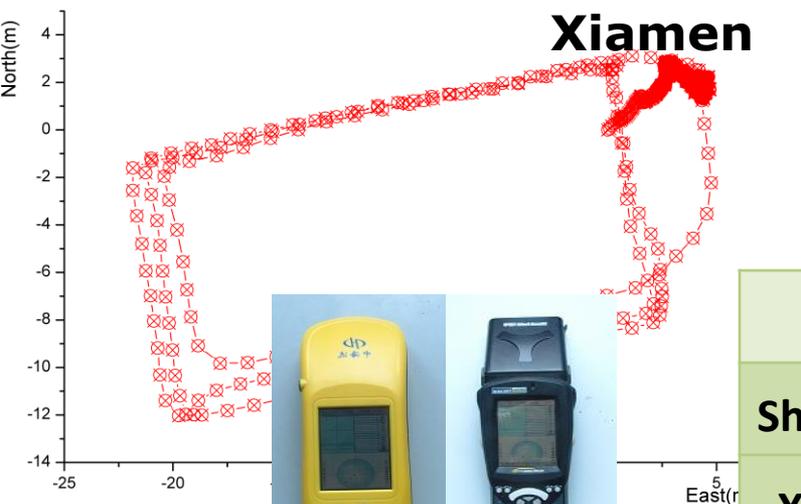
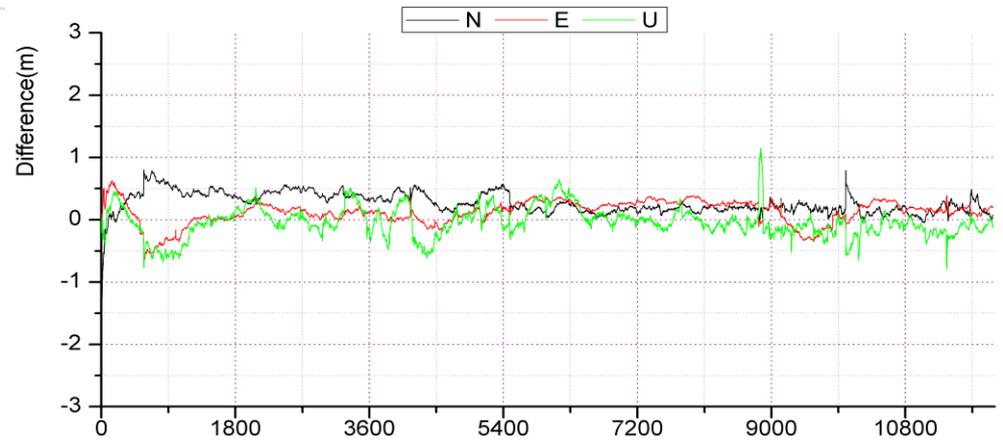
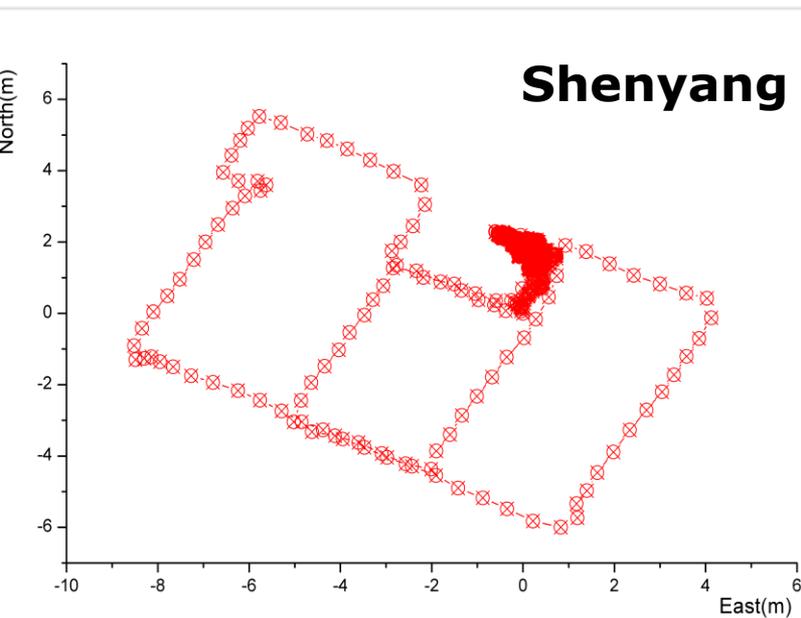
**Kunming**



**Hangzhou**

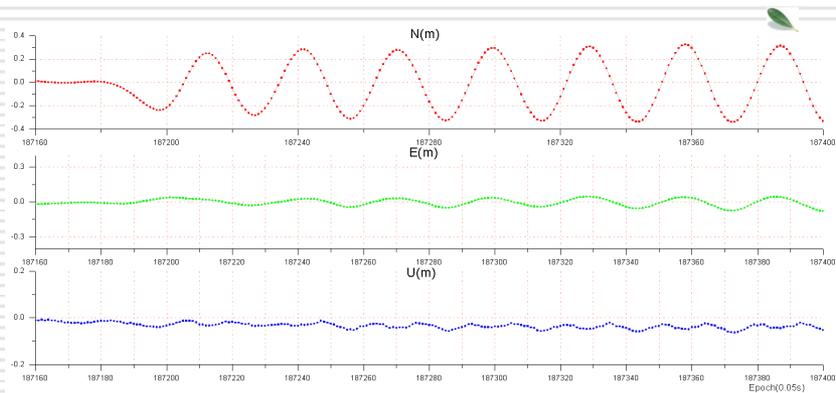
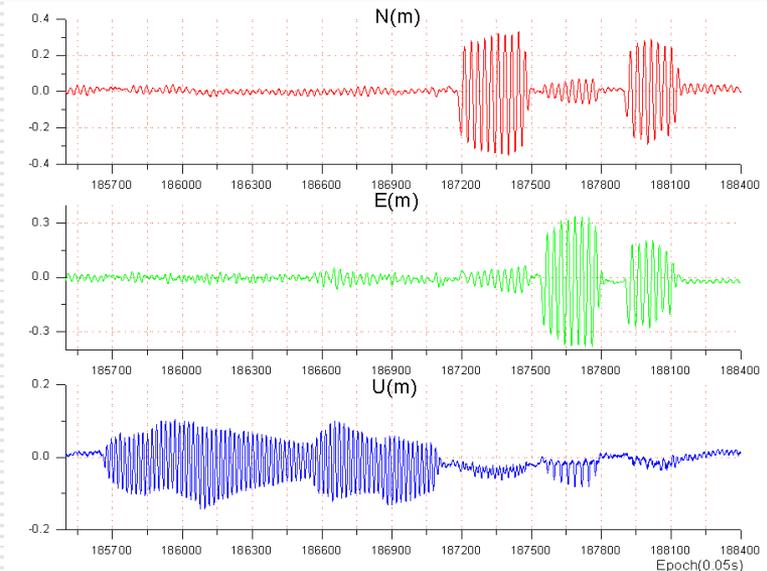


# Kinematic RT-PPP (Single-frequency)



		N(m)	E(m)	U(m)
Shenyang	STD	0.170	0.188	0.236
Xiamen	STD	0.324	0.435	1.086

# Real-time Kinematic RT-PPP test



# Outline

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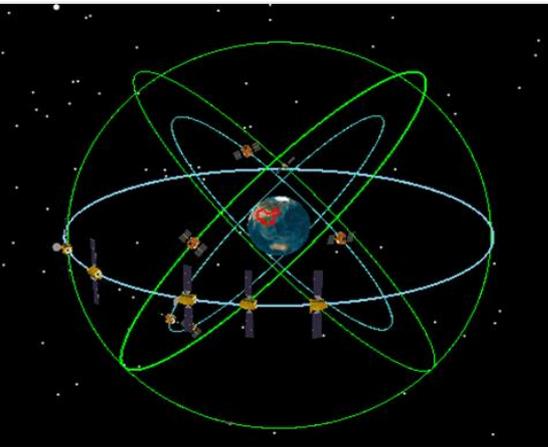
- Introduction of PANDA software
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  - COMPASS Precise Position Results
  - Summary
-

# COMPASS Precise Positioning and Navigation

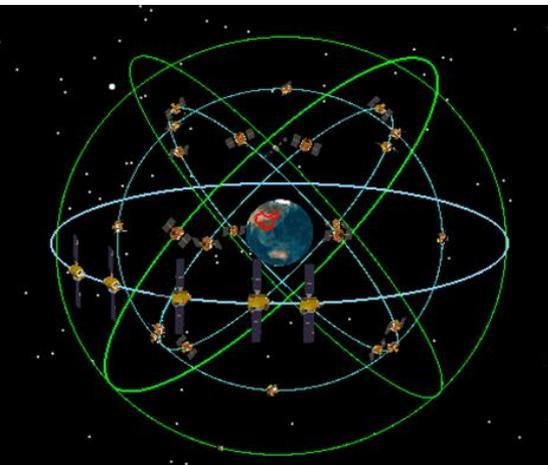
- **Status of COMPASS**
  - Baseline solutions (mm-level)
  - COMPASS RTK (cm level)
  - COMPASS PPP (dm level)
  - D-COMPASS Navigation (m level)
  - Benefit of GPS+COMPASS
-

# Status of COMPASS

- Current operational Satellites: 4GEO+5IGSO+2MEO
- 2012: 5GEO+5IGSO+4MEO (Regional Service)
- 2020: 5GEO+3IGSO+27MEO (Global Service)

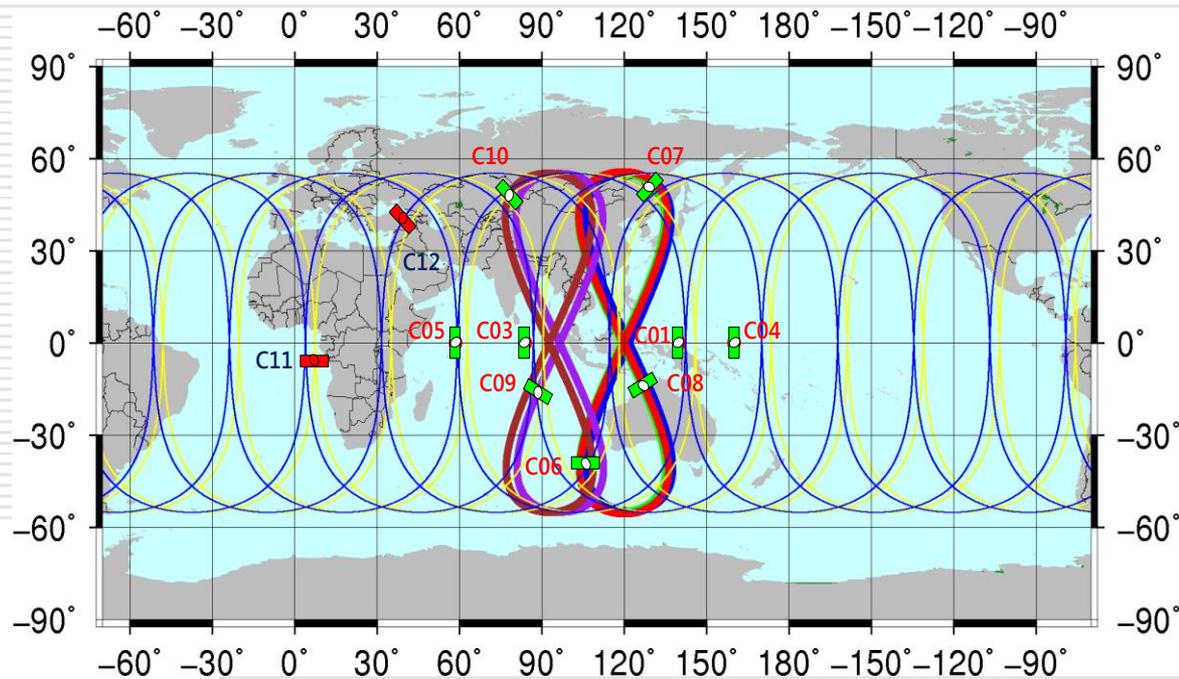


**2012**

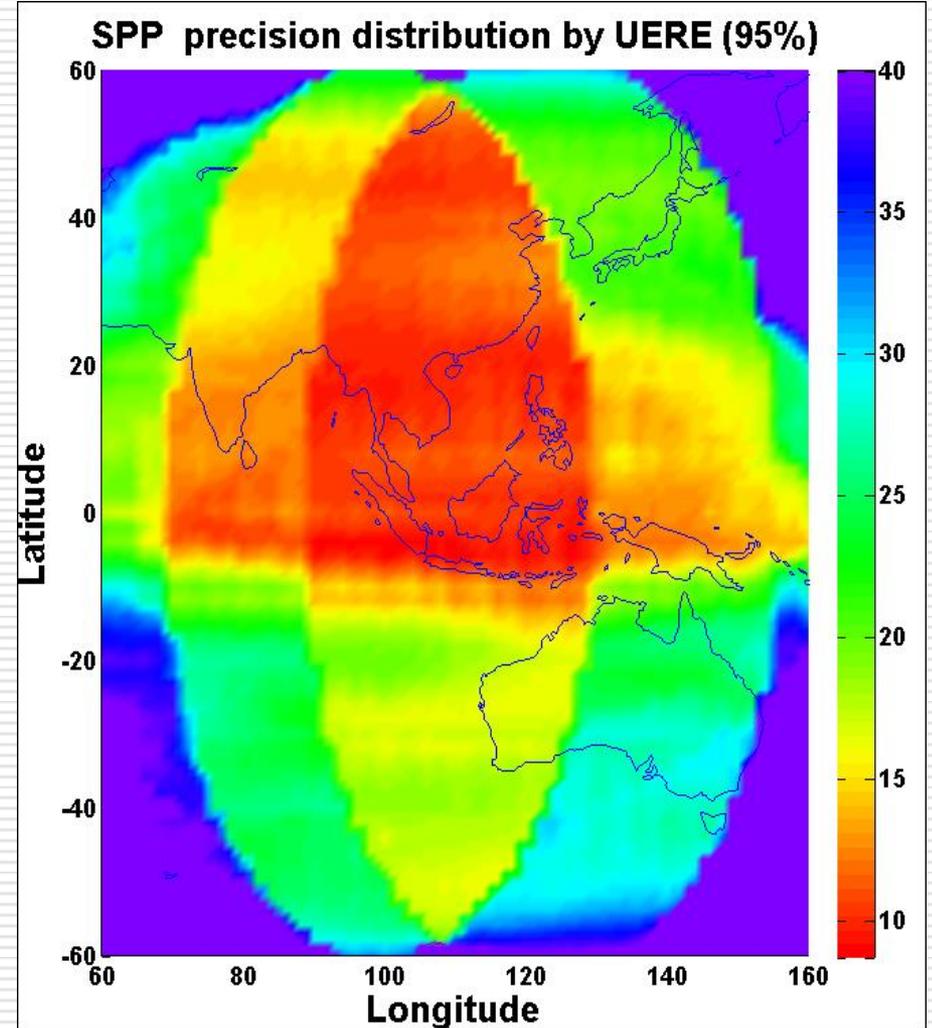
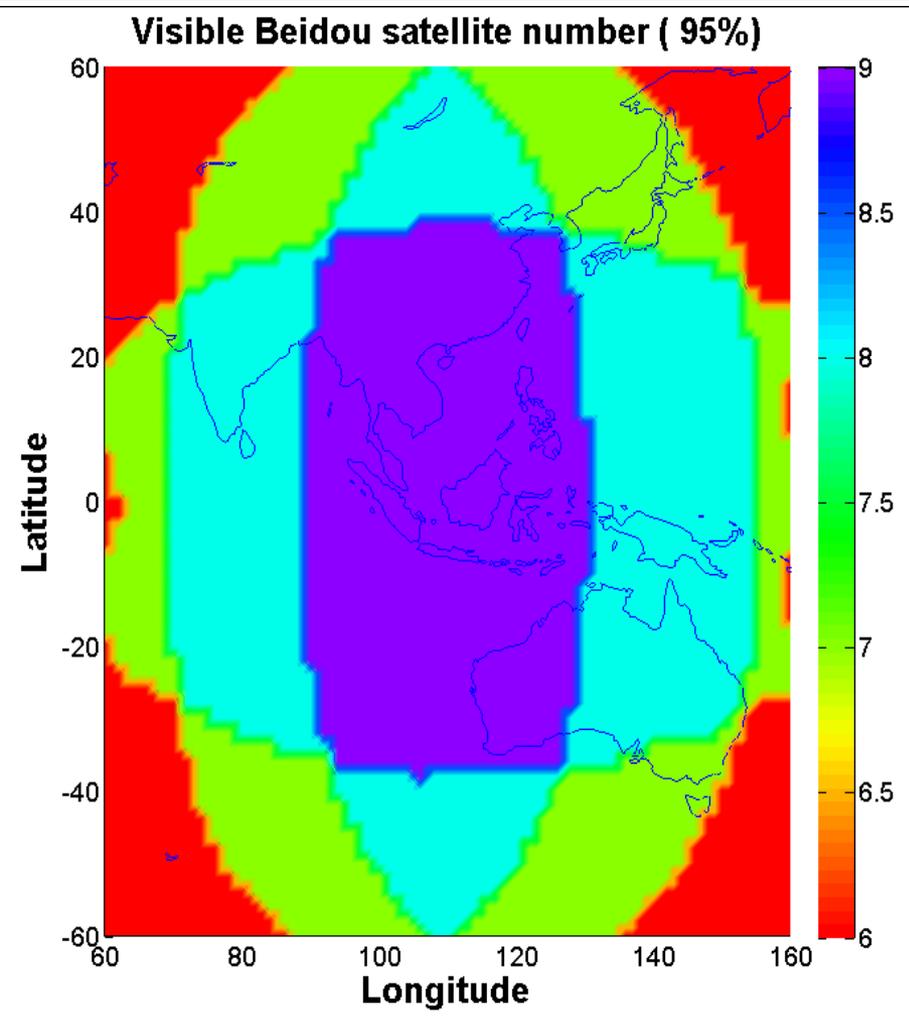


**2020**

**July, 2012**



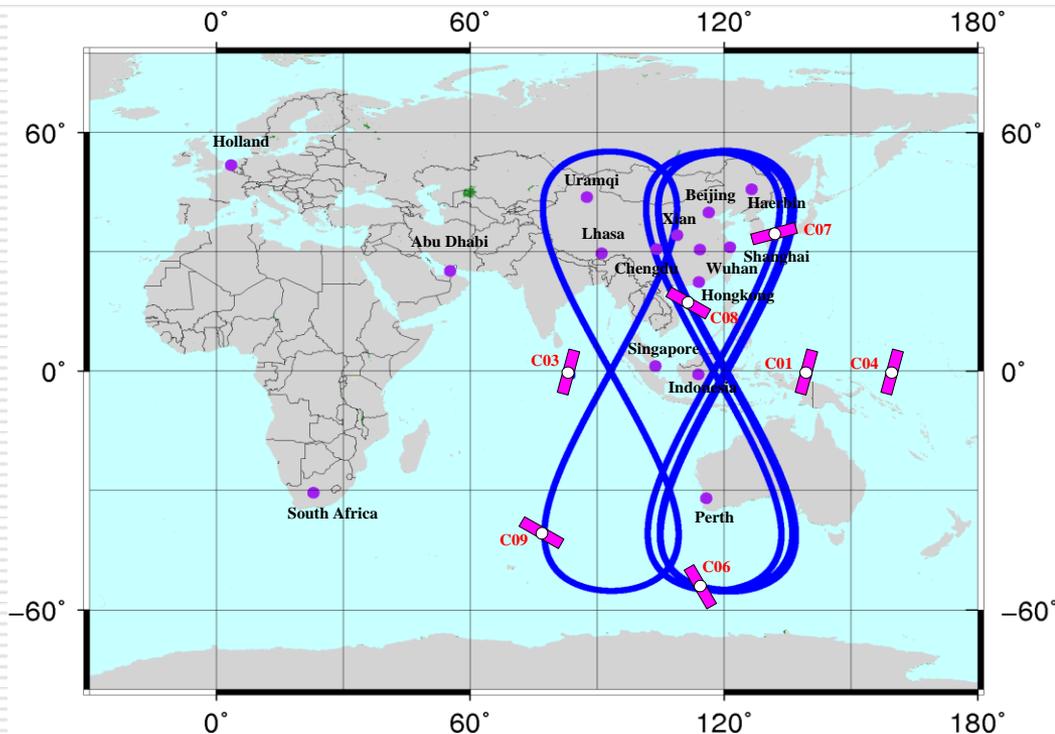
# SPP Performance of Current Constellation



# COMPASS Precise Positioning and Navigation

- Status of COMPASS
  - Baseline Solutions (mm-level)
  - COMPASS RTK (cm level)
  - COMPASS PPP (dm level)
  - D-COMPASS Navigation (m level)
  - Benefit of GPS+COMPASS
-

# Beidou Tracking Network by Wuhan University



境内（12个）：上海、北京、武汉、香港、西安、  
成都、拉萨、乌鲁木齐、哈尔滨、沈阳、广东  
境外（8）：荷兰、佩斯、新加坡、南非、希腊、  
阿联酋、印尼、墨尔本

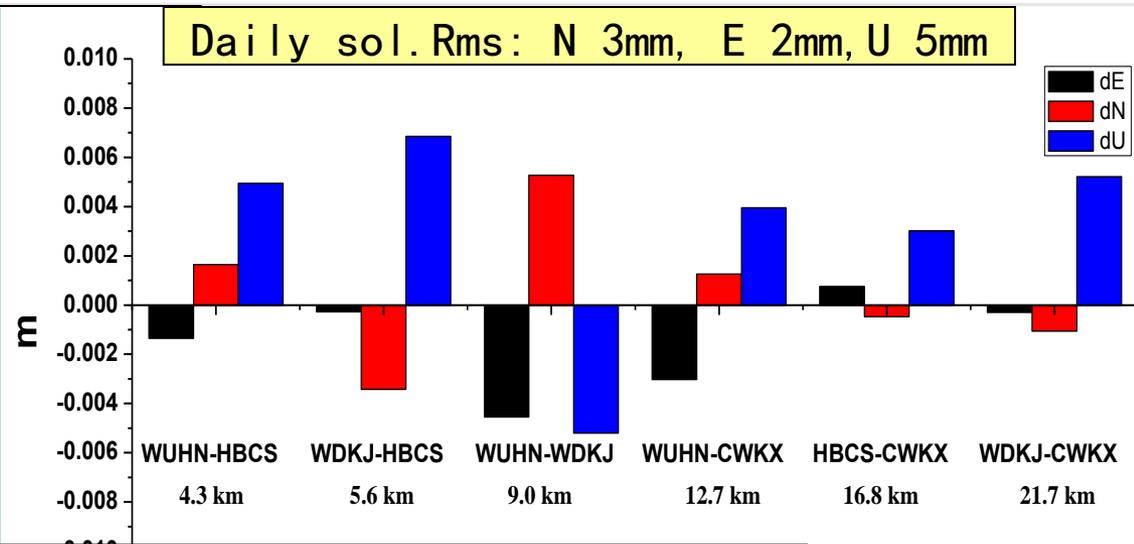
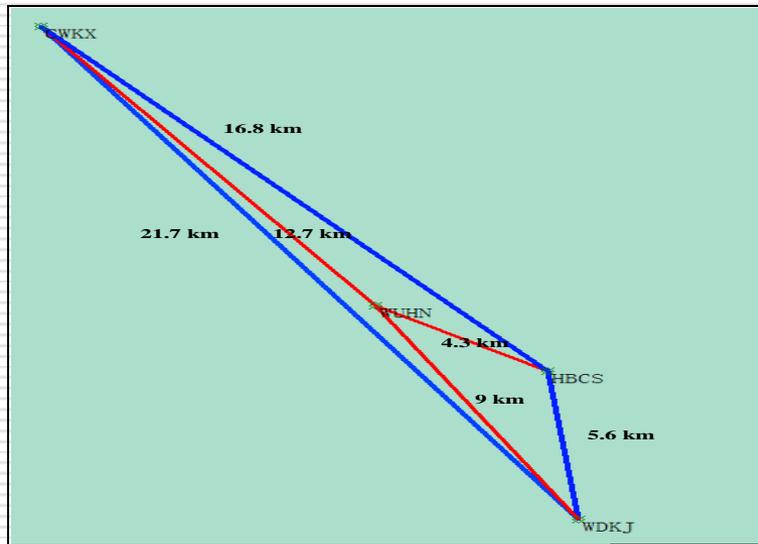
北斗/GPS双频观测

# First Beidou CORS Network

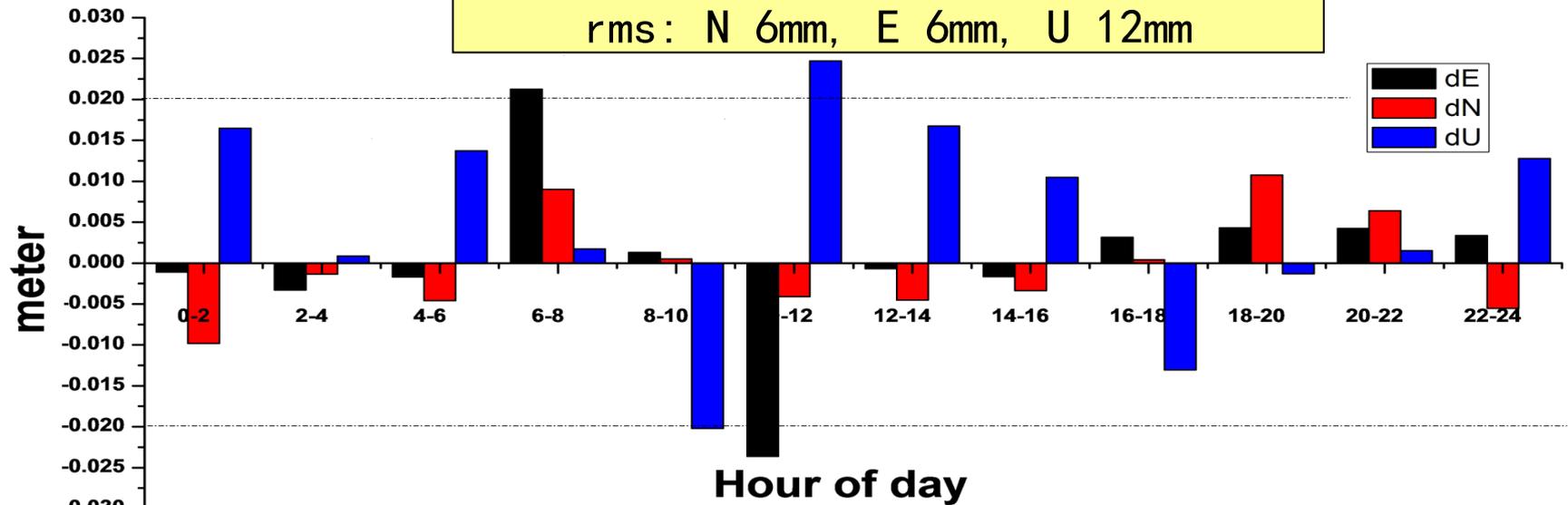
北斗地基增强系统湖北省示范项目参考站分布图



# COMPASS baseline solutions compared to GPS



WDKJ-CWKX (21.7km) 2hour sol.  
rms: N 6mm, E 6mm, U 12mm



# COMPASS Baseline Compared with Laser Result

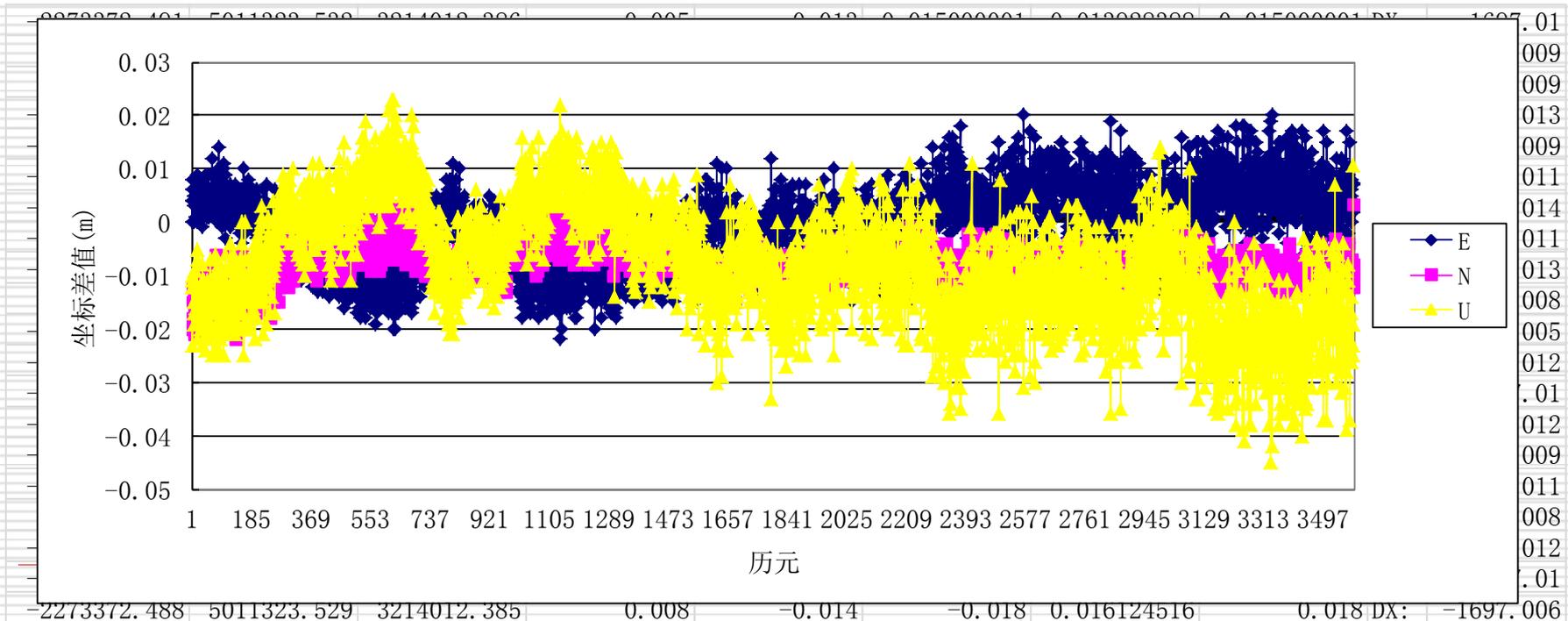
Baselines	Laser Distances (m)	Obs.	GNSS vs laser (mm)	
			Compass	GPS
SH00 - SN41	1008.179	B1/L1	2.0	3.0
SH00 - SN37	528.101	B1/L1	2.0	1.0
SH00 - JD01	28070.411	BC/LC	9.0	8.0

# COMPASS Precise Positioning and Navigation

- ❑ Status of COMPASS
  - ❑ Baseline Solutions (mm-level)
  - ❑ COMPASS RTK (cm level)
  - ❑ COMPASS PPP (dm level)
  - ❑ D-COMPASS Navigation (m level)
  - ❑ Benefit of GPS+COMPASS
-

# COMPASS RTK Results

- Receiver: reference and rover: UNICORE UB240 (dual-frequency)
- Ambiguity fixed : 99.987%
- Real-time rms (Compare with GPS RTK) :  
E:7mm, N: 3mm, U:11mm



# Network RTK Precision

## □ BDS Network RTK Precision

- Rover: South S82-C (BDS Triple+GPS double Freq) 、 Hi-Target V30 (BDS double+GPS double Freq.)
- 34rovers used, 5 positioning modes involved

mode	Success rate of AMB Fix	Initial Time (s)	Internal precision/m (average)		accuracy/m (average)	
			plane	height	plane	height
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

# COMPASS RTK Test VS. GPS RTK



标尺

线条 路径

测量地面上两个点之间的距离

地图长度: 20.46 厘米

地面长度: 20.47

方位: 88.97 度数

鼠标导航(M)

标尺

线条 路径

测量地面上两个点之间的距离

地图长度: 261.73 厘米

地面长度: 261.75

方位: 179.84 度数

鼠标导航(M)

标尺

线条 路径

测量地面上两个点之间的距离

地图长度: 120.15 厘米

地面长度: 120.20

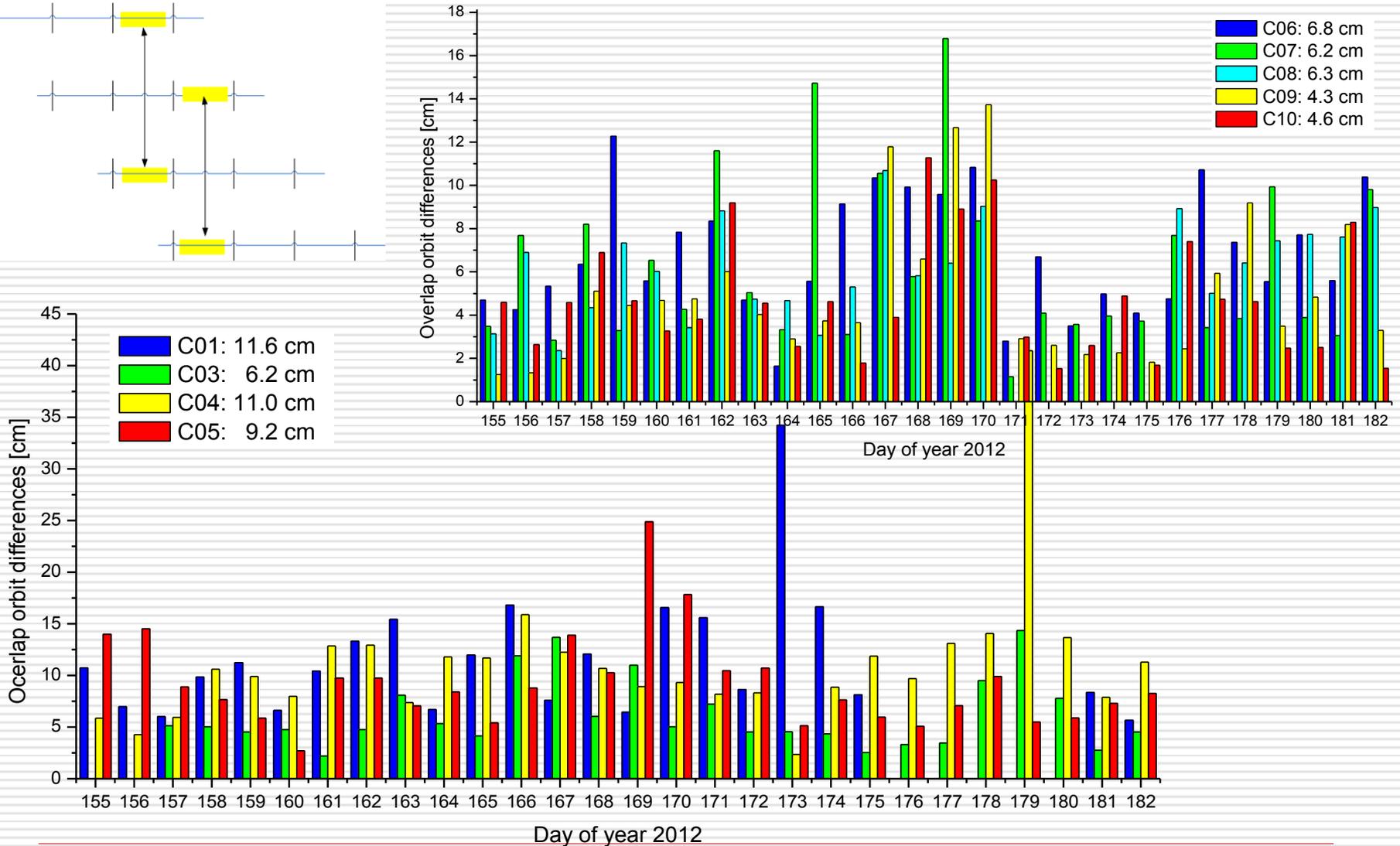
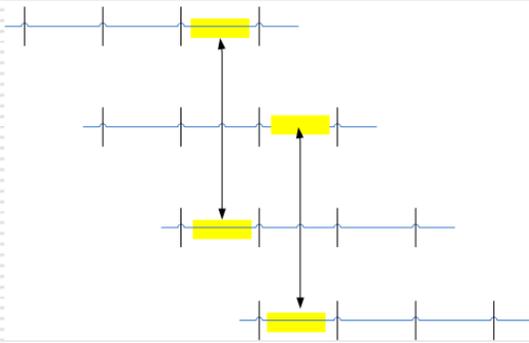
方位: 90.02 度数

鼠标导航(M)

# COMPASS Precise Positioning and Navigation

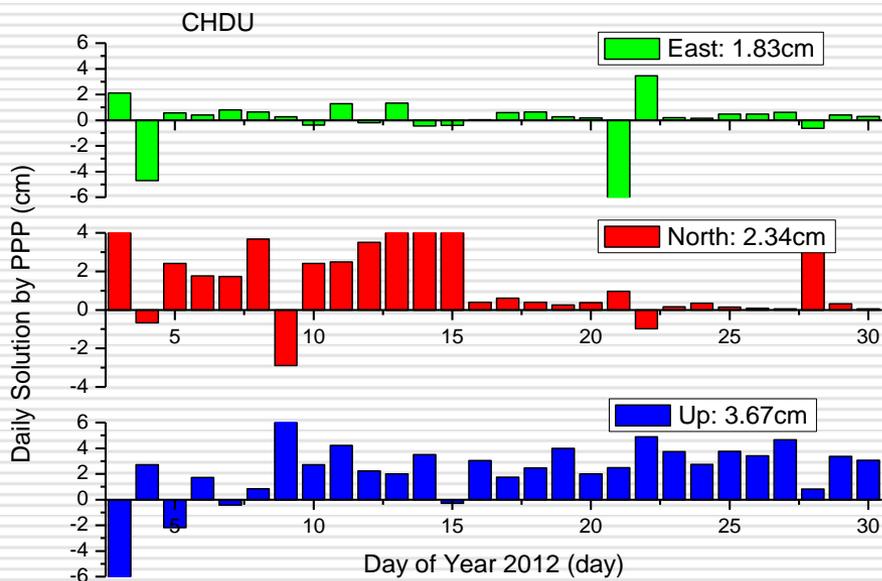
- ❑ Status of COMPASS
  - ❑ Baseline Solutions (mm-level)
  - ❑ COMPASS RTK (cm level)
  - ❑ COMPASS PPP (dm level)
  - ❑ D-COMPASS Navigation (m level)
  - ❑ Benefit of GPS+COMPASS
-

# POD for COMPASS Satellites



Orbit Overlap difference(Radial) RMS: 10cm

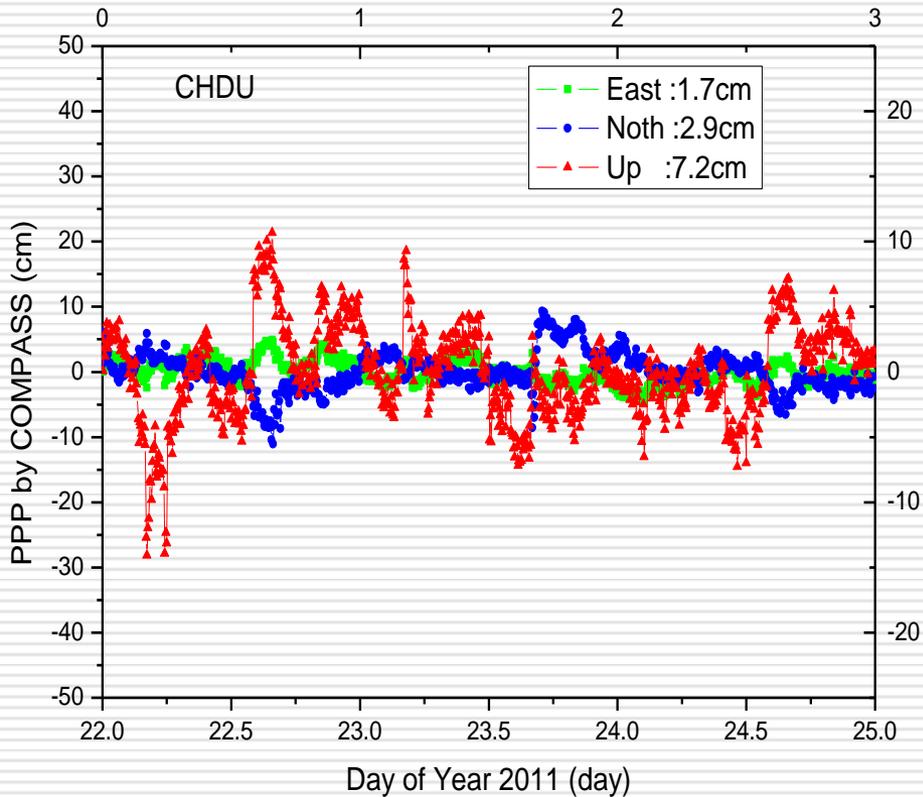
# Daily Static PPP (Jan. 2012)



	East (cm)	North (cm)	Up (cm)
CENT	1.83	0.75	3.54
<b>CHDU</b>	<b>1.83</b>	<b>2.36</b>	<b>3.67</b>
SHA1	2.45	1.24	2.97
XIAN	1.43	1.58	1.74
BJF1	2.63	0.84	2.70
SIGP	3.73	1.43	5.53
HRBN	3.89	2.19	6.45
<b>Avg.</b>	<b>2.54</b>	<b>1.48</b>	<b>3.80</b>

CHDU not used for POD

# Kinematic PPP (RT-PPP mode)

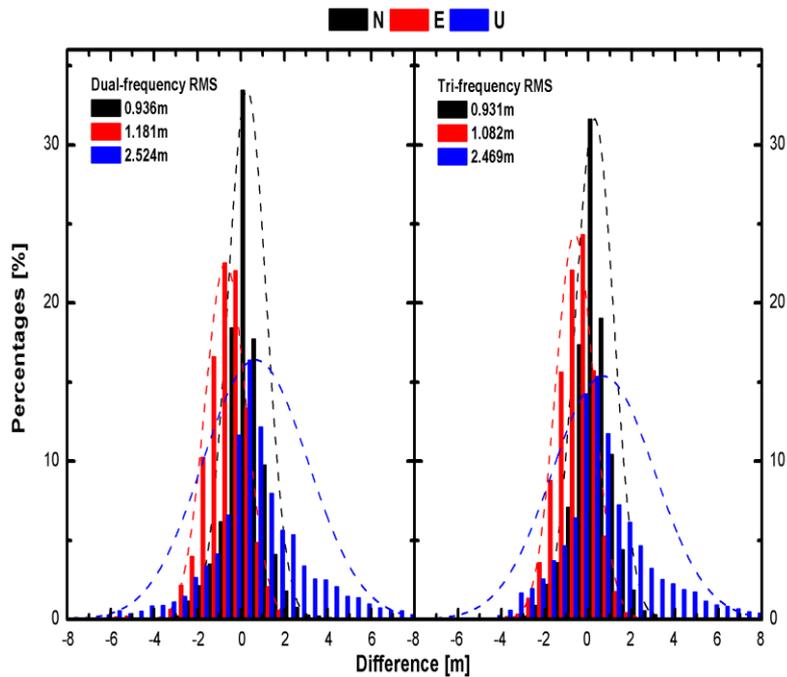


	East (cm)	North (cm)	Up (cm)
CENT	1.18	1.91	6.66
<b>CHDU</b>	<b>1.73</b>	<b>2.93</b>	<b>7.24</b>
SHA1	1.45	4.02	8.62
XIAN	0.92	2.00	6.62
BJF1	2.06	5.02	10.91
SIGP	2.62	3.03	4.63
HRBN	1.48	7.01	10.91
<b>Avg.</b>	<b>1.63</b>	<b>3.70</b>	<b>7.94</b>

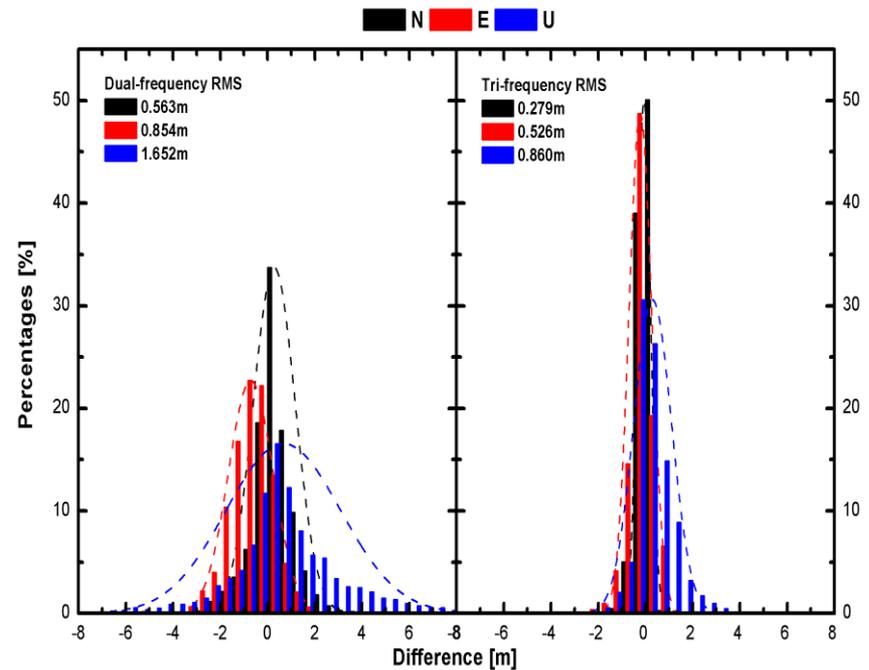
**Kinematic PPP from DOY 21 to DOY 25**

# PPP Convergence with BDS Double/Triple Frequency OBS

items	
Data source	Hubei BDS CORS Network, about 27 BDS/GPS/GLONASS sites
sessions	2013.02.01~2013.02.28, sampling rate: 30s
strategy	BDS double/triple frequency PPP

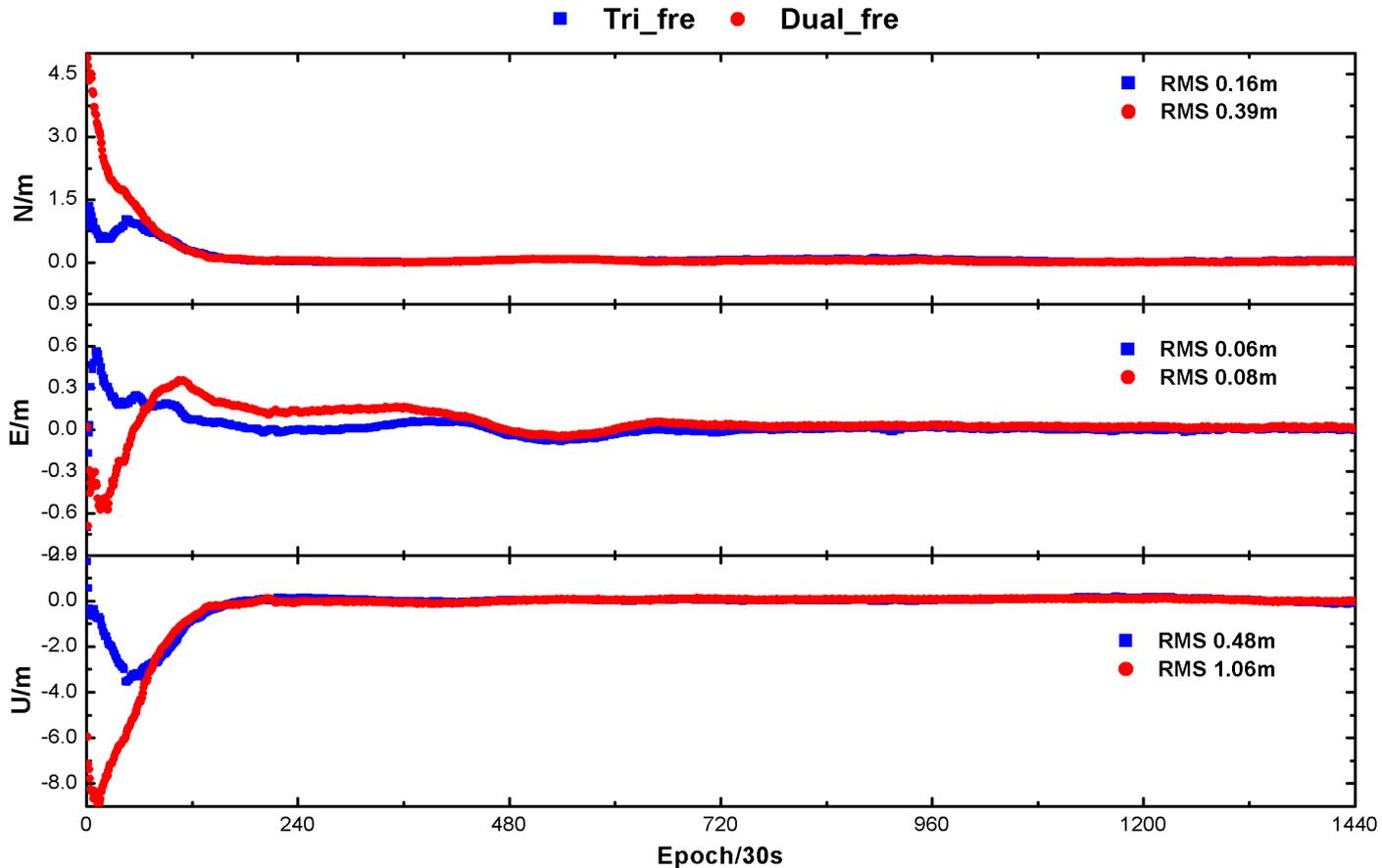


**NEU Precision in first 0~30 minutes**



**NEU Precision in first 30~60 minutes**

# PPP Convergence with BDS Double/Triple Frequency OBS



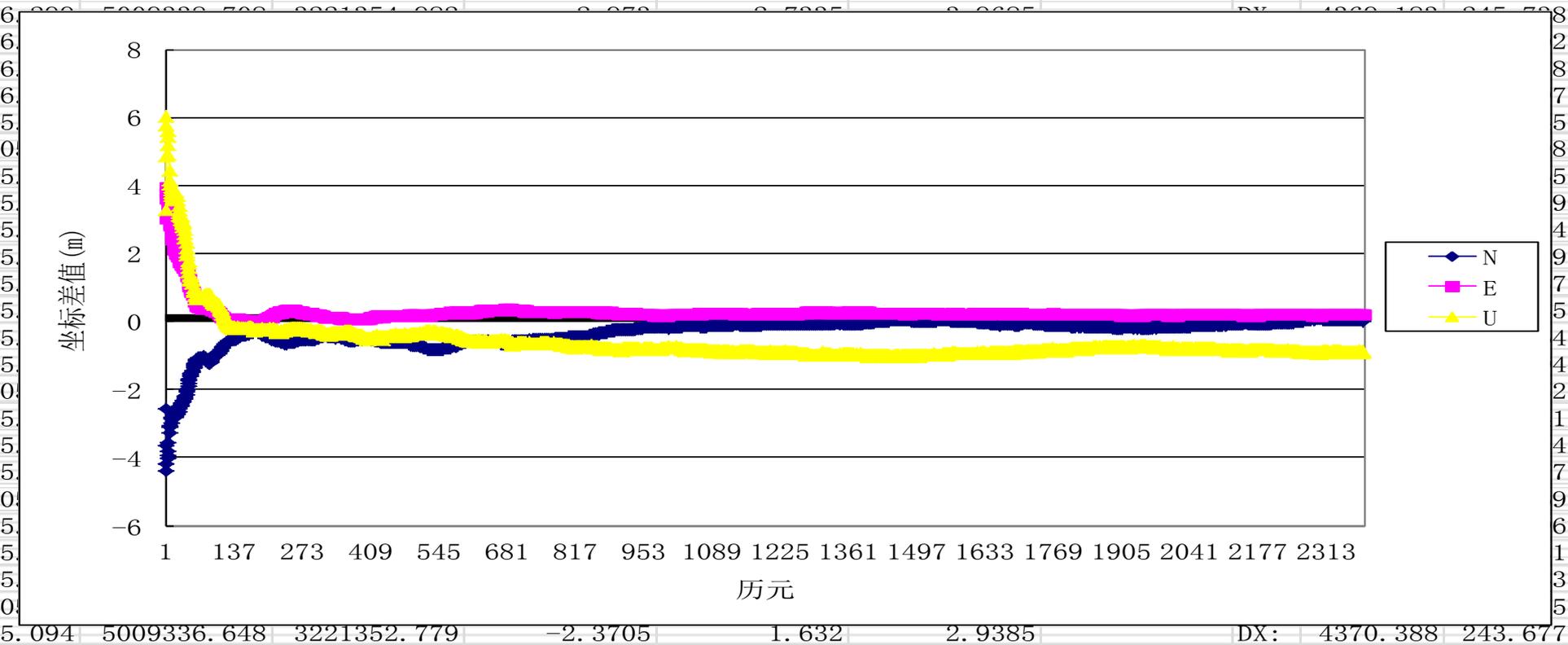
**PPP Convergence Example at site ES02 on 2013.02.07**

# COMPASS Precise Positioning and Navigation

- ❑ Status of COMPASS
  - ❑ Baseline Solutions (mm-level)
  - ❑ COMPASS RTK (cm level)
  - ❑ COMPASS PPP (dm level)
  - ❑ D-COMPASS Navigation (m level)
  - ❑ Benefit of GPS+COMPASS
-

# Pseudo-range Differential COMPASS

- Reference: UNICORE UB240
- Rover: CNS100-BG (single-frequency)
- Real-time rms (Compare with GPS RTK) :  
H:0.8m, V: 1.2m



# D-COMPASS Navigation

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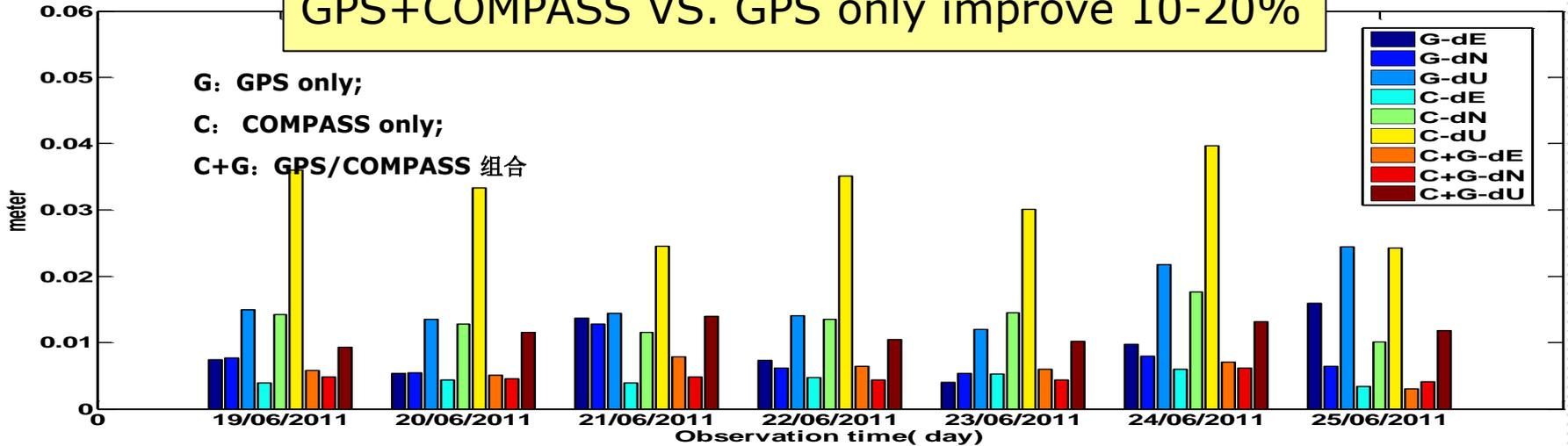


# COMPASS Precise Positioning and Navigation

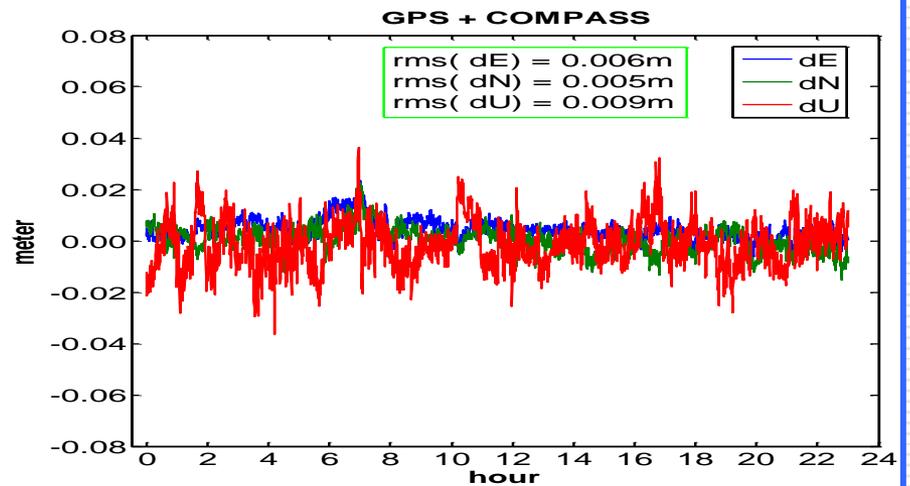
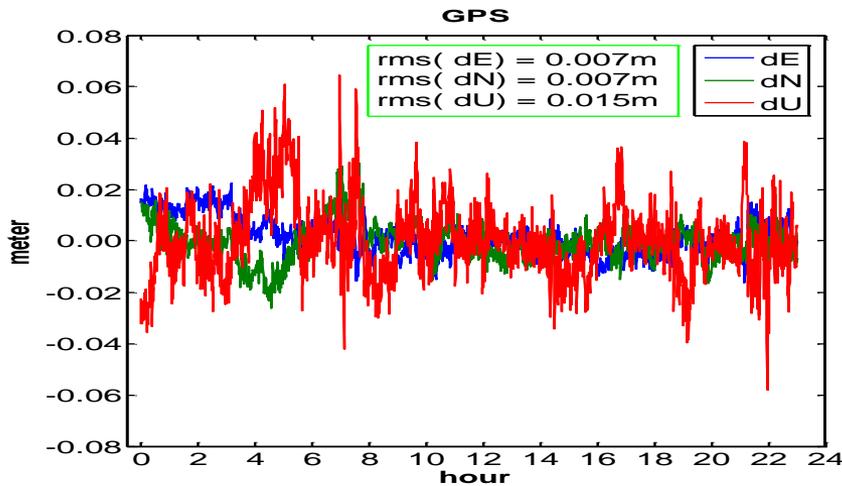
- Status of COMPASS
  - Baseline Solutions (mm-level)
  - COMPASS RTK (cm level)
  - COMPASS PPP (dm level)
  - D-COMPASS Navigation (m level)
  - Benefit of GPS+COMPASS
-

# Benefit of GPS+COMPASS

GPS+COMPASS VS. GPS only improve 10-20%



7 day Baseline Kinematic solutions



DOY170 Kinematic solution (epoch by epoch)

# Summary

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## □ PANDA software

- GNSS real-time products: orb., clo., ion., trop.,,,
- Dm level RT-PPP

## □ MASS developed in China

- Dm level RT-PPP for double-frequency
- Better than 1m accuracy for single-frequency

## □ COMPASS results

- Baseline: mm level @ 30km
  - RTK: cm level
  - PPP: dm level
  - Pseudo-range Differential: meter level
  - Comparing with GPS only, emerging Compass data could improve the accuracy of baseline kinematic solution about 10-20%
-

Thank You for your attention!



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