

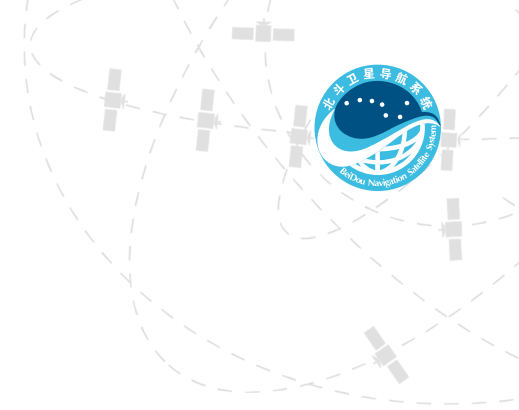
# Algorithms and Implementation of GNSS Monitoring and Assessment Parameters on iGMAS

13<sup>th</sup> Meeting of the International Committee on  
Global Navigation Satellite Systems

## Jia Xiaolin Lu Xiaochun Ren Xia

2018-11-06





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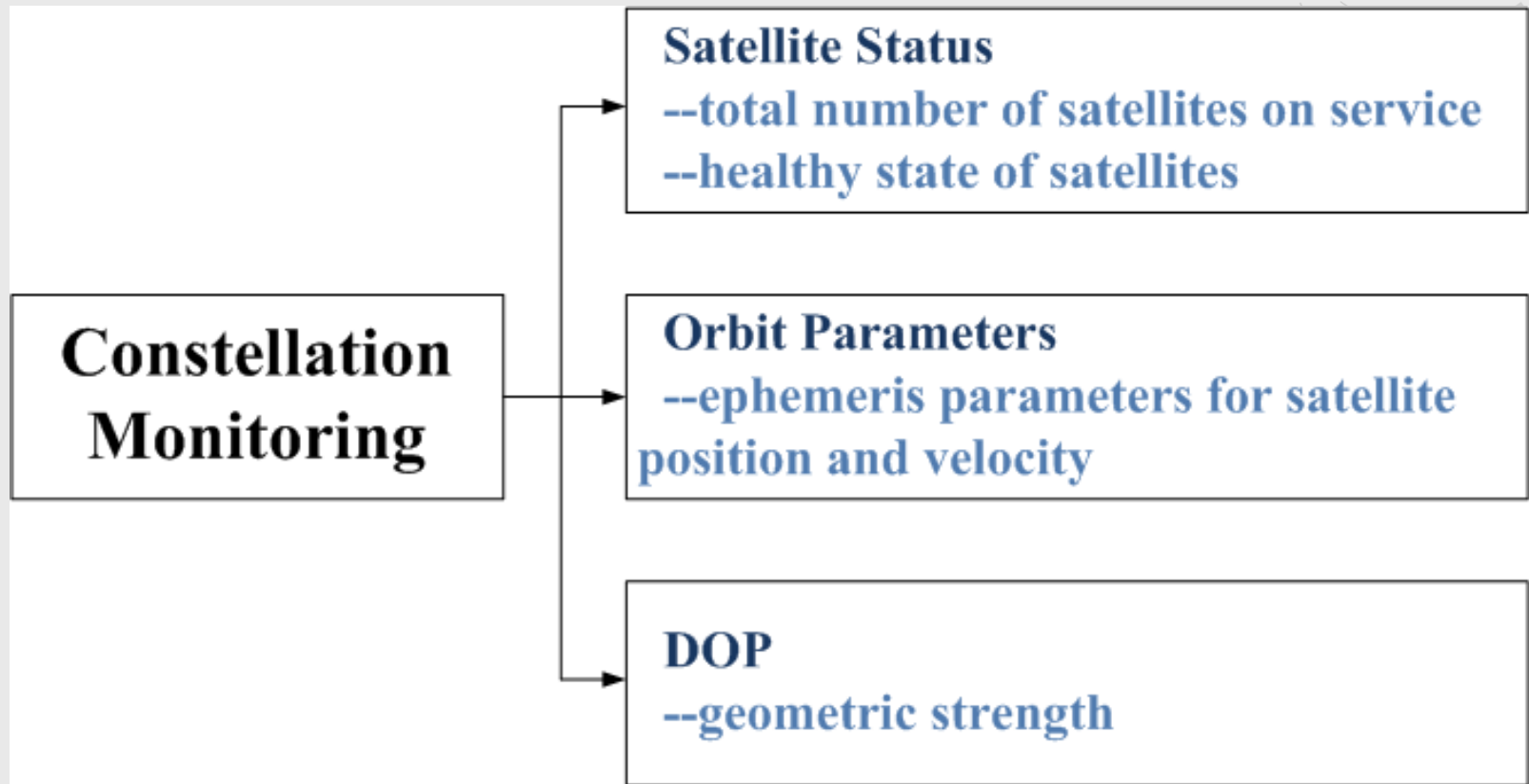
**05** Conclusion

A diagram in the top right corner showing a satellite constellation. It features several satellite icons in orbit around a central point, with dashed lines representing orbital paths and ground stations on the ground.

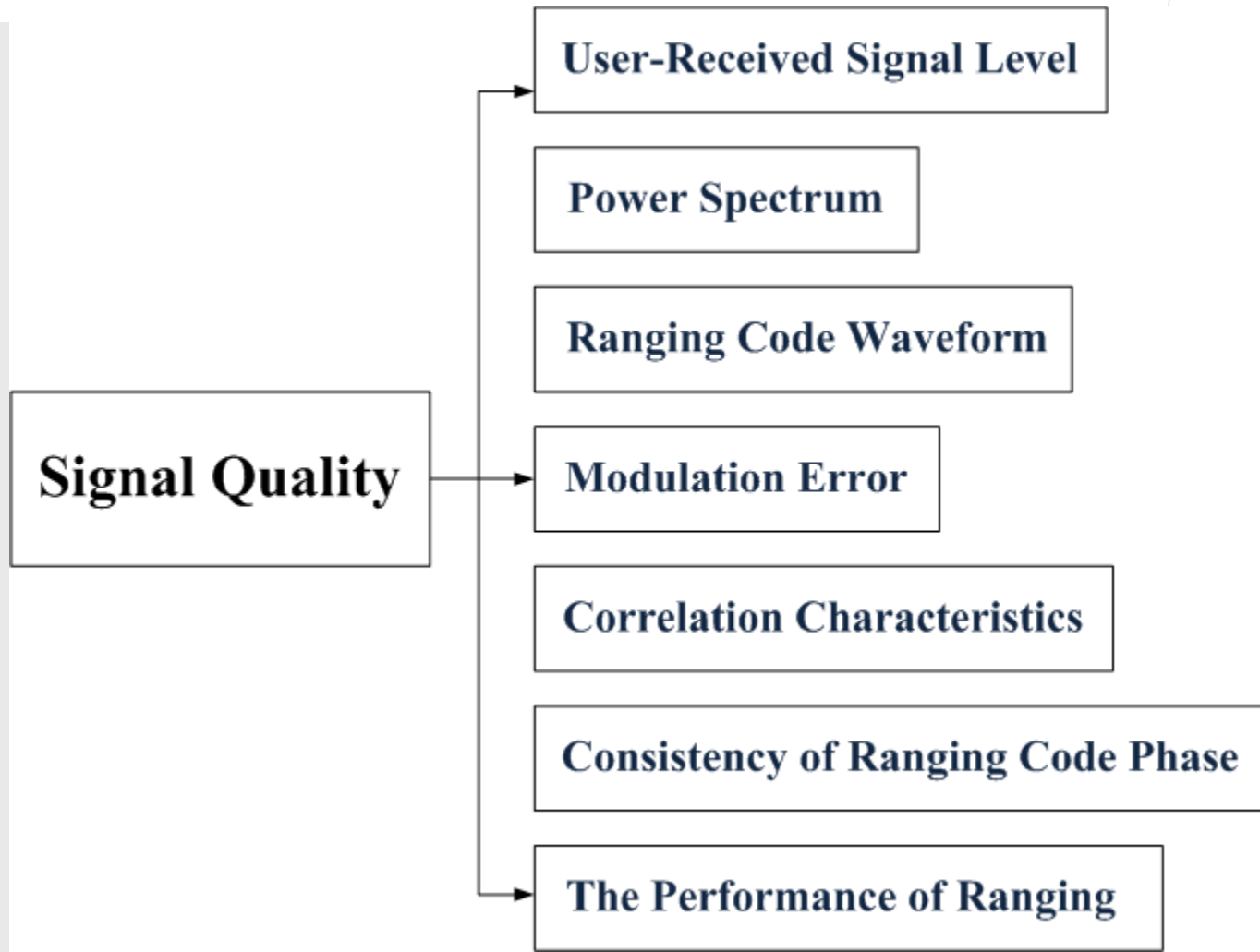
# 01

## Monitoring and Assessment Parameters

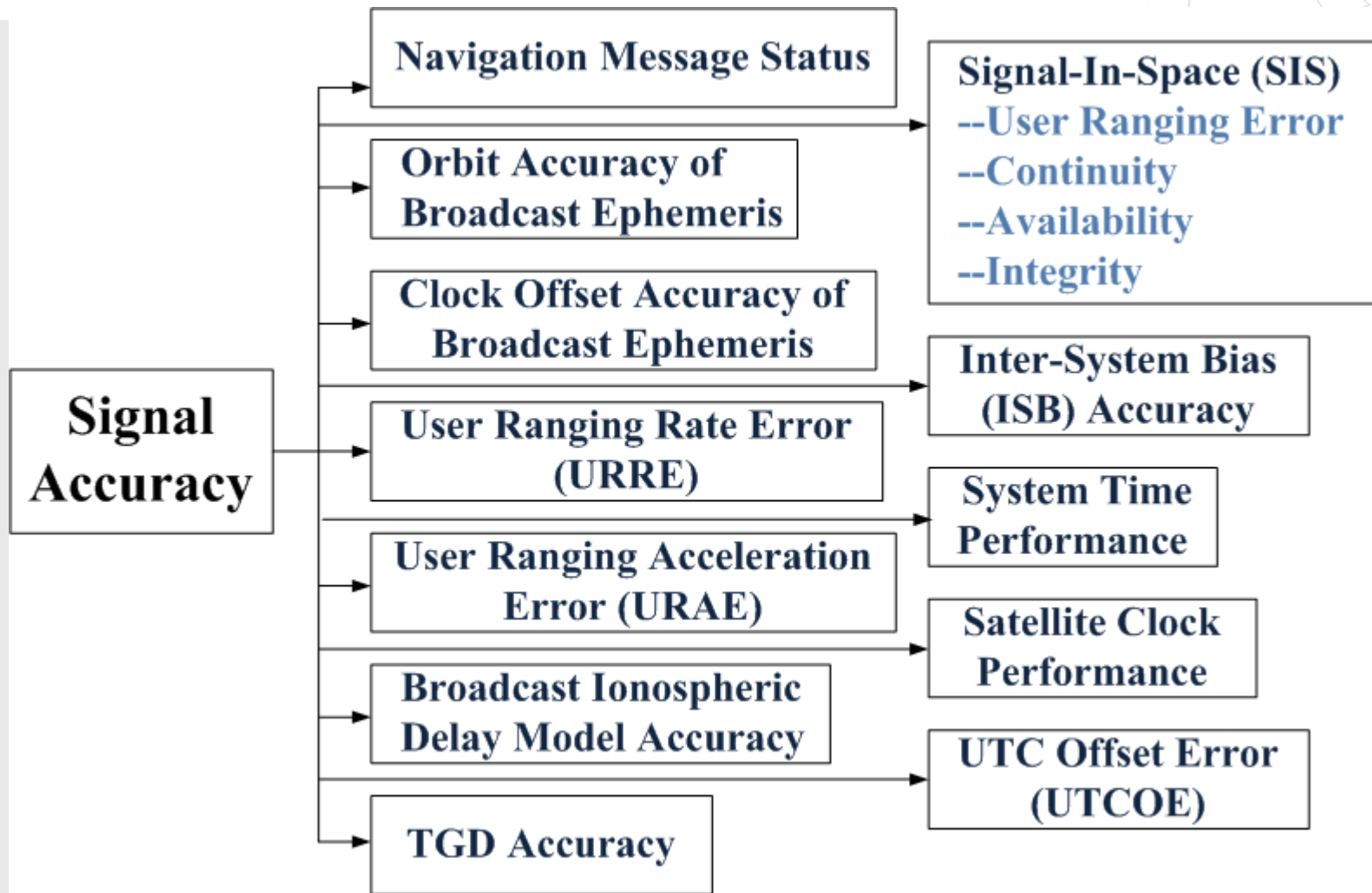
- **Constellation Status**
- **Signal Quality**
- **Signal Accuracy**
- **Service Performance**

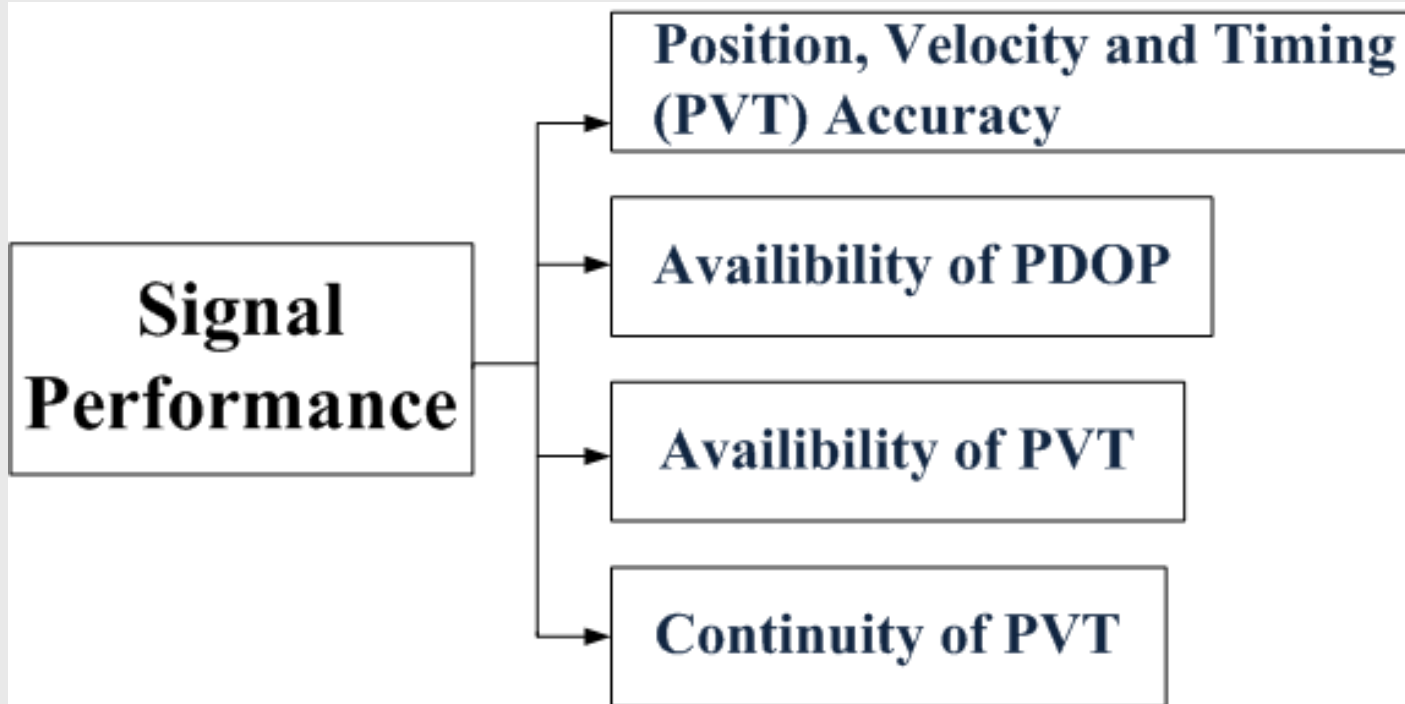


# Monitoring and Assessment Parameters /Signal Quality



# Monitoring and Assessment Parameters /Signal Accuracy







# 02

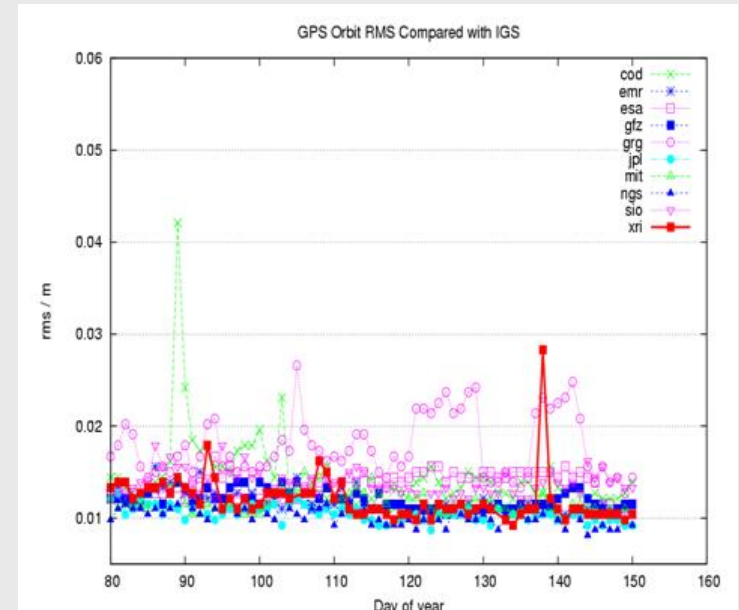
## Algorithm

- **Broadcast Ephemeris Accuracy**
- **SIS User Range Error**



## 1. Broadcast Ephemeris Accuracy (Orbits and Clocks)

- The broadcast orbits and clocks are calculated according to the formulas given in the respective GNSS ICDs.
- The Orbits and clocks obtained from **IGS/iGMAS** and providers are used as **reference orbits and clocks**.
- The differences between broadcast ephemeris and reference ephemeris are calculated.



Orbit RMS Compared with IGS



## 1. Broadcast Ephemeris Accuracy (Orbits and Clocks)

### ➤ Orbit corrections

- ❑ All broadcast orbits are referred to a Uniform Time Scale, A common Terrestrial Reference Frame: **consistent with that of the precise ephemeris products.**
- ❑ Both broadcast orbit and clock data are referred to the satellite Antenna Phase Center(APC).
- ❑ The Antenna offsets for CoM correction of broadcast ephemeris.



## 1. Broadcast Ephemeris Accuracy (Orbits and Clocks)

- Clock corrections
  - An ensemble clock difference is computed at each epoch from the **average broadcast-minus-precise clock values** of satellites in each constellation.
  - The individual clock offset differences are corrected for this ensemble average.



## 1. Broadcast orbit Accuracy(Orbits and Clocks)

### ➤ Clock corrections

The constellation-specific considerations:

#### □ The periodic relativistic clock correction for GLONASS

For GLONASS, the relativistic clock correction **must be removed** from the broadcast values to obtain proper clock offsets for comparison with the precise clock products.

#### □ The correction of differential code biases (DCBs) for BDS-2

## 2. SIS User Range Error

A “Global Average URE” for each navigation system can be calculated as:

$$\begin{aligned}
 \text{SISURE} &= \text{rms}[(w_R \cdot \Delta r_R - c\Delta dt)^2 + w_{A,C}^2 \cdot (\Delta r_A^2 + \Delta r_C^2)] \\
 &= \sqrt{R^2 + w_{A,C}^2 \cdot (A^2 + C^2)}
 \end{aligned} \tag{1}$$

$$R = \text{rms}(w_R \cdot \Delta r_R - c\Delta dt) \quad A = \text{rms}\Delta r_A \quad C = \text{rms}\Delta r_C$$

System(type)	$W_R$	$W_{A,C}^2$
GPS	0.98	1/49
GLO	0.98	1/45
GAL	0.98	1/61
BDS(MEO)	0.98	1/54
BDS(IGSO,GEO)	0.99	1/126

## 2. SIS User Range Error

A different method to compute the SISURE of BDS before 17th January 2017.

$$\begin{aligned} SISURE &= \text{rms} \left[ w_R^2 \cdot \Delta r_R^2 + w_{A,C}^2 \cdot (\Delta r_R^2 + \Delta r_C^2) + (c\Delta dt)^2 \right] \quad (2) \\ &= \sqrt{w_R^2 \cdot R^2 + w_{A,C}^2 \cdot (A^2 + C^2) + T^2} \end{aligned}$$

Where

$$T = \text{rms}(c\Delta dt)$$

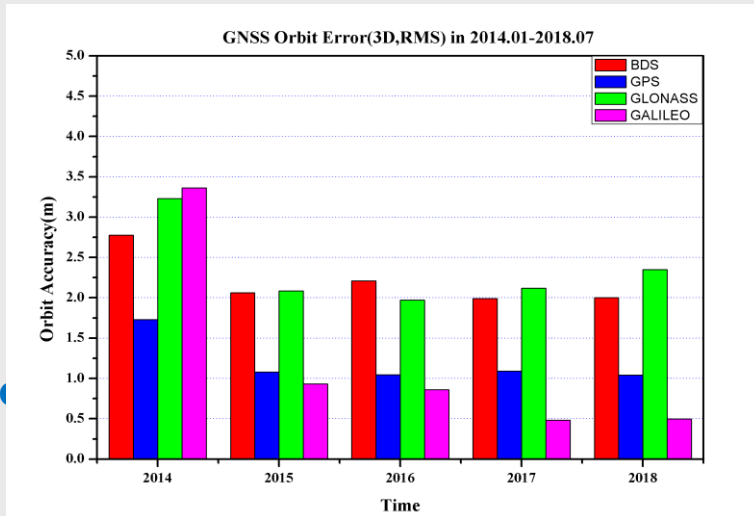


03

## Results

- Performance variation tendency (2014~2018)

## Performance variation tendency/ Broadcast Ephemeris Accuracy (Orbits)

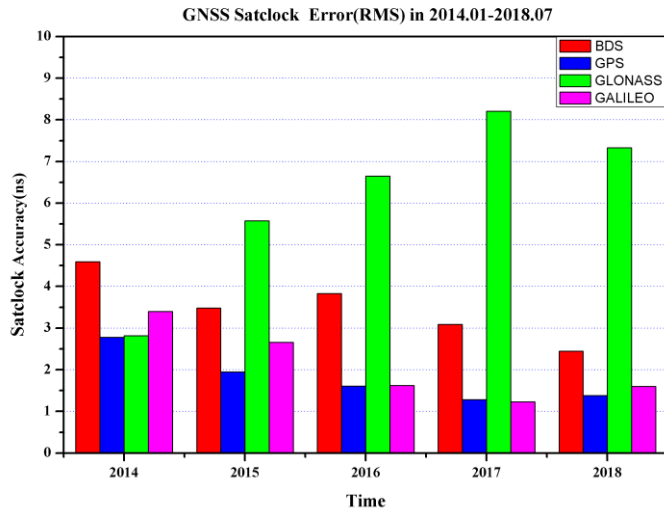


Year	BDS-2			GPS	GLONASS	Galileo
	GEO	IGSO	MEO			
2014	10.95	3.03	2.78	1.73	3.23	3.36
2015	7.82	2.27	2.06	1.08	2.09	0.93
2016	6.82	2.14	2.21	1.04	1.97	0.86
2017	5.63	2.20	1.99	1.09	2.12	0.48
2018	7.12	2.17	2.00	1.04	2.35	0.50
AVG	7.67	2.36	2.21	1.20	2.35	1.23

- The orbit accuracy of the 4 systems is **improved** since 2015;
- The orbit accuracy of the 4 systems is relatively stable during 2015 and 2018;
- For BDS, the accuracy of GEOs is relatively lower than that of IGSOs and MEOs.



## Performance variation tendency/ Broadcast Ephemeris Accuracy (Clocks)



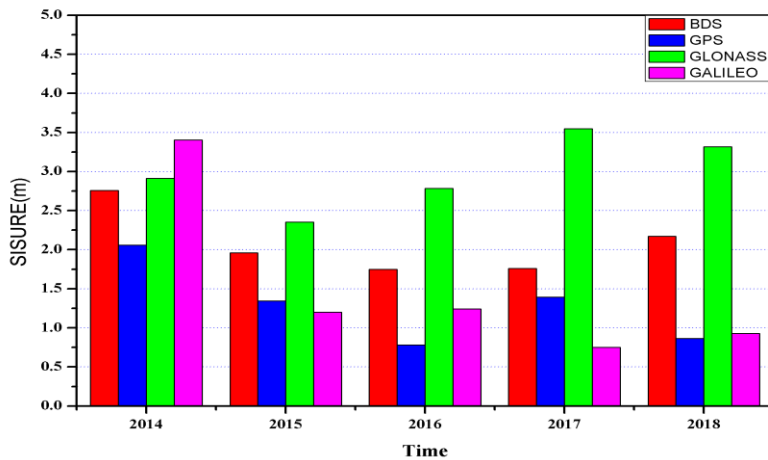
Year	BDS-2	GPS	GLONASS	Galileo
2014	4.59	2.78	2.81	3.40
2015	3.48	1.95	5.58	2.66
2016	3.83	1.61	6.65	1.62
2017	3.09	1.28	8.21	1.23
2018	2.45	1.38	7.33	1.60
AVG	3.49	1.80	6.12	2.10

- For BDS-2, GPS and Galileo, the accuracy of satellite clocks is **improved** since 2015.

# Results / Performance variation tendency

## Performance variation tendency/ URE(95%)

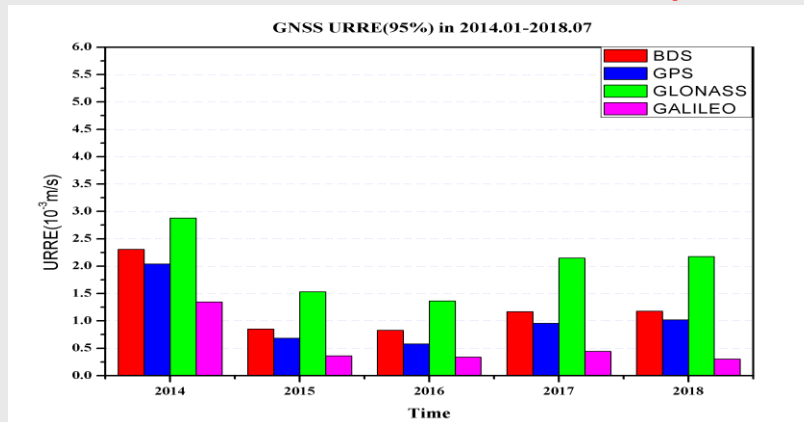
GNSS SISURE(95%) in 2014.01-2018.07



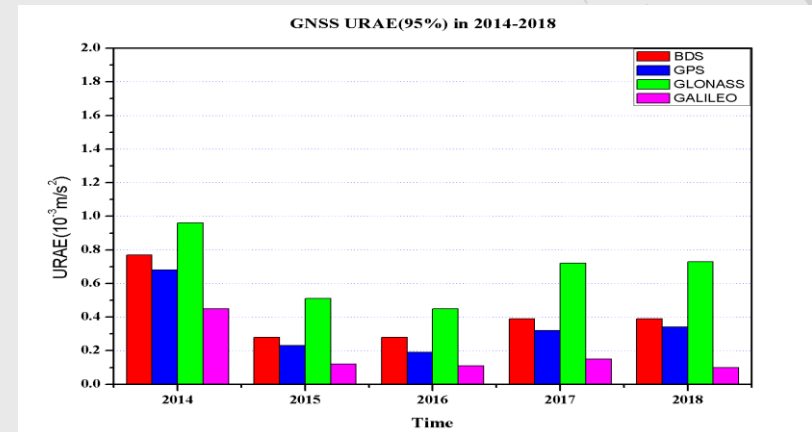
Year	BDS-2	GPS	GLONASS	Galileo
2014	2.76	2.06	2.91	3.40
2015	1.96	1.34	2.35	1.20
2016	1.75	0.78	2.78	1.24
2017	1.76	1.39	3.55	0.75
2018	2.17	0.86	3.32	0.93
AVG	2.08	1.29	2.98	1.50

- The URE of GPS and GLONASS is **relatively stable** from 2015 to 2018 ;
- The URE of BDS-2 and Galileo is **improved** gradually since 2015.

## Performance variation tendency/ URRE/URAE



URRE

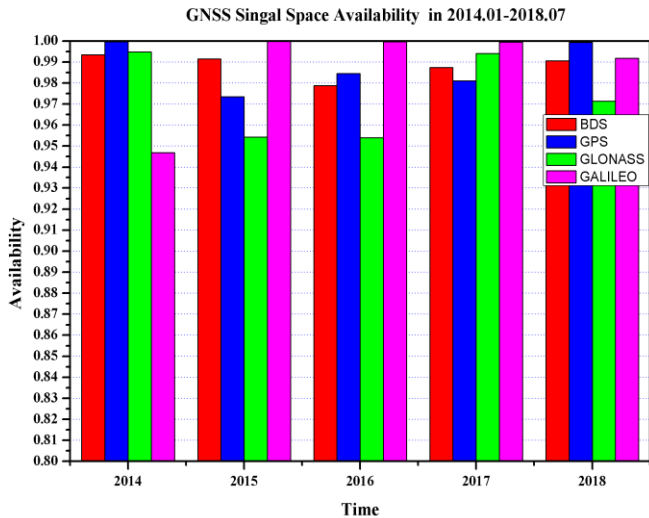


URAE

- The URRE and URAE of the four systems are **relatively stable** within 2014 and 2018 .

# Results / Performance variation tendency

## Performance variation tendency/ SIS Availability

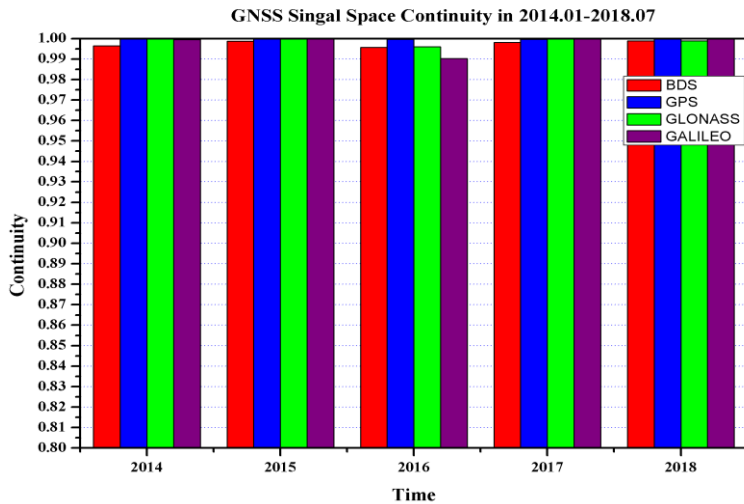


Year	BDS-2	GPS	GLONASS	Galileo
2014	0.993	0.999	0.995	0.947
2015	0.991	0.973	0.954	1.000
2016	0.979	0.984	0.954	1.000
2017	0.987	0.981	0.994	0.999
2018	0.991	0.999	0.971	0.992
AVG	0.988	0.988	0.974	0.988

### SIS Availability

- The average SIS Availability from 2014 to 2018 of BDS-2 , GPS and Galileo is better than 0.988.

## Performance variation tendency/ SIS Continuity



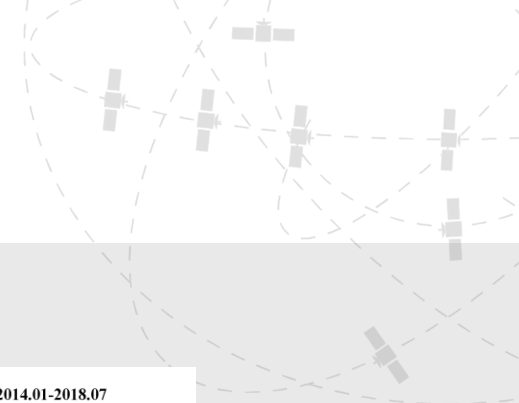
Year	BDS-2	GPS	GLONASS	Galileo
2014	0.9965	0.9998	0.9999	0.9995
2015	0.9988	0.9997	1.0000	1.0000
2016	0.9958	0.9996	0.9960	0.9903
2017	0.9981	0.9997	0.9999	0.9999
2018	0.9989	0.9998	0.9988	1.0000
AVG	0.9976	0.9997	0.9989	0.9979

### SIS Continuity

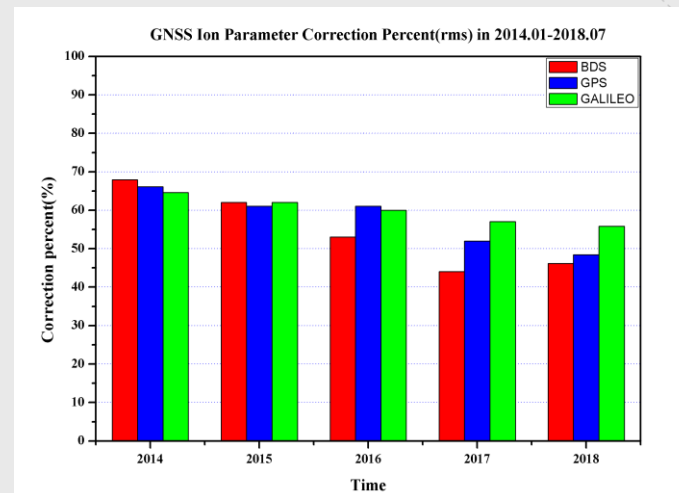
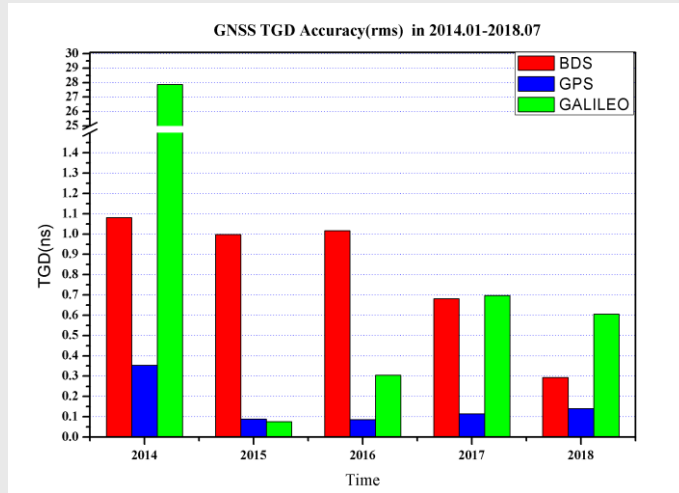
- For the 4 systems, the average SIS Continuity from 2014 to 2018 is better than 0.998.



# Results / Performance variation tendency



## Performance variation tendency/ TGD/ION



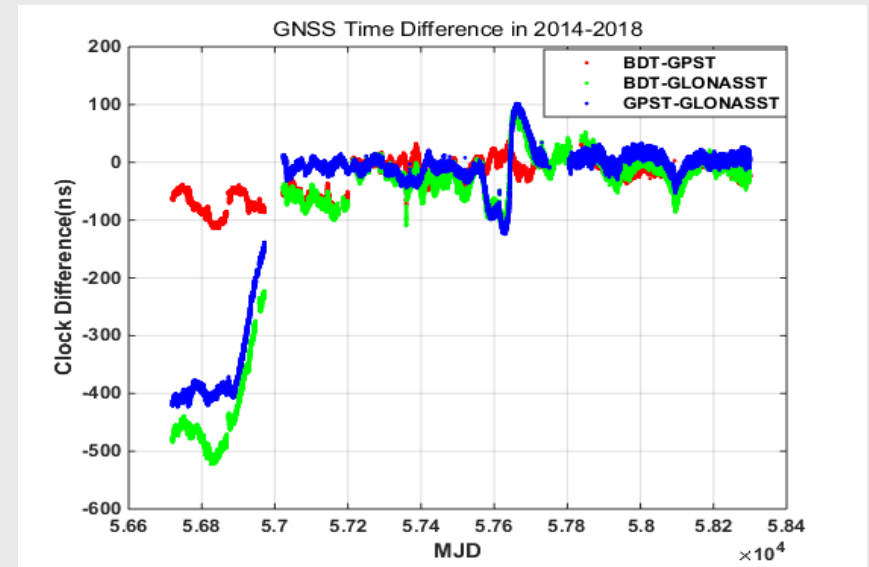
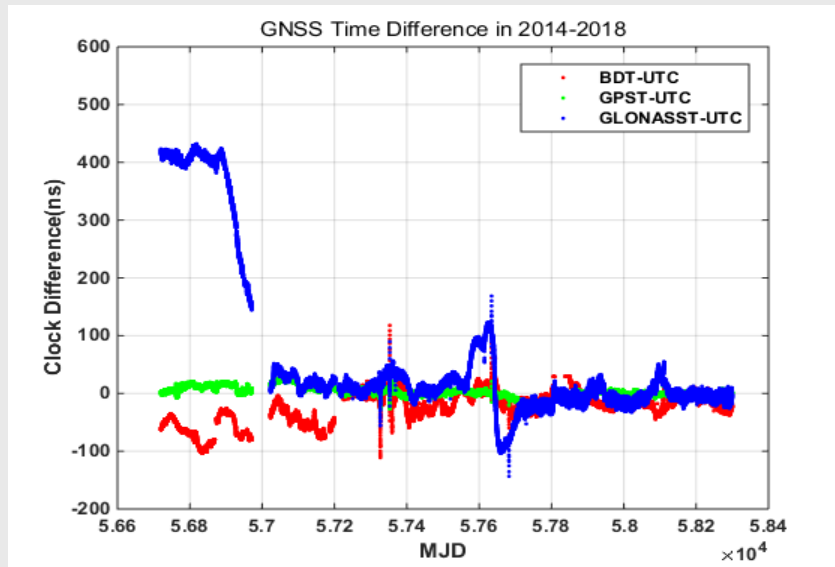
GNSS TGD Accuracy

GNSS ION Correction

- The TGD of each navigation system is all relatively stable from 2014 to 2018, except for Galileo in 2014;
- The correction percentage of ionospheric model **decreases** since 2014.

# Results / Performance variation tendency

## Performance variation tendency/ GNSST-UTC(NTSC)/ Inter-System



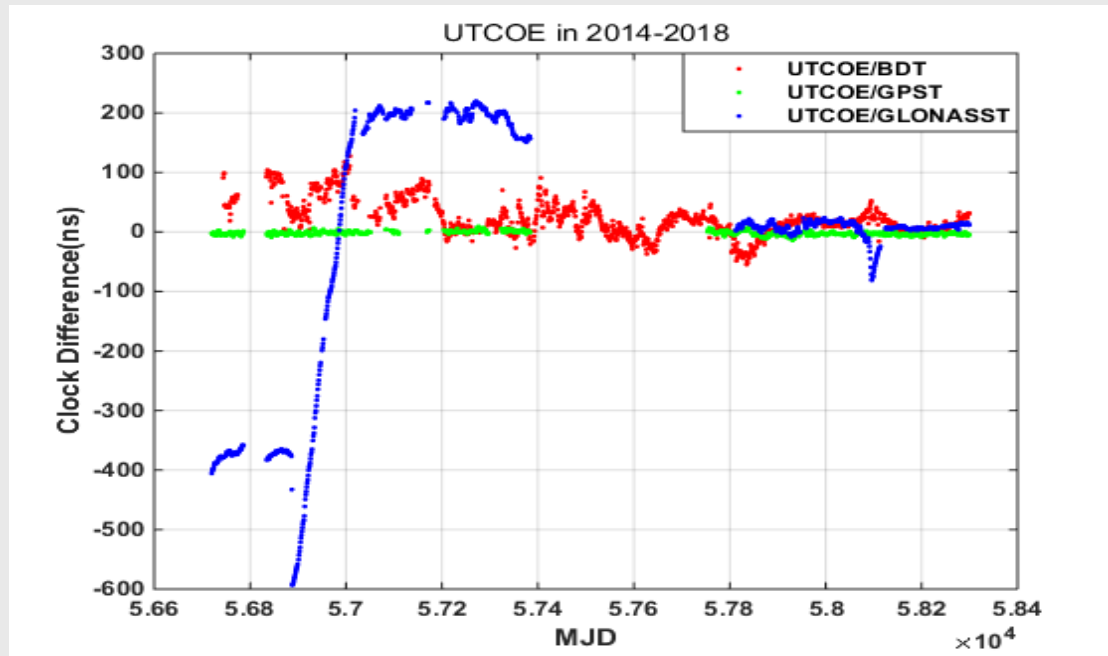
### GNSST-UTC(NTSC)

### Inter-System

- since 2015, the accuracy of GNSST is improved obviously.
- The accuracy of GNSST is stable from 2015 to 2018.



## Performance variation tendency/ UTCOE



### UTC OE

- The variation tendency of UTEOE is consistent with that of GNSST.





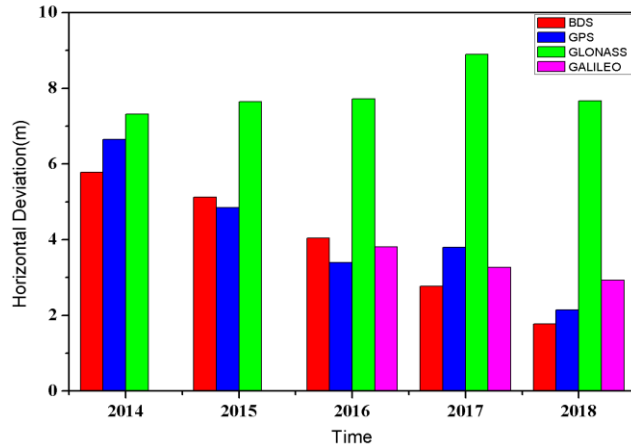
# Results / Performance variation tendency



## Performance variation tendency/ Positioning

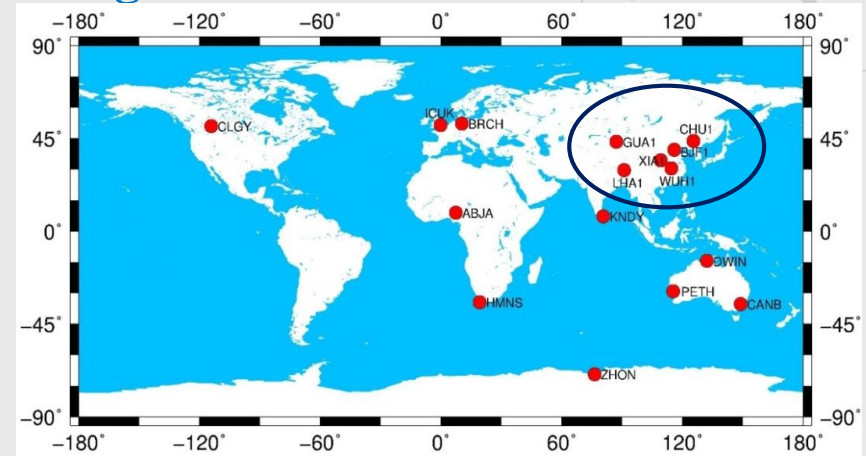
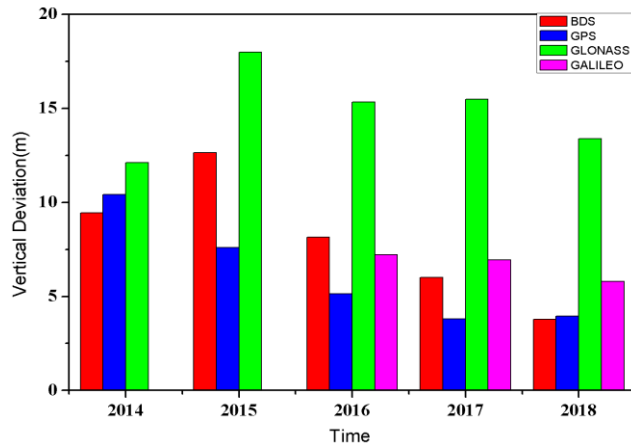
Horizontal

GNSS Horizontal Position Accuracy(95%) in 2014.01-2018.07

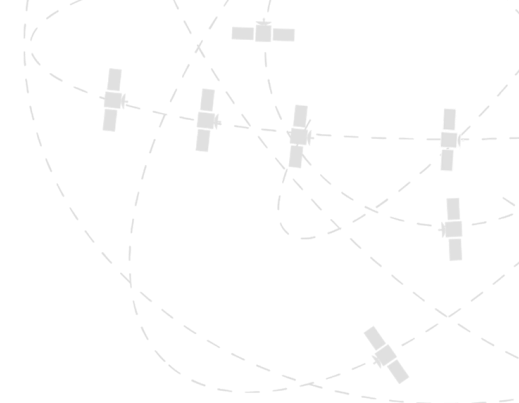


Vertical

GNSS Vertical Position Accuracy(95%) in 2014.01-2018.07



- The availability percentage of Galileo is about 20%-60% from 2016;
- The positioning accuracy of GPS and GLONASS is stable during 2014 and 2018;
- The positioning accuracy of BDS-2 shows obvious improvement since 2014.



04

## Demonstration

# Demonstration/Home page

## 国际GNSS监测评估系统

### 监测评估中心

网站首页    中心概况    GNSS监测评估    分析中心    数据/产品    研究成果    科研团队    合作交流    资源共享

今天是：2018年11月3日 星期六

#### 中心概况

监测评估中心是全球连续监测评估系统的重要组成部分，主要是对GNSS的星座状态、空间信号质量、导航信息及服务性能实现及时准确的监测和评估。一方面，对GNSS系统民用信号、信息及服务等方面进行评估，及时准确地通报评估结果；另一方面，对北斗系统军用信号、信息及服务等方面进行评估，及时发现问题，并向有关部门上报。监测评估中心主要任务是：a. 接收数据中心的原始观测数据和产品数据，接收观测站实时监测数据；b. 开展数据分析与处理工作，进行GNSS星座状态、空间信号质量、空间信号精度、服务性能等监测评估；c. 实现监测评估中心全部的数据和产品的存储和管理；d. 向产品综合与服务中心发布监测评估产品；e. 向运行控制管理中心发布xml信息。监测评估中心接收数据中心的原始观测数据和产品数据，进行分析和处理，生成星座状态监测评估产品、空间信号质量监测评估产品、空间信号精度监测评估产品、服务性能监测评估产品，将业务产品发送给产品综合与服务中心。监测评估中心生成数据接收xml信息文件、业务xml信息文件，发送给运行控制管理中心。 [\[详细\]](#)

#### 数据/产品

- 轨道产品
- 电离层产品
- 地球自转产品
- 空间信号精度监测产品
- 服务性能监测产品
- 钟差产品
- 对流层产品
- 星座状态监测产品
- 空间信号质量监测产品
- 事后监测评估产品

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- 学术论文 03-10
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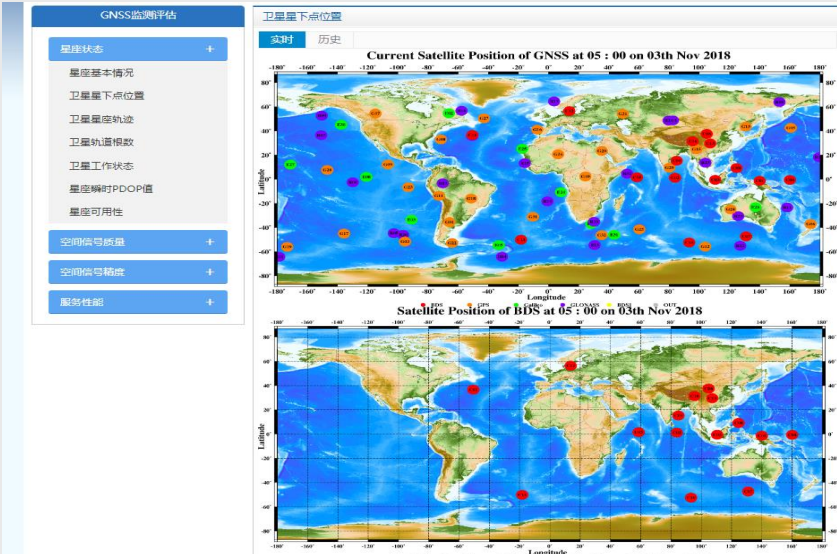
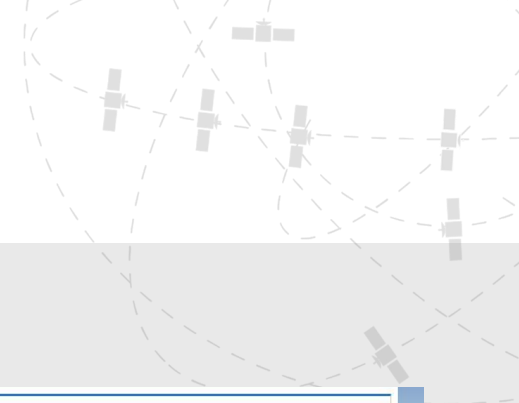
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#### 留言板

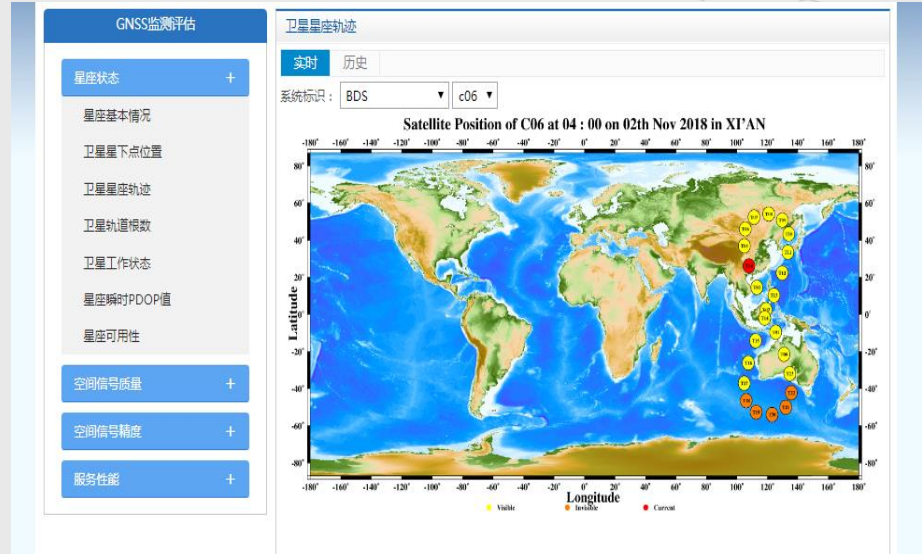
#### Station Distribution of iGMAS

The map displays the global distribution of iGMAS monitoring stations. The x-axis represents longitude from -180 to 180, and the y-axis represents latitude from -60 to 80. Stations are marked with red dots and labeled with codes: tigy (North America), tnyz (North America), jenk (Europe), ksch (Europe), kua1 (Asia), xia1 (Asia), bj1 (Asia), gh1 (Asia), kch (Africa), lna1 (Africa), kun1 (Africa), wuf1 (Africa), lha1 (South America), abja (Africa), kndy (Asia), drwa (Australia), byns (South America), tnyz (Africa), and tnyz (Australia).

# Demonstration/Ground tracks of satellites

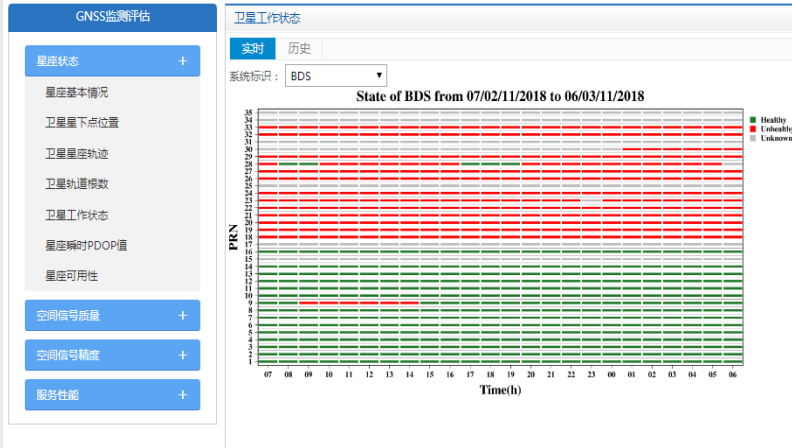


Instantaneous position of GNSS

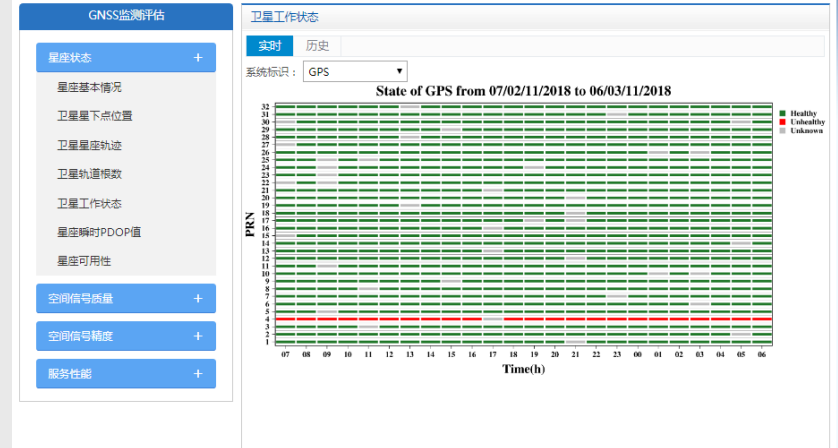


Track of BDS-2 C06

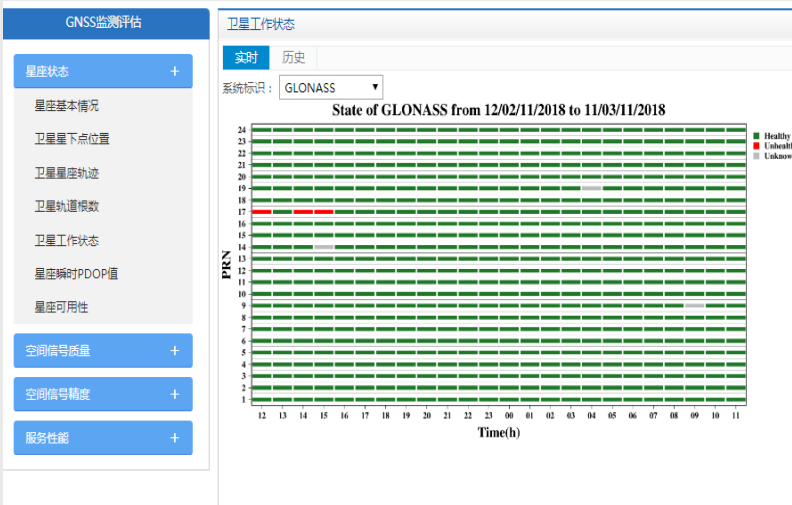
# Demonstration/Single satellite working status



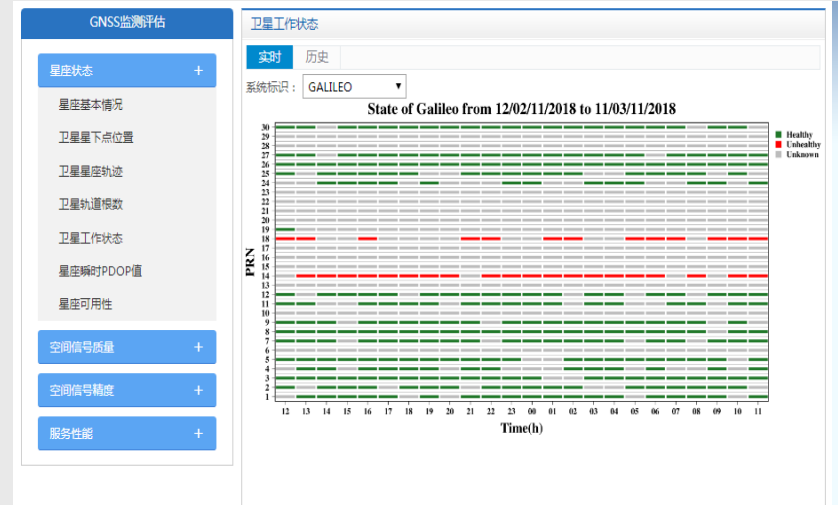
**BDS**



**GPS**

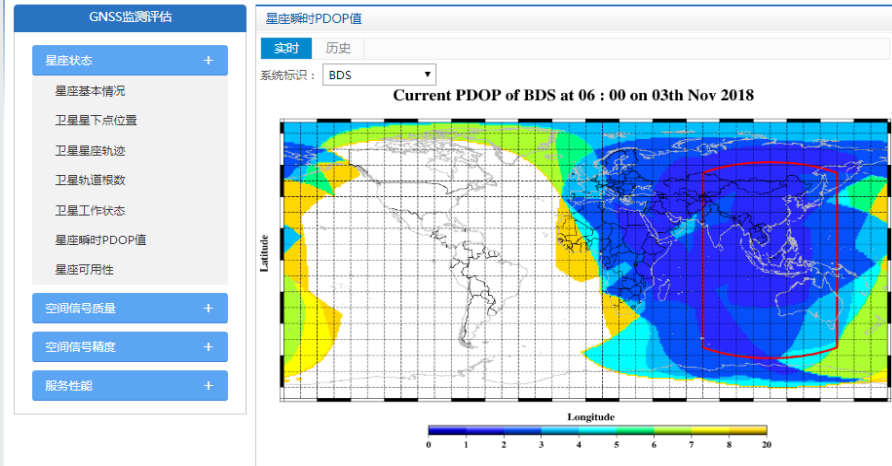


**GLONASS**

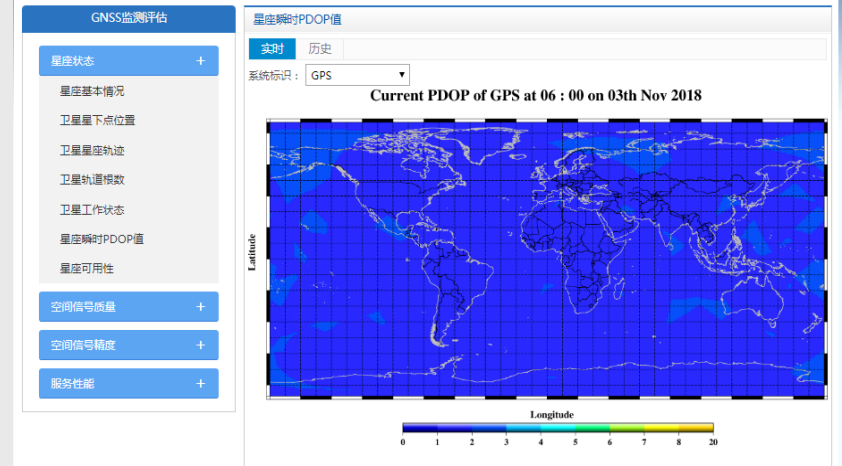


**Galileo**

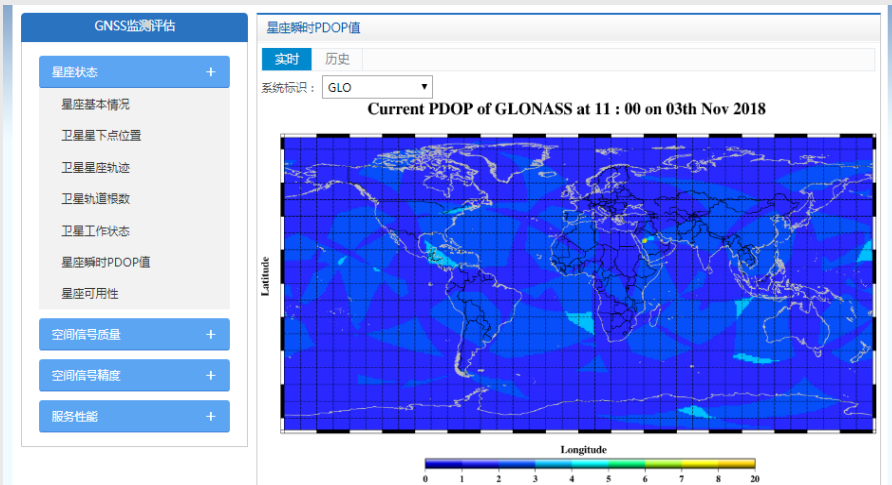
# Demonstration/PDOP



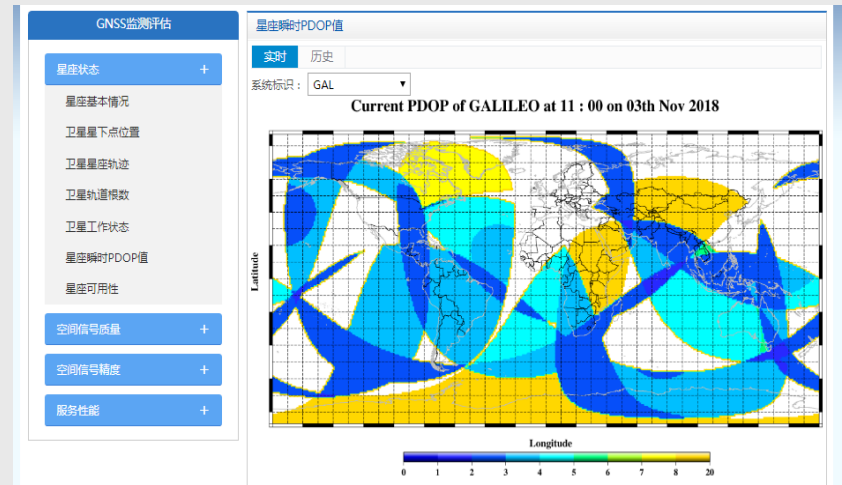
## PDOP of BDS-2



## PDOP of GPS

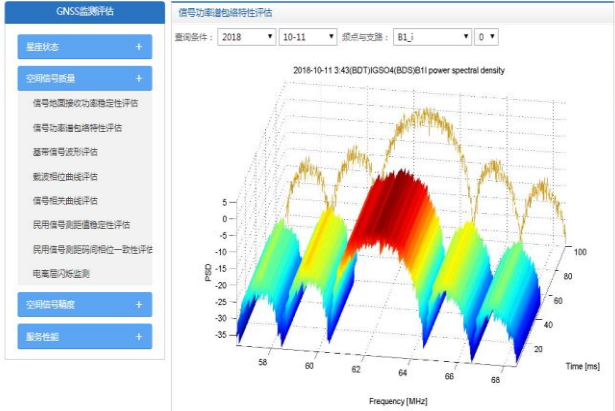


## PDOP of GLONASS

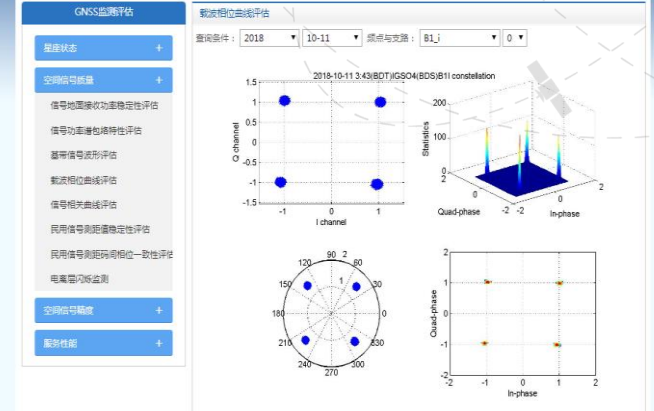


## PDOP of Galileo

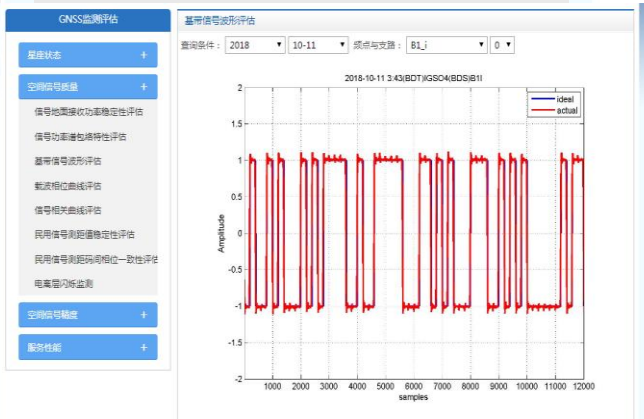
# Demonstration/Signal Quality



Power spectral density



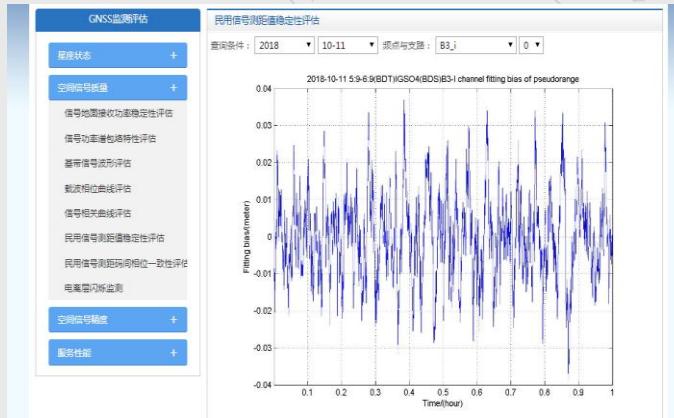
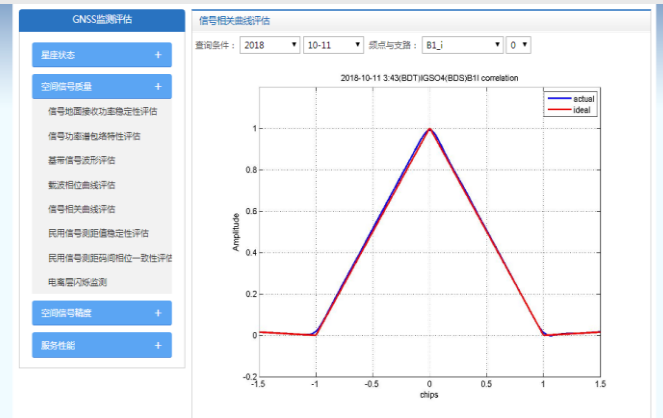
Modulation error



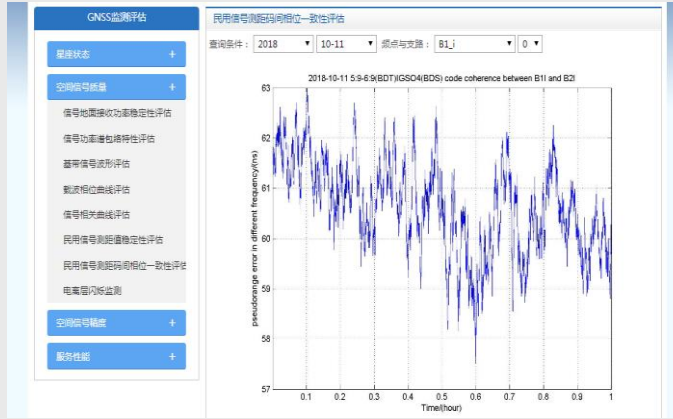
Ranging code waveform



# Demonstration/Signal Quality



## Correlation characteristics

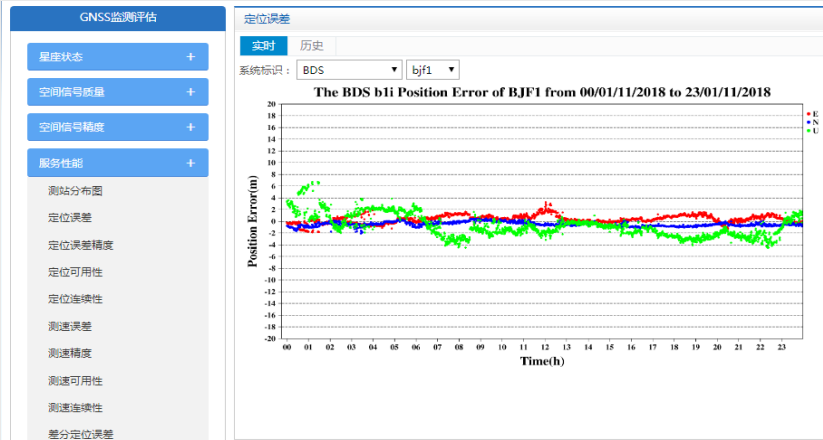
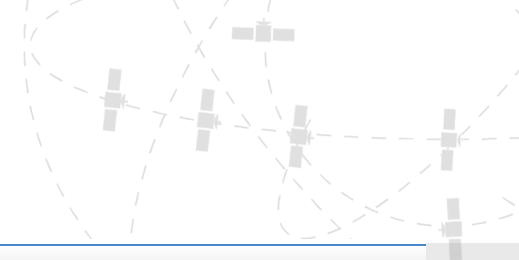


## The Performance of Ranging

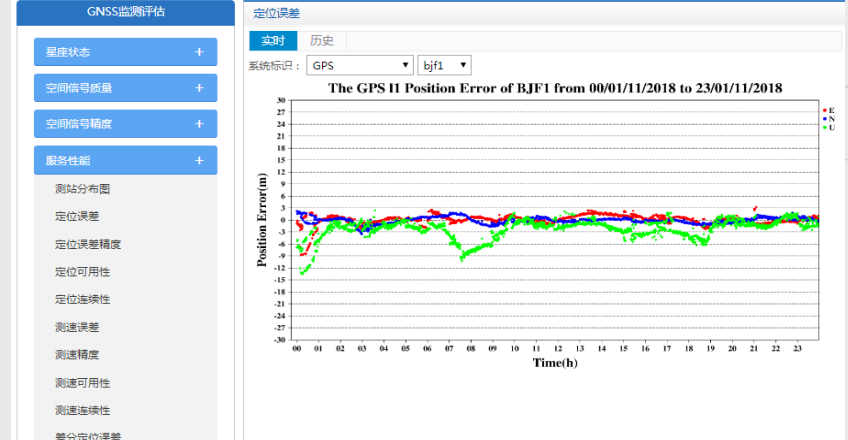
## Consistency of Ranging Code Phase



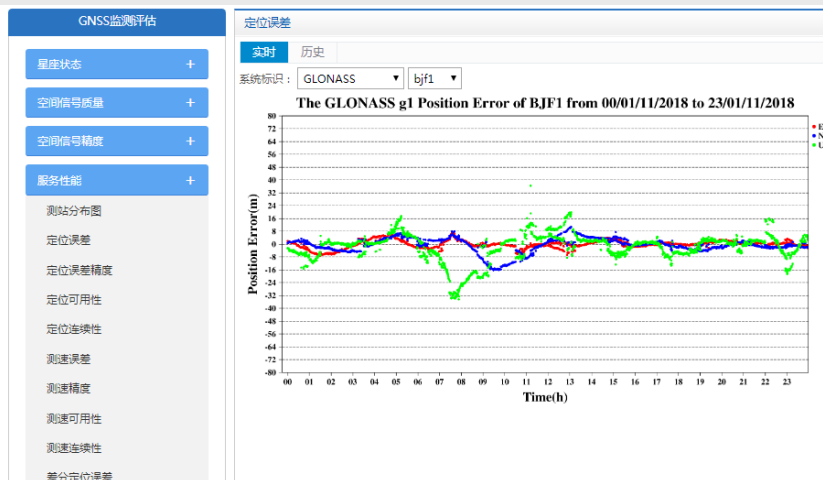
# Demonstration/Positioning



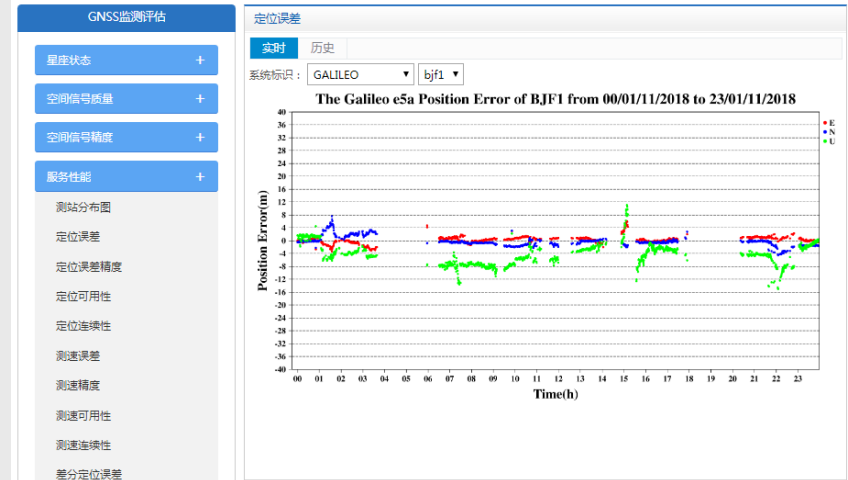
BDS



GPS

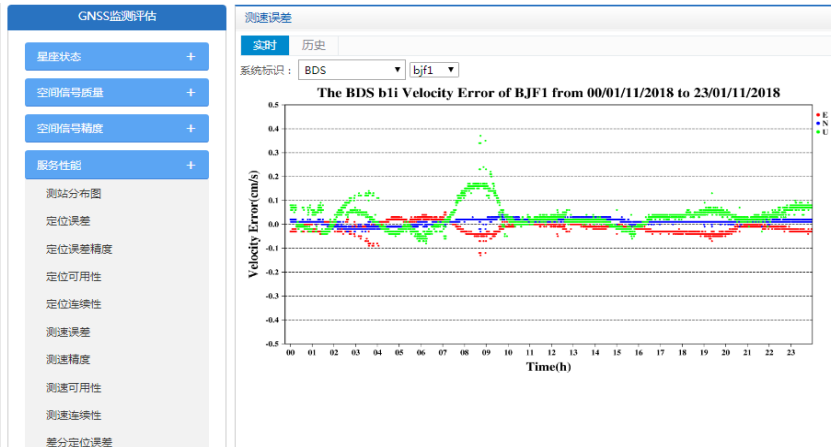


GLONASS

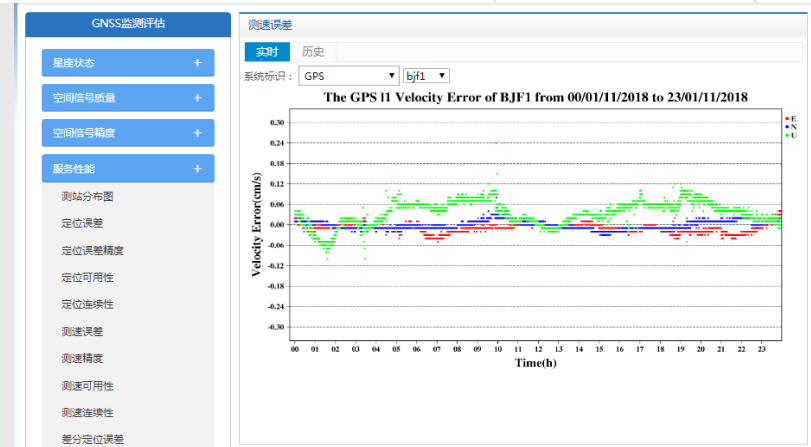


Galileo

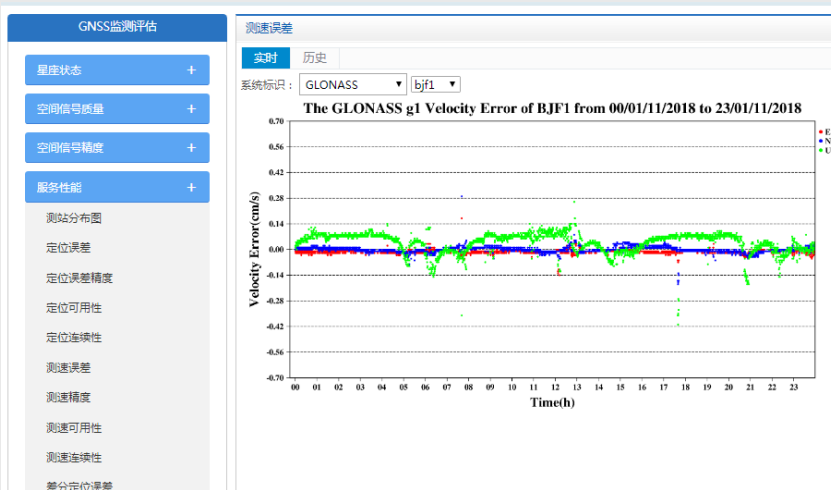
# Demonstration/Velocity



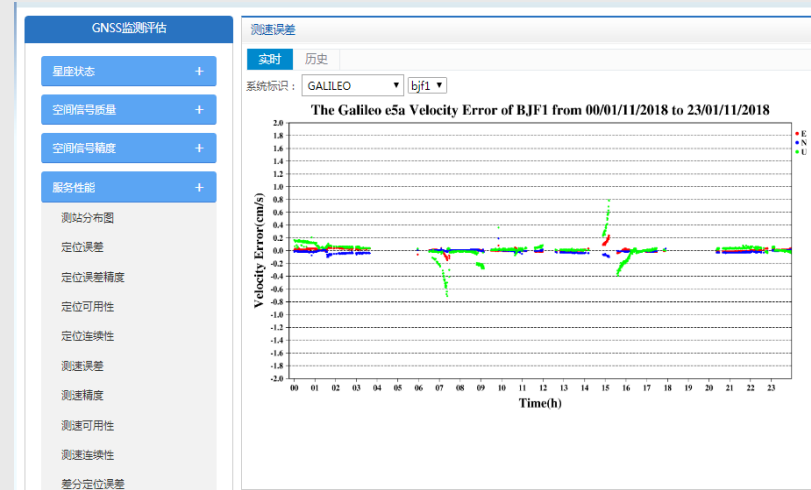
## BDS



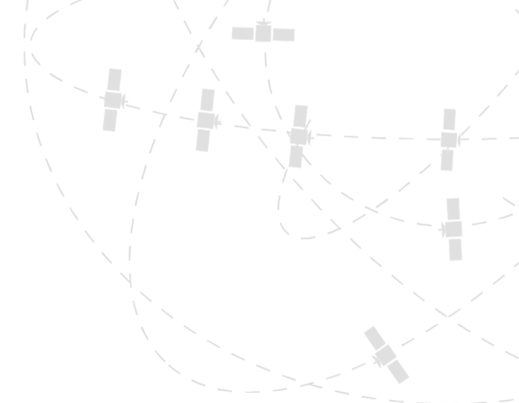
## GPS



## GLONASS



## Galileo



05

## Conclusion



## 1. Monitoring and Assessment parameters

The 4 types and 29 parameters are given on iGMAS.

## 2. Algorithm and Implementations

The algorithms of some parameters are given for implementations

## 3. Performance variation tendency

- The performance of GPS and GLONASS is stable during 2014 and 2018;
- The performance of BDS-2 and Galileo present obvious improvement since 2014.

## 4. Publishing

- Website
- Mobile Terminal(MT)

# THANK YOU!

13<sup>th</sup> Meeting of the International Committee on  
Global Navigation Satellite Systems

