Algorithms and Implementation of GNSS Monitoring and Assessment Parameters on iGMAS

13th Meeting of the International Committee on Global Navigation Satellite Systems

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2018-11-06

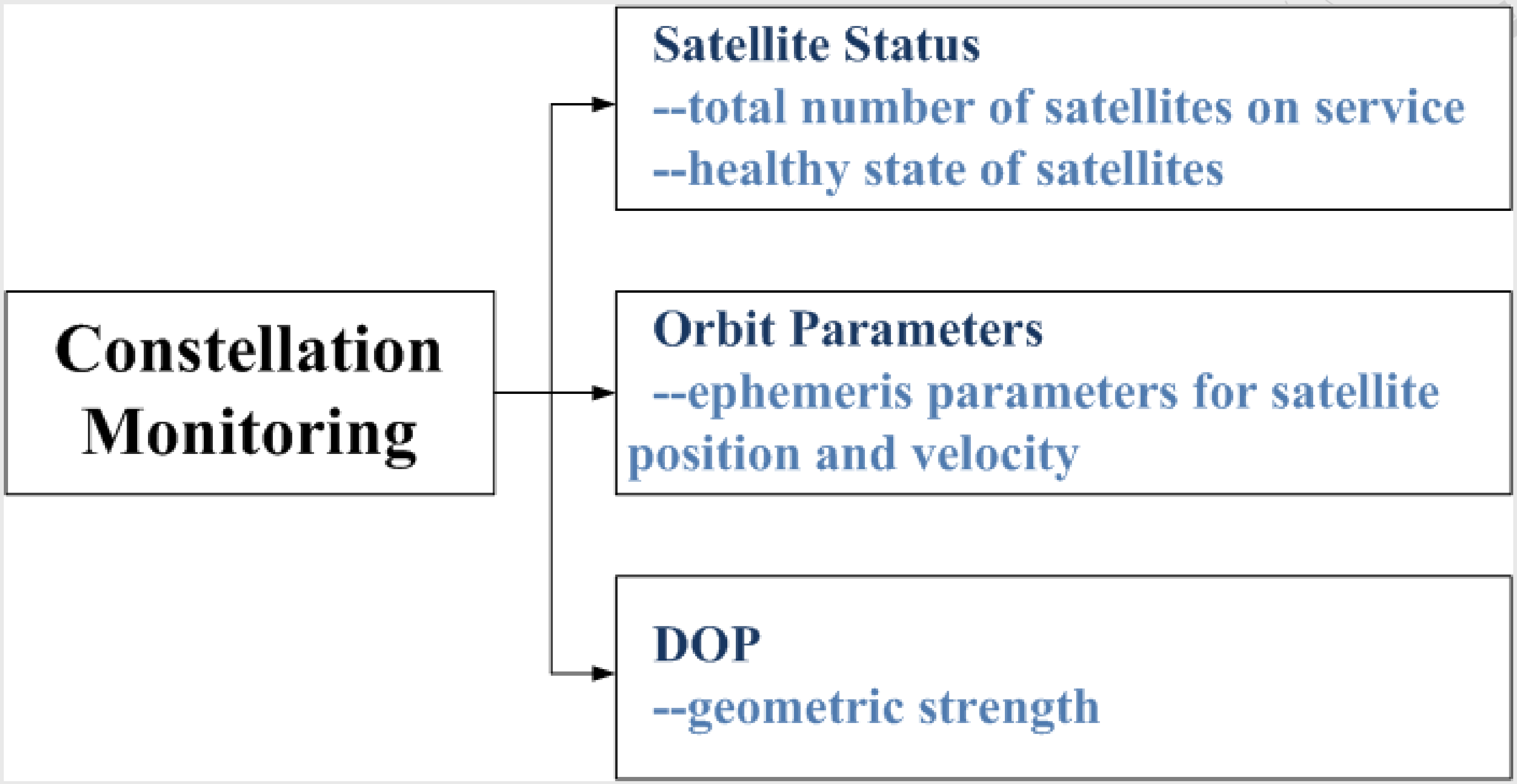
CONTENT

01

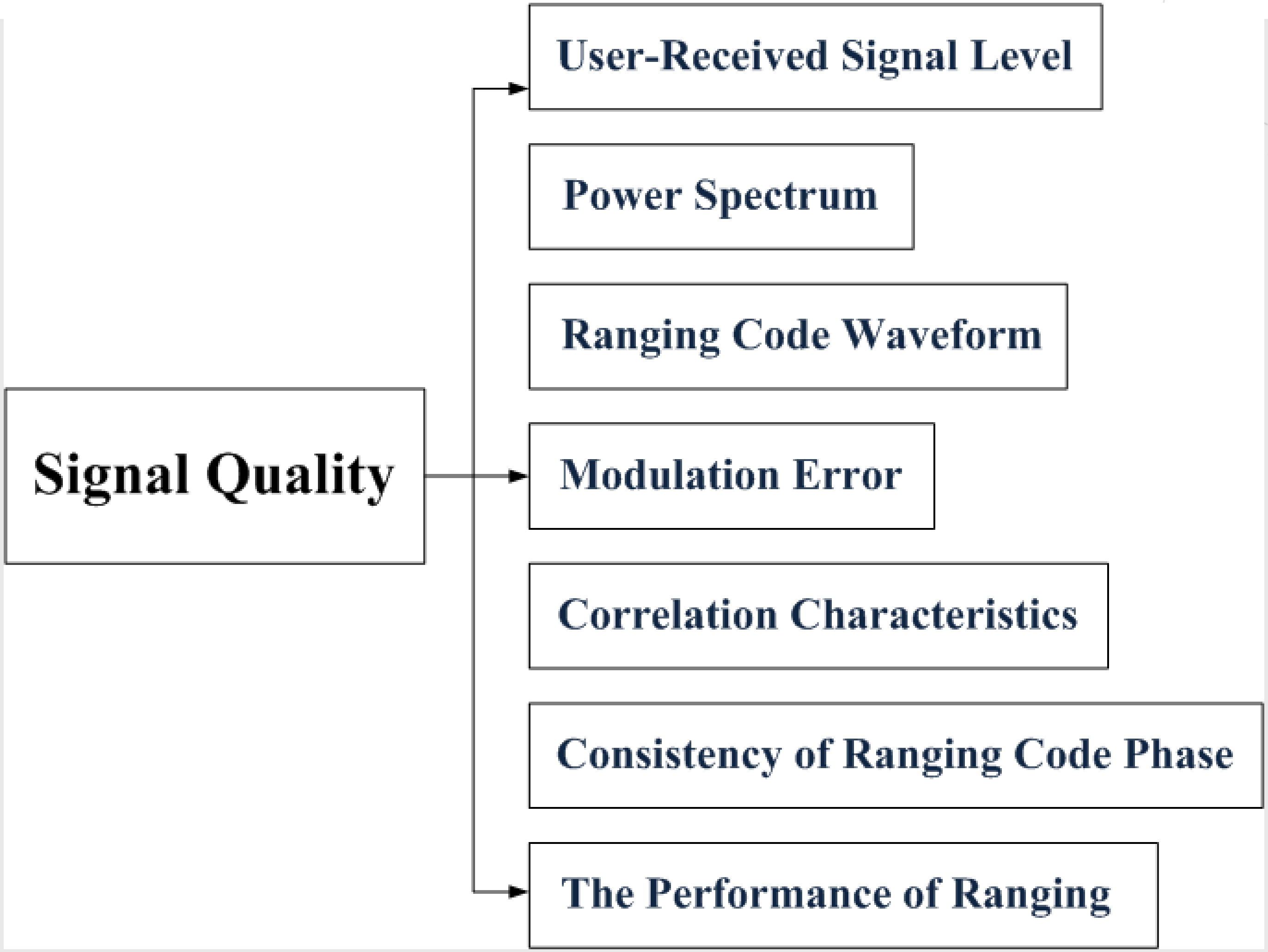
Monitoring and Assessment Parameters

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

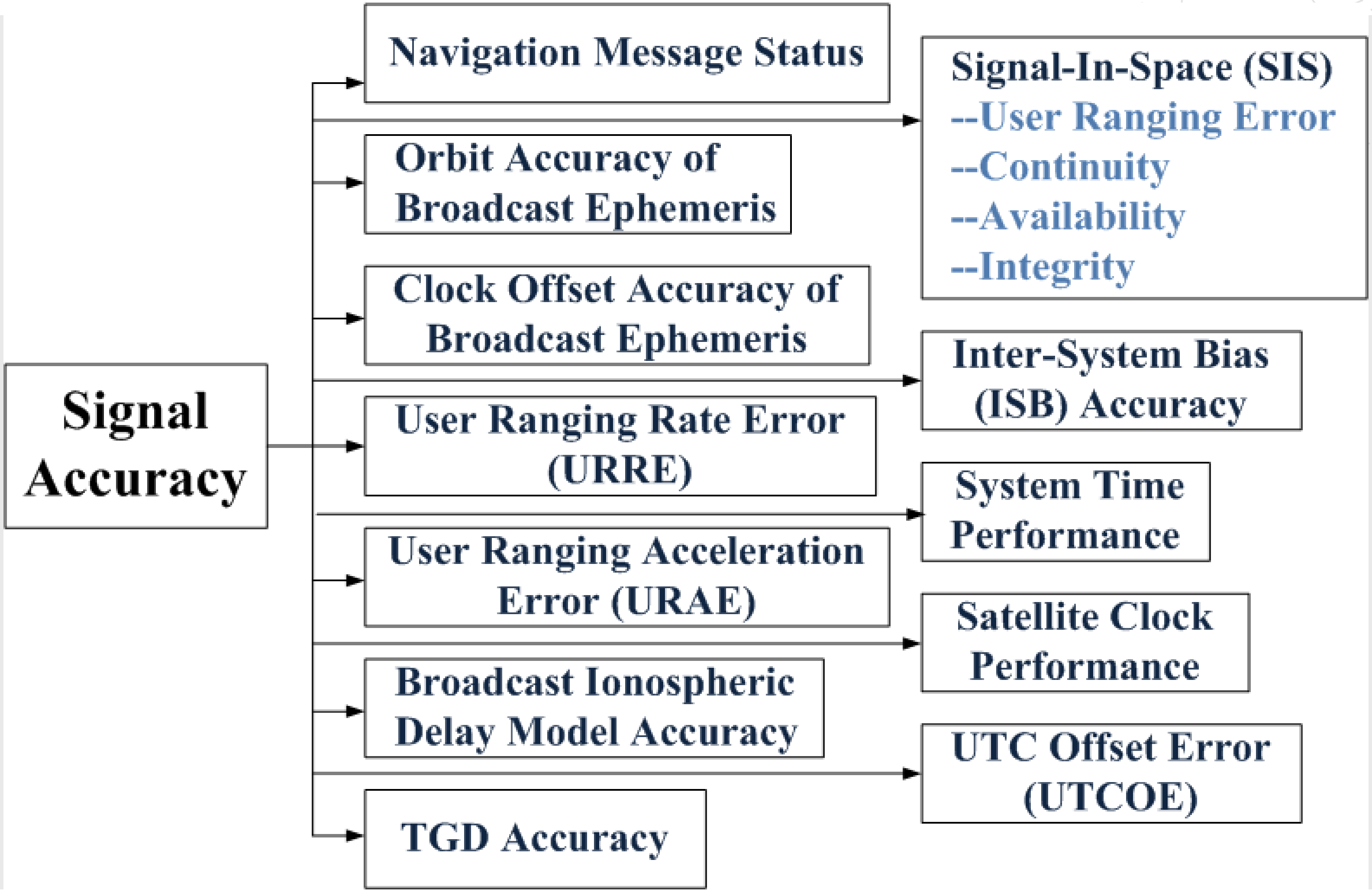
Monitoring and Assessment Parameters /Constellation Monitoring



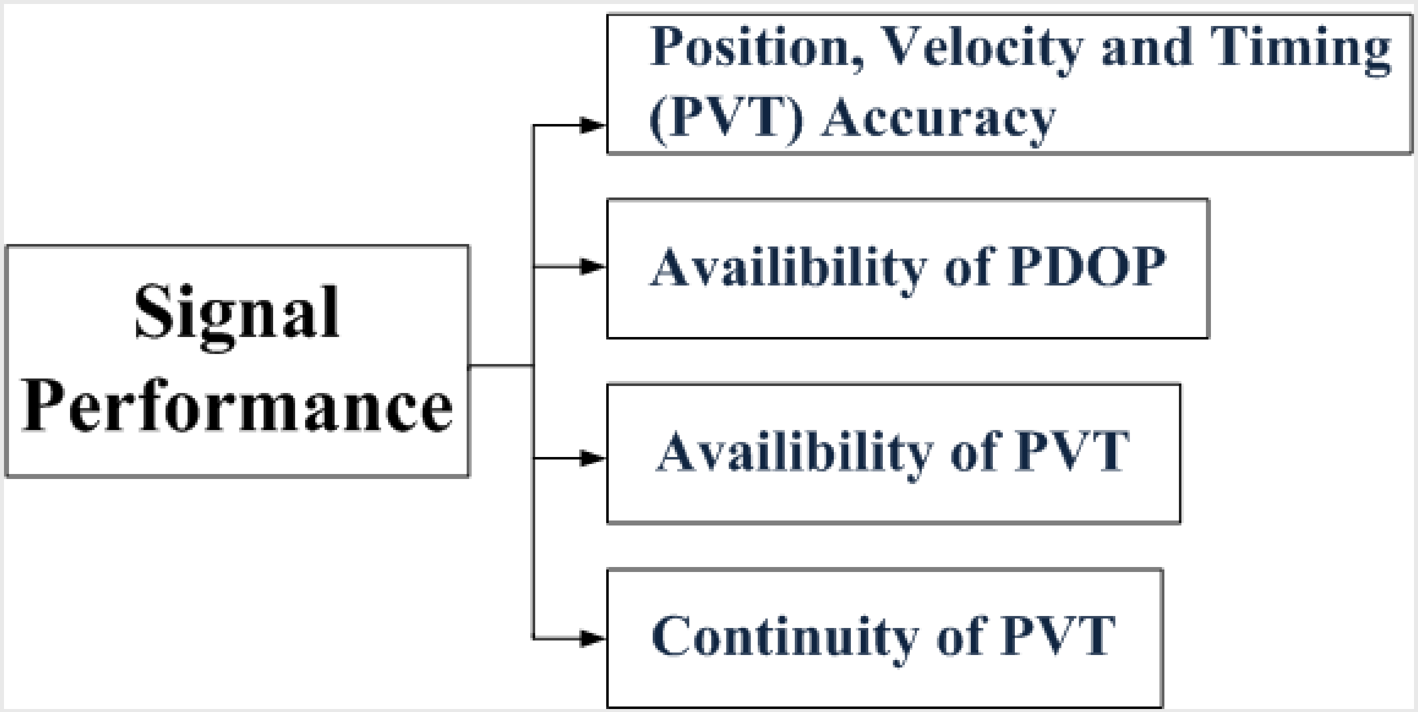
Monitoring and Assessment Parameters /Signal Quality



Monitoring and Assessment Parameters /Signal Accuracy



Monitoring and Assessment Parameters /Signal Performance



02

Algorithm

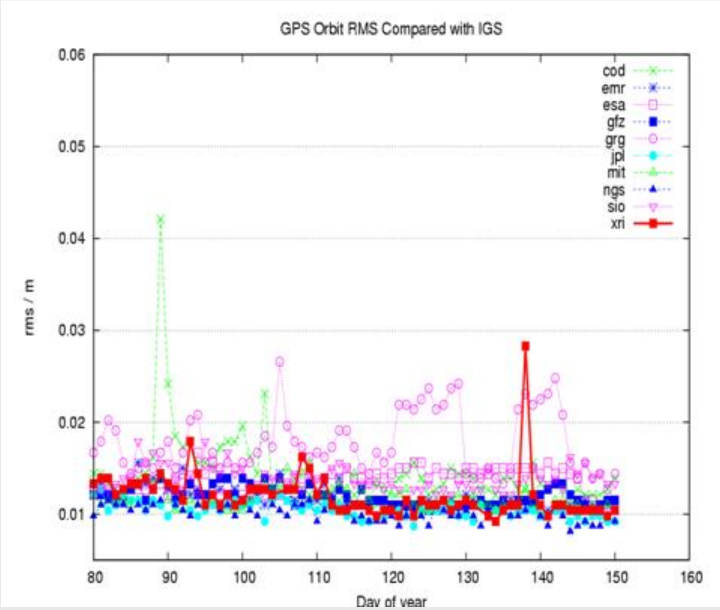
- Broadcast Ephemeris Accuracy
- SIS User Range Error

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:

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

$$R = rms(w_R \cdot \Delta r_R - c\Delta dt) \qquad A = rms\Delta r_A \qquad C = rms\Delta r_C$$

System(type)	W_R	$W^2_{A,C}$
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.

$$SISURE = \mathrm{rms}\left[\mathrm{w}_R^2 \cdot \Delta r_R^2 + \mathrm{w}_{A,C}^2 \cdot (\Delta r_R^2 + \Delta r_C^2) + (c\Delta dt)^2 \right] \qquad (2)$$

$$= \sqrt{\mathrm{w}_R^2 \cdot R^2 + \mathrm{w}_{A,C}^2 \cdot (A^2 + C^2) + T^2}$$

Where

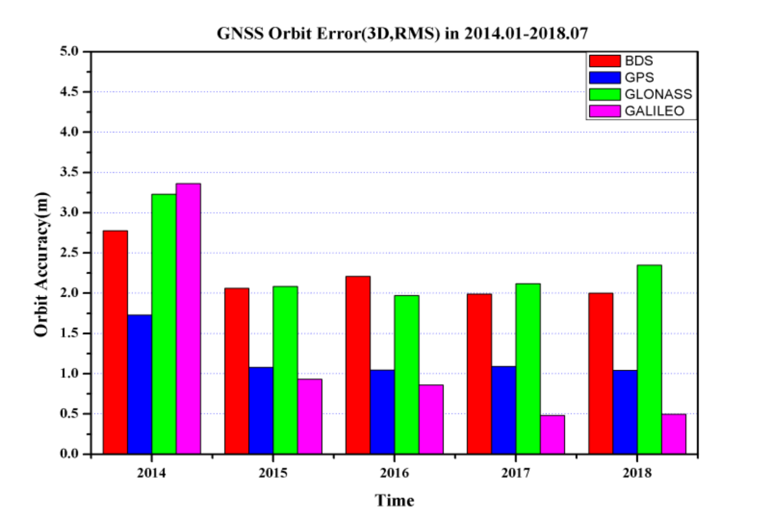
$$T = rms(c\Delta dt)$$

03

Results

- Performance variation tendency (2014~2018)

Performance variation tendency/ Broadcast Ephemeris Accuracy (Orbits)

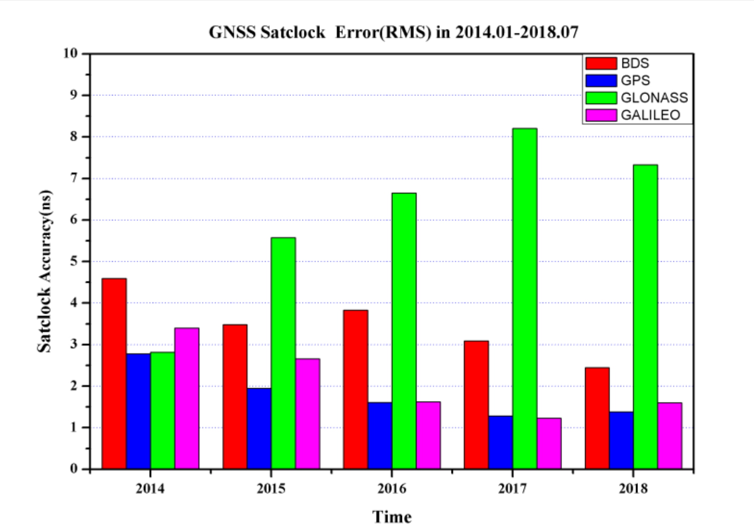


Year	BDS-2			GPS	GLONASS	Galileo
	GEO	IGSO	MEO			
2014	10.95	3.03	2.78	1.73	3.23	3.36
2015	7.82	2.27	2.06	1.08	2.09	0.93
2016	6.82	2.14	2.21	1.04	1.97	0.86
2017	5.63	2.20	1.99	1.09	2.12	0.48
2018	7.12	2.17	2.00	1.04	2.35	0.50
AVG	7.67	2.36	2.21	1.20	2.35	1.23

- **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.**

Results / Performance variation tendency

Performance variation tendency/ Broadcast Ephemeris Accuracy (Clocks)

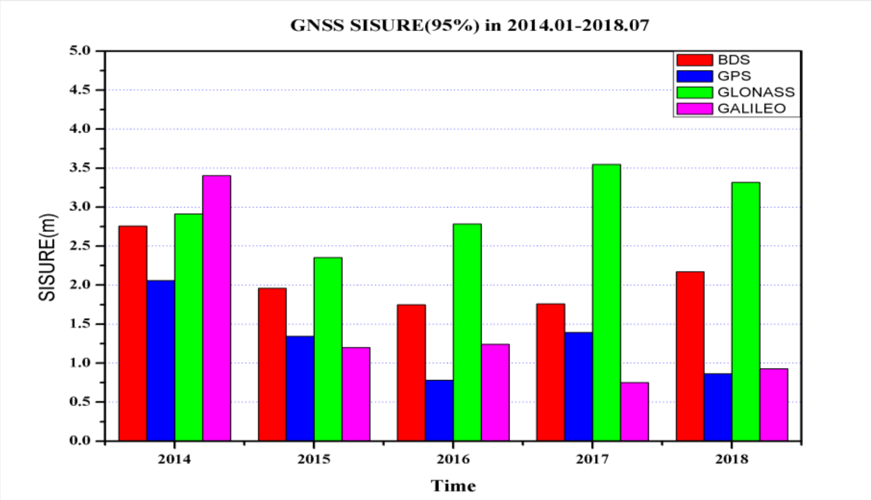


Year	BDS-2	GPS	GLONASS	Galileo
2014	4.59	2.78	2.81	3.40
2015	3.48	1.95	5.58	2.66
2016	3.83	1.61	6.65	1.62
2017	3.09	1.28	8.21	1.23
2018	2.45	1.38	7.33	1.60
AVG	3.49	1.80	6.12	2.10

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

Results / Performance variation tendency

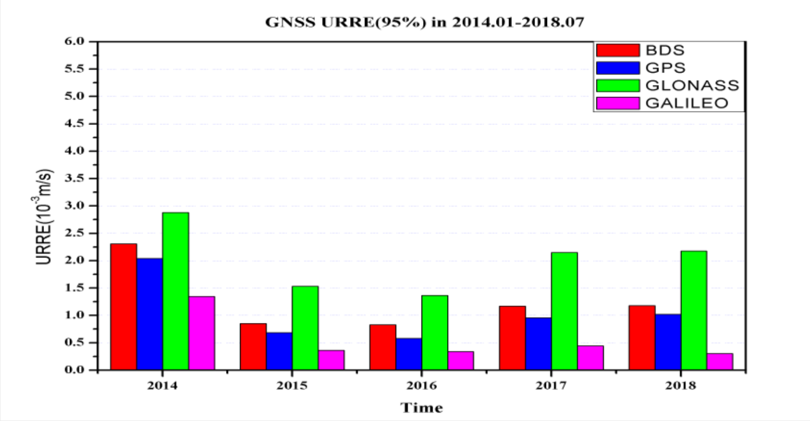
Performance variation tendency/ URE(95%)



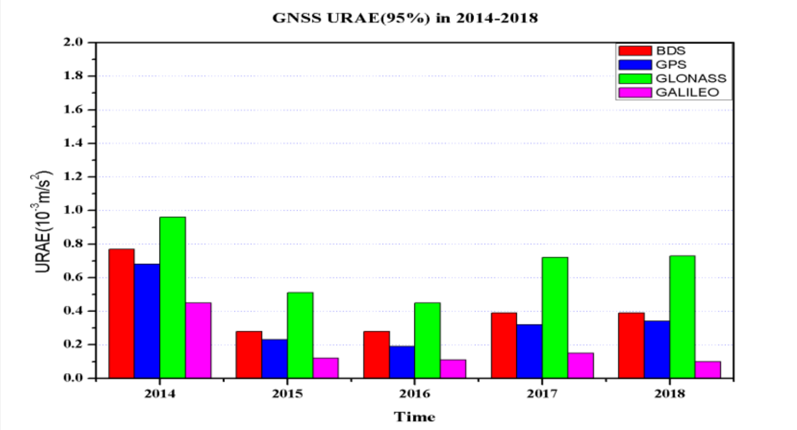
Year	BDS-2	GPS	GLONASS	Galileo
2014	2.76	2.06	2.91	3.40
2015	1.96	1.34	2.35	1.20
2016	1.75	0.78	2.78	1.24
2017	1.76	1.39	3.55	0.75
2018	2.17	0.86	3.32	0.93
AVG	2.08	1.29	2.98	1.50

- **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

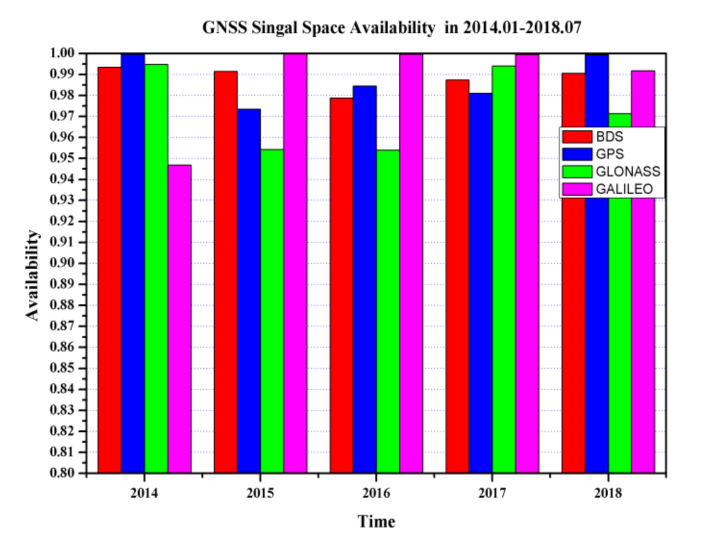


URAE

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

Results / Performance variation tendency

Performance variation tendency/ SIS Availability

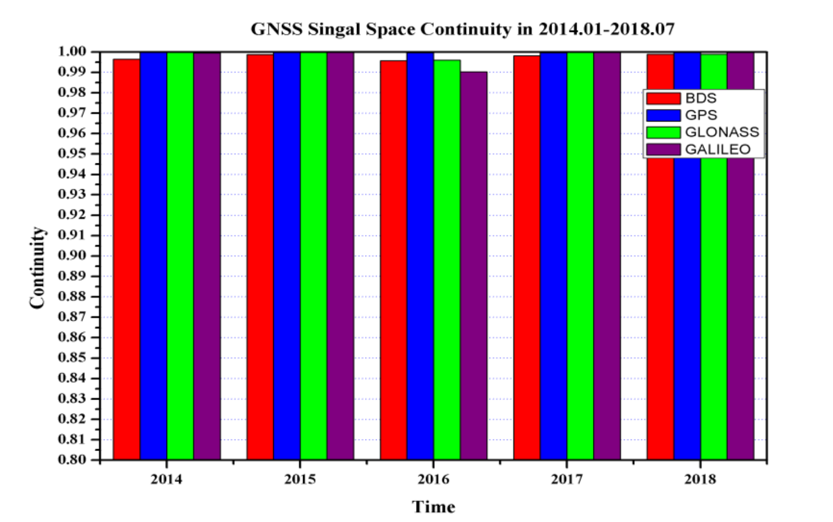


Year	BDS-2	GPS	GLONASS	Galileo
2014	0.993	0.999	0.995	0.947
2015	0.991	0.973	0.954	1.000
2016	0.979	0.984	0.954	1.000
2017	0.987	0.981	0.994	0.999
2018	0.991	0.999	0.971	0.992
AVG	0.988	0.988	0.974	0.988

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



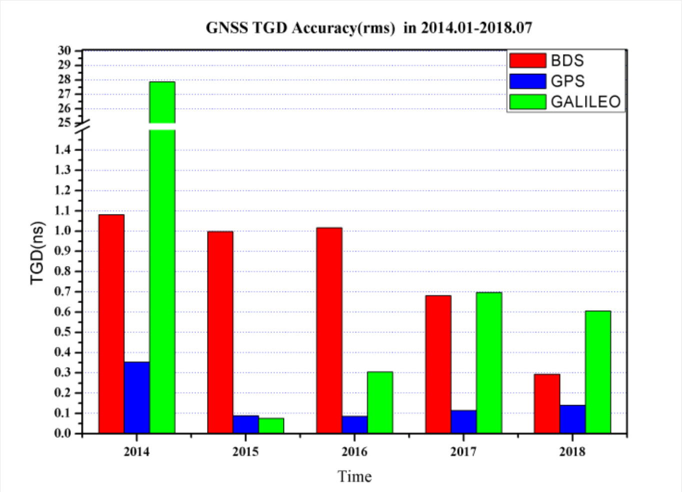
SIS Continuity

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

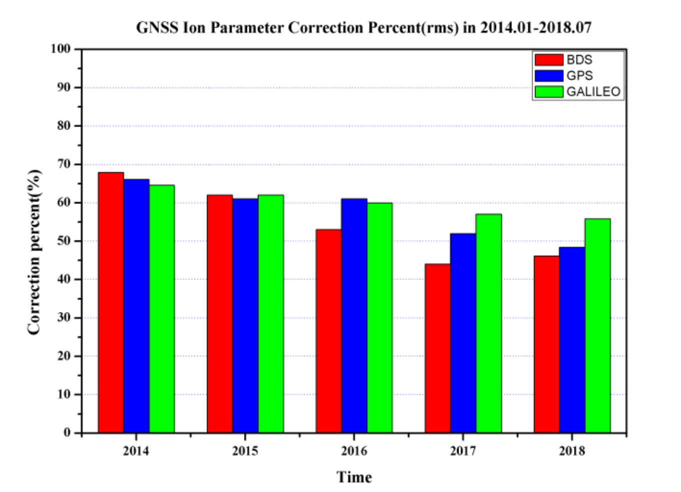
- **For the 4 systems, the average SIS Continuity from 2014 to 2018 is better than 0.998.**

Results / Performance variation tendency

Performance variation tendency/ TGD/ION



GNSS TGD Accuracy

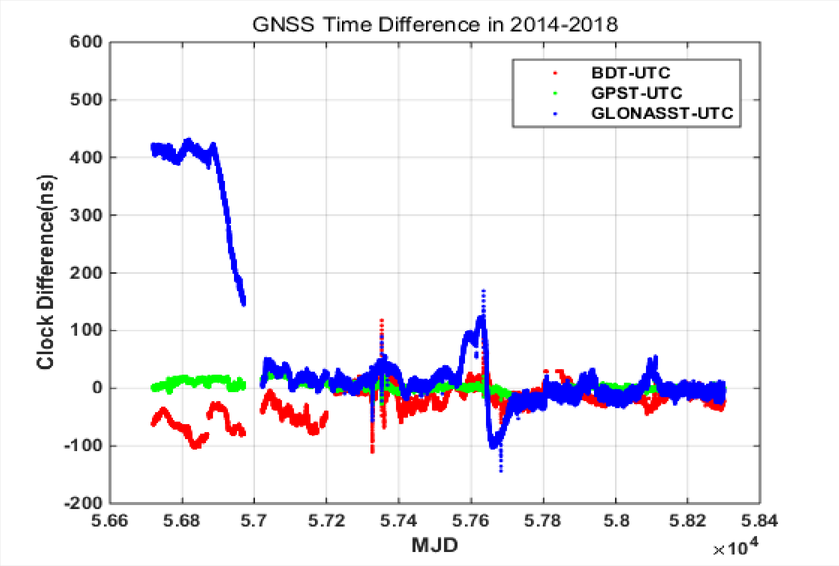


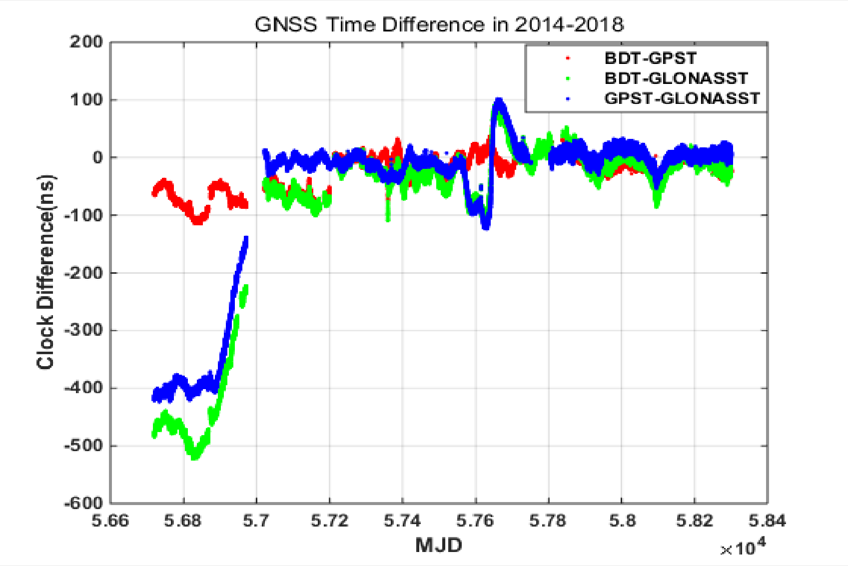
GNSS ION Correction

- **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





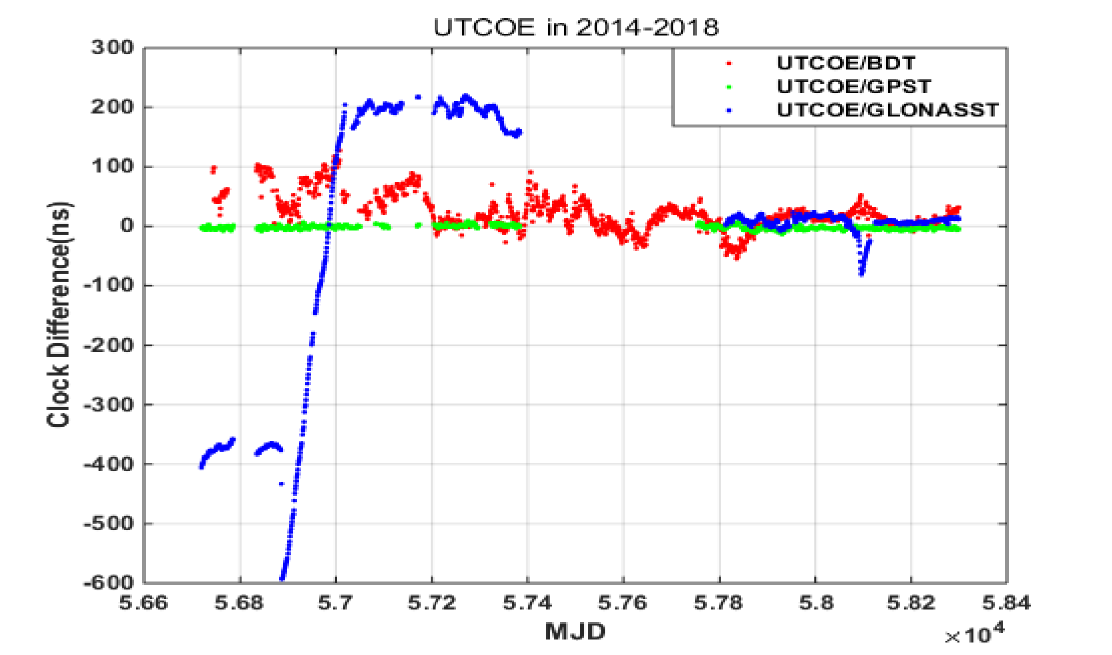
GNSST-UTC(NTSC)

Inter-System

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

Results / Performance variation tendency

Performance variation tendency/ UTCOE



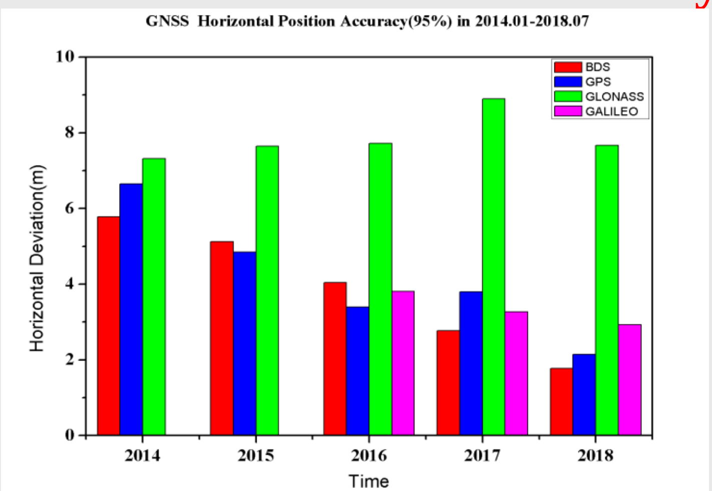
UTCOE

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

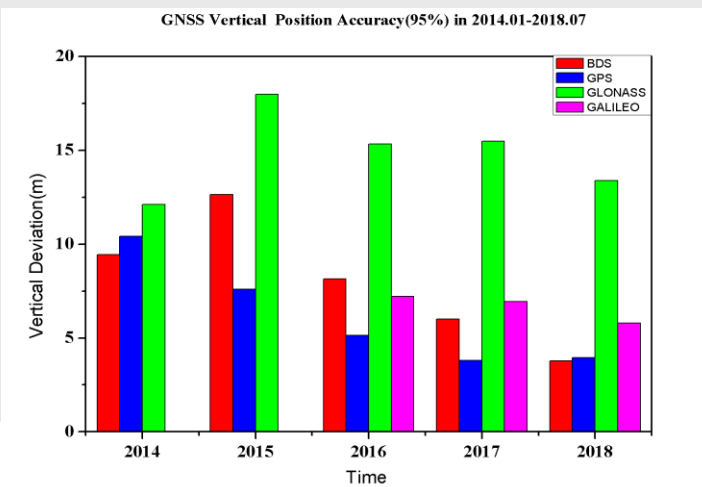
Results / Performance variation tendency

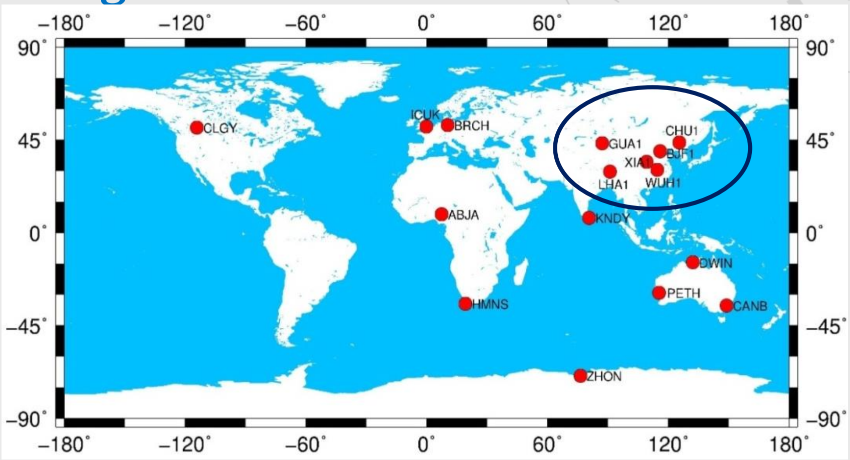
Performance variation tendency/ Positioning

Horizontal



Vertical



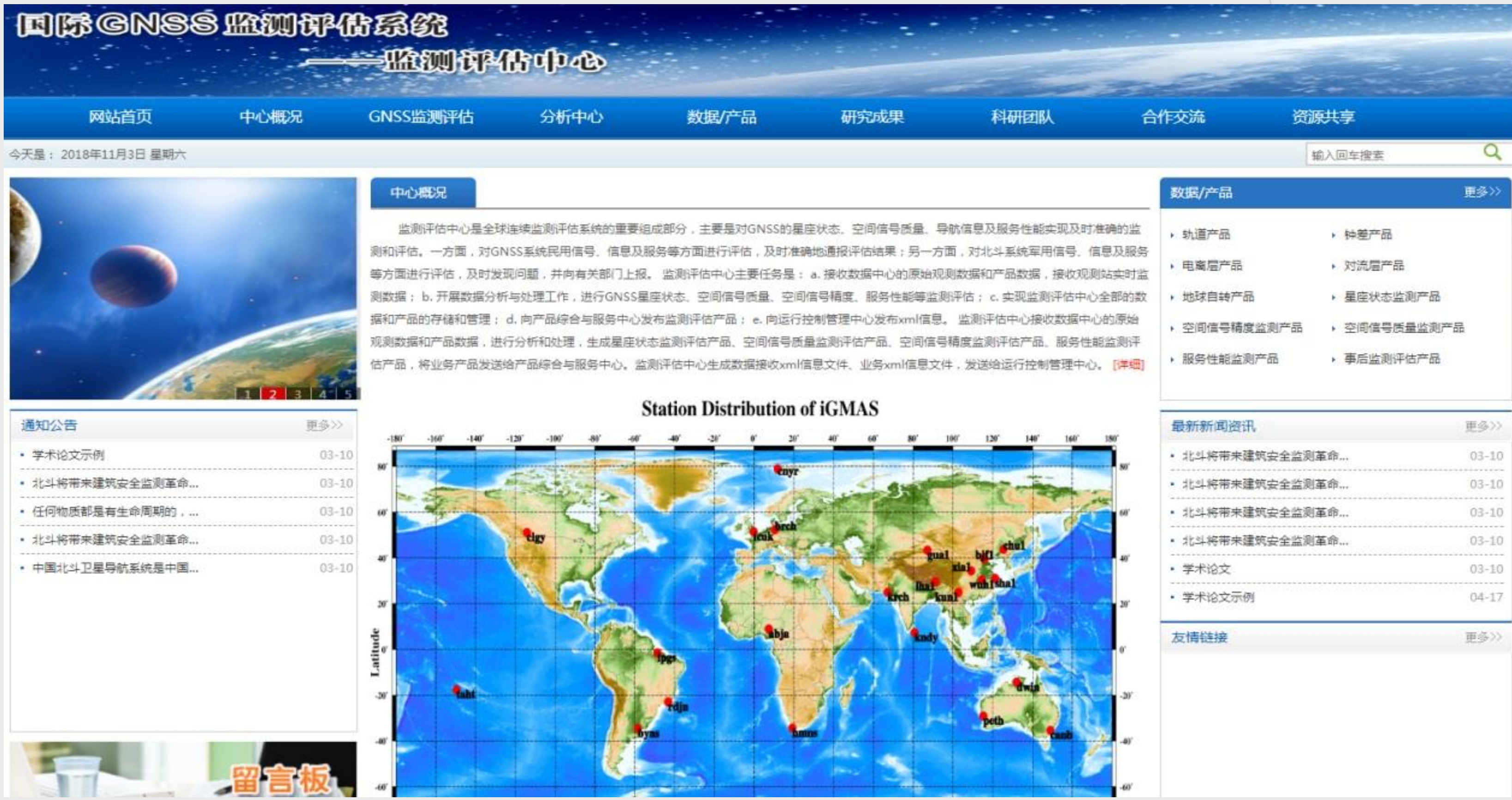


- The availability percentage of Galileo is about 20%-60% from 2016;
- The positioning accuracy of GPS and GLONASS is stable during 2014 and 2018;
- The positioning accuracy of BDS-2 shows obvious improvement since 2014.

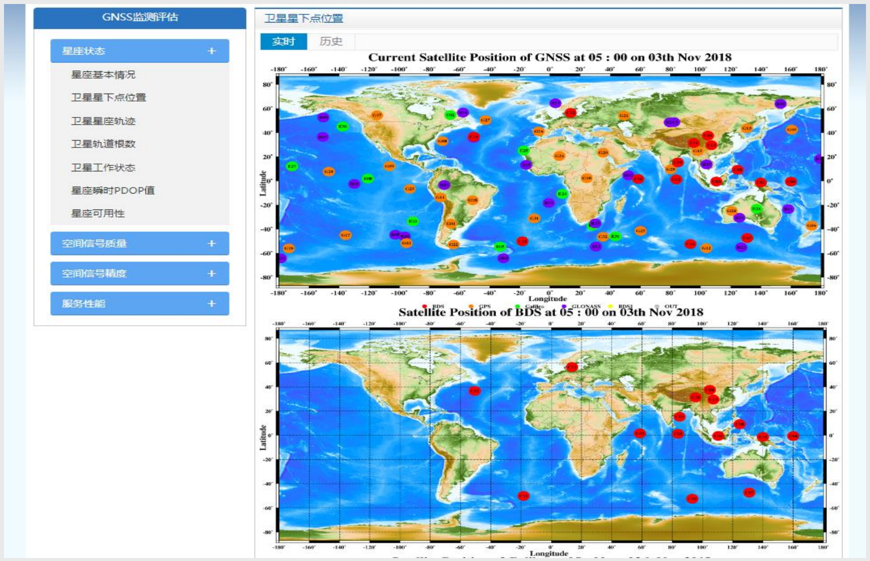
04

Demonstration

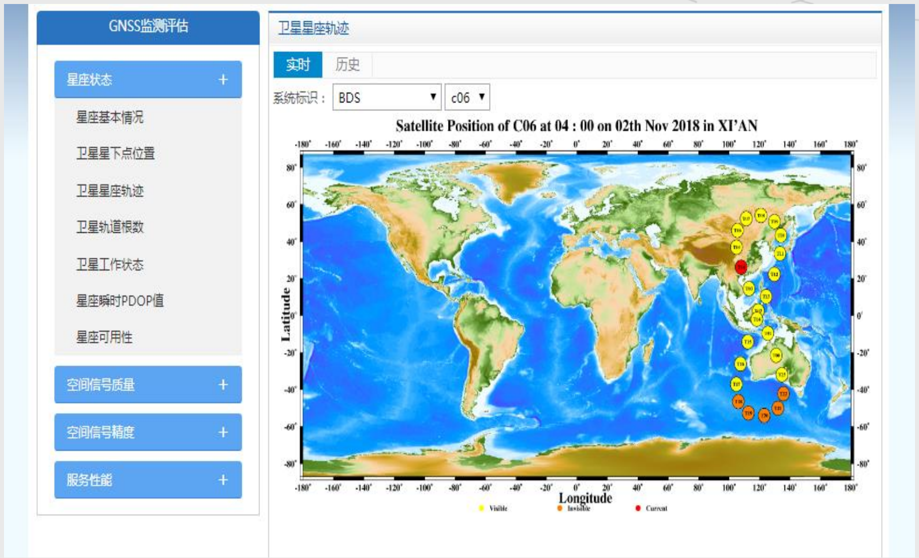
Demonstration/Home page



Demonstration/Ground tracks of satellites

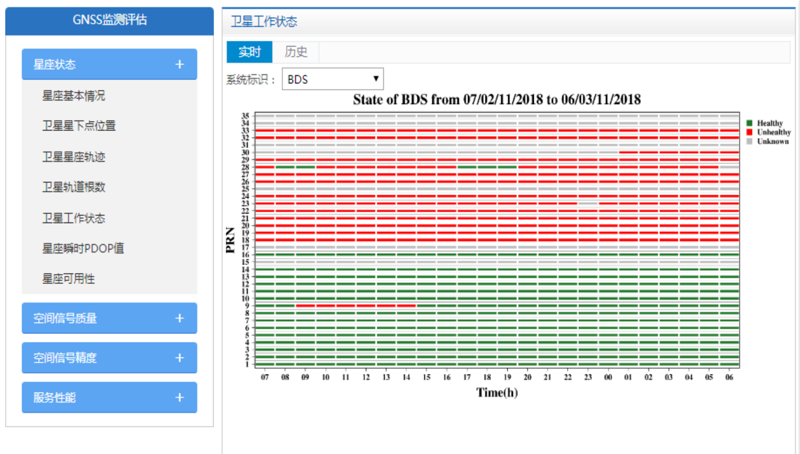


Instantaneous position of GNSS

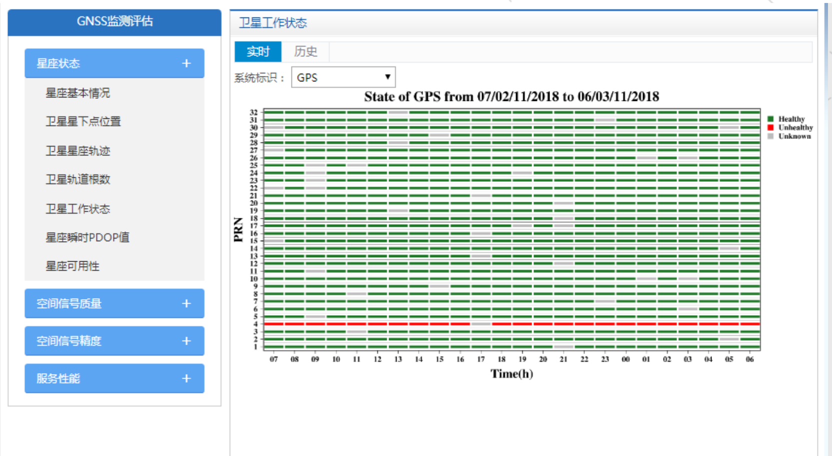


Track of BDS-2 C06

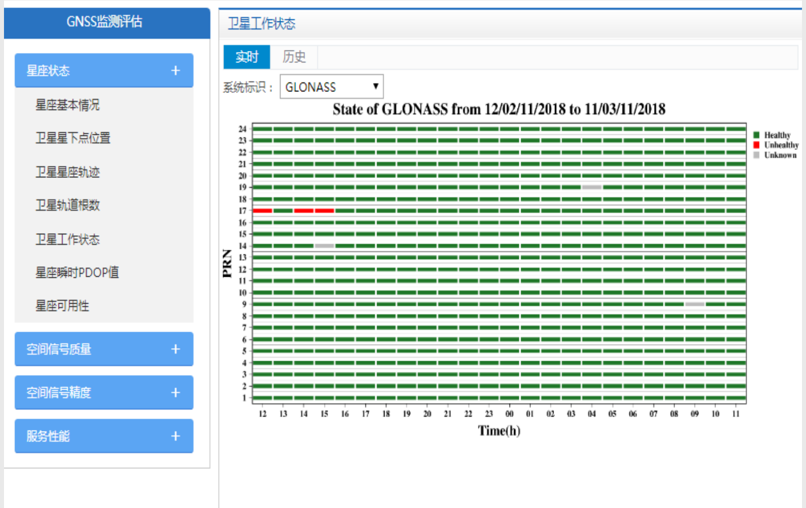
Demonstration/Single satellite working status



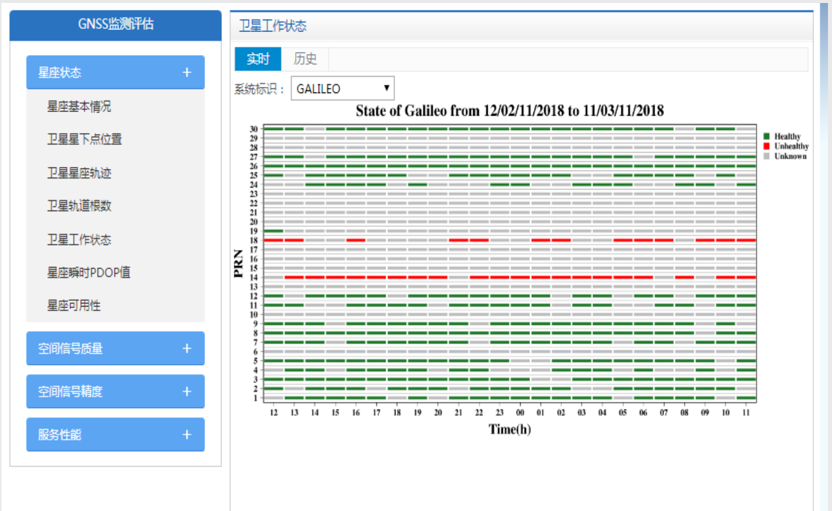
BDS



GPS

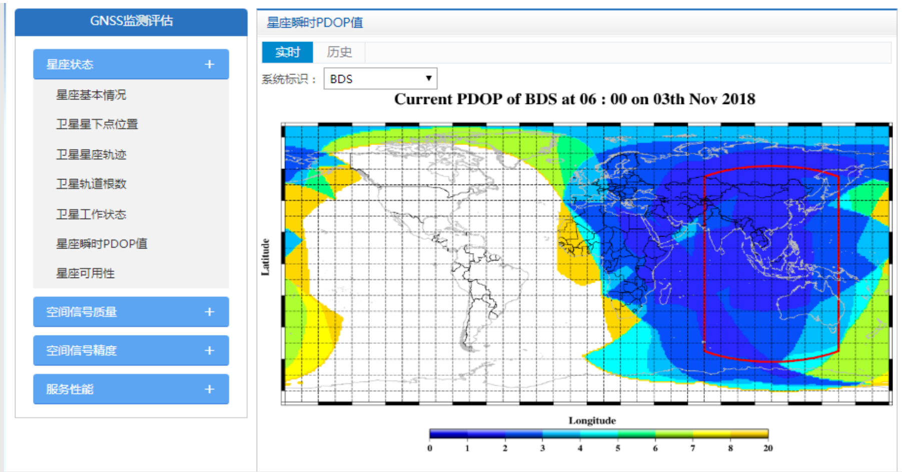


GLONASS

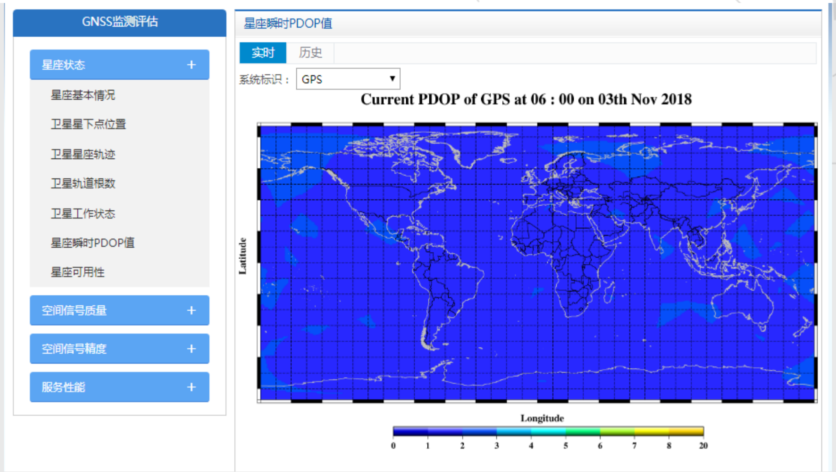


Galileo

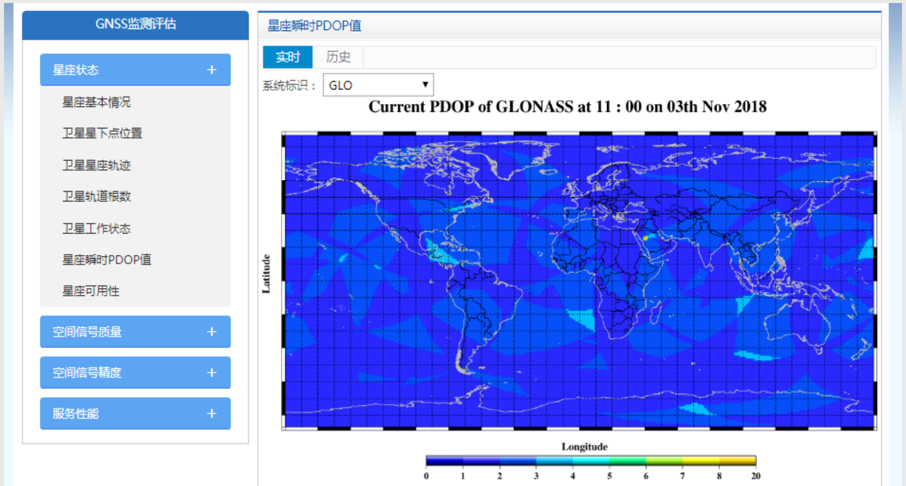
Demonstration/PDOP



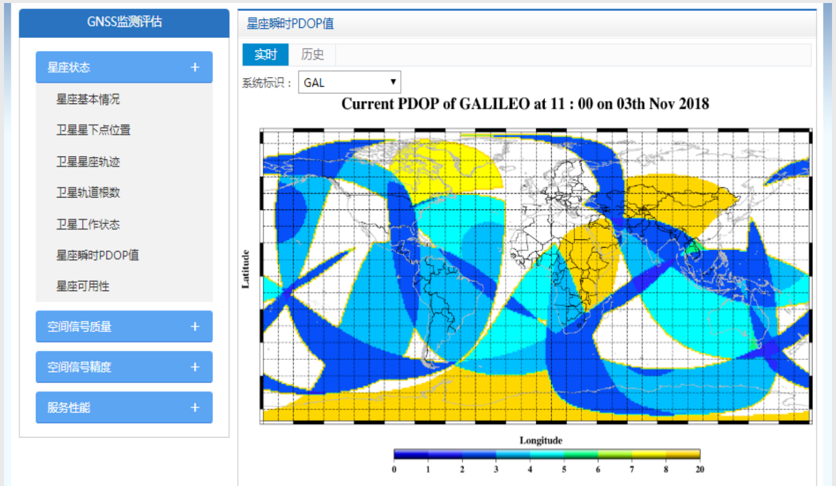
PDOP of BDS-2



PDOP of GPS

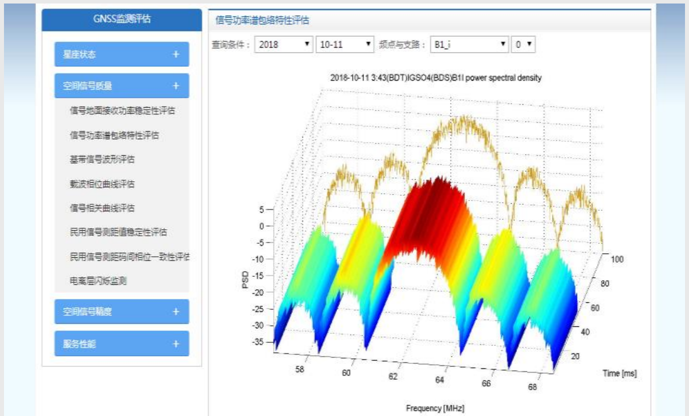


PDOP of GLONASS

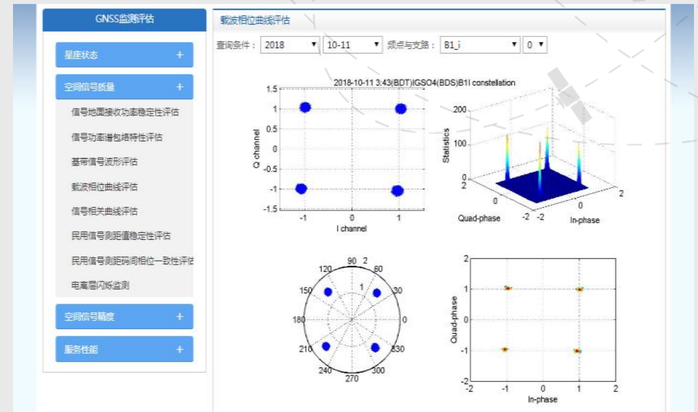


PDOP of Galileo

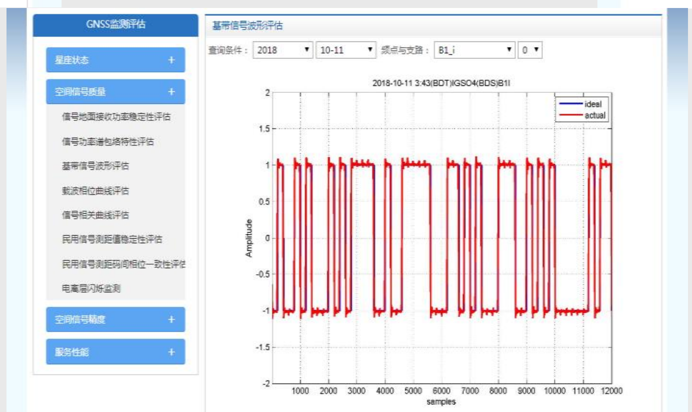
Demonstration/**Signal Quality**



Power spectral density

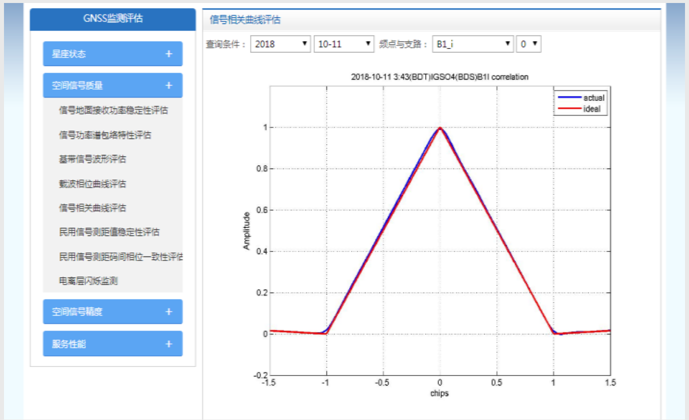


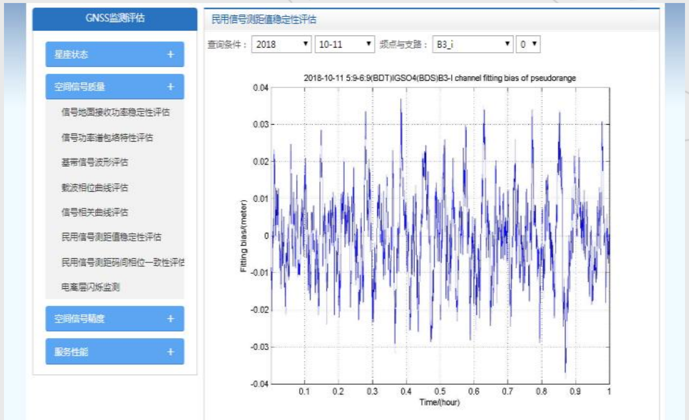
Modulation error



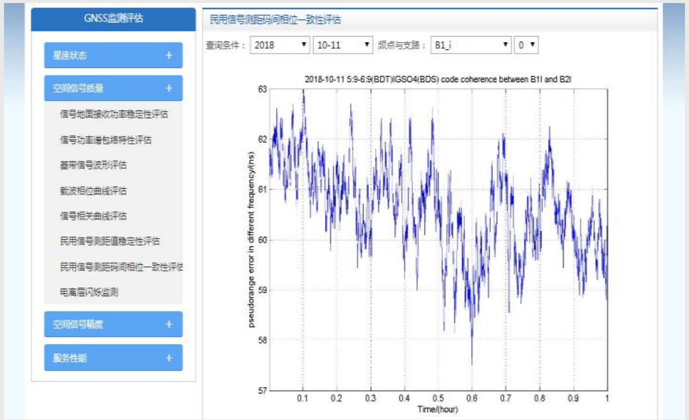
Ranging code waveform

Demonstration/**Signal Quality**





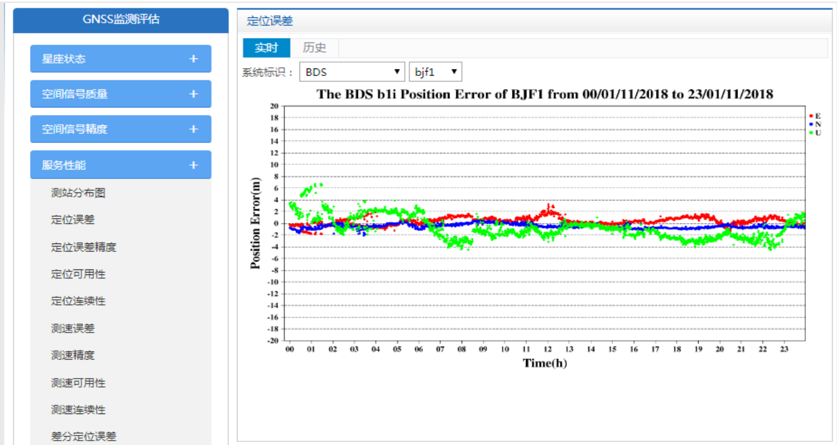
Correlation characteristics



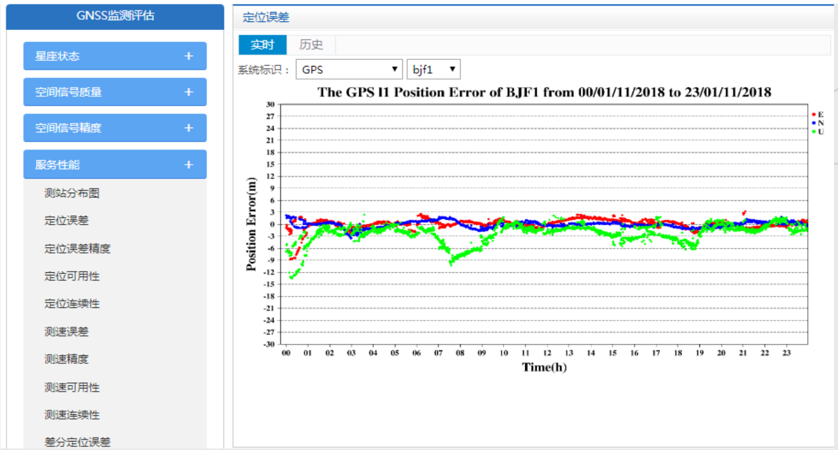
The Performance of Ranging

Consistency of Ranging Code Phase

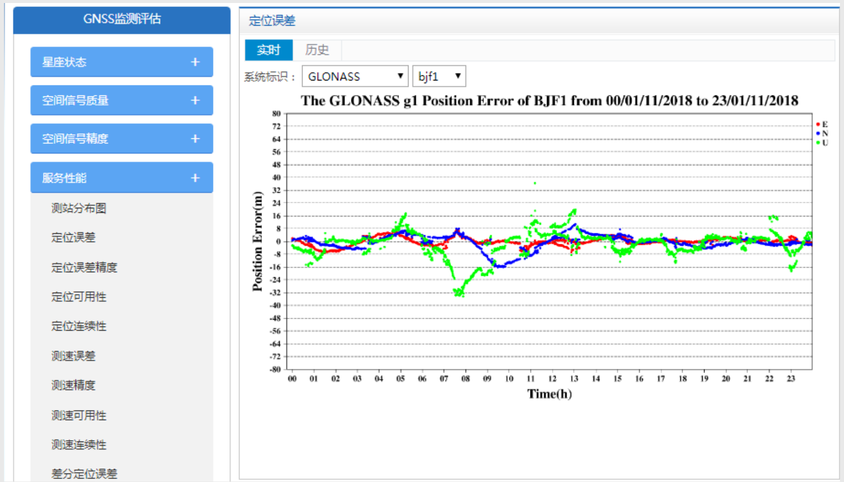
Demonstration/Positioning



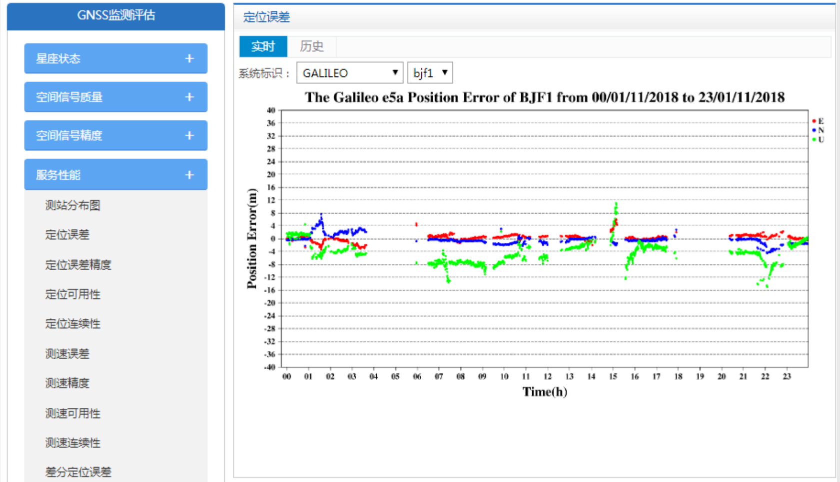
BDS



GPS

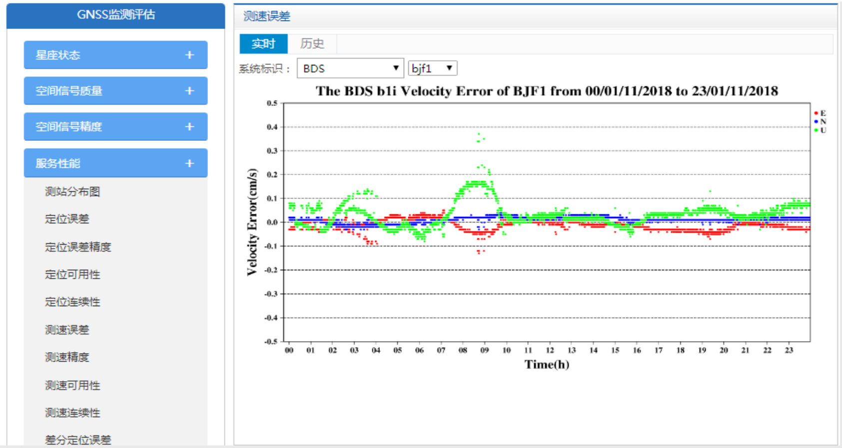


GLONASS

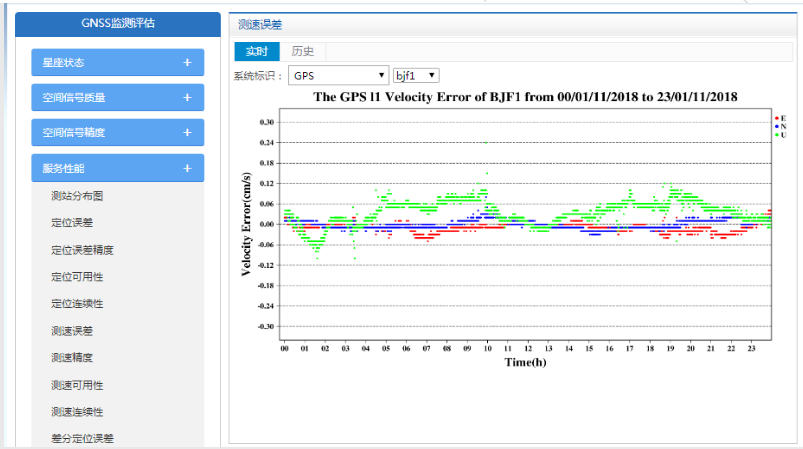


Galileo

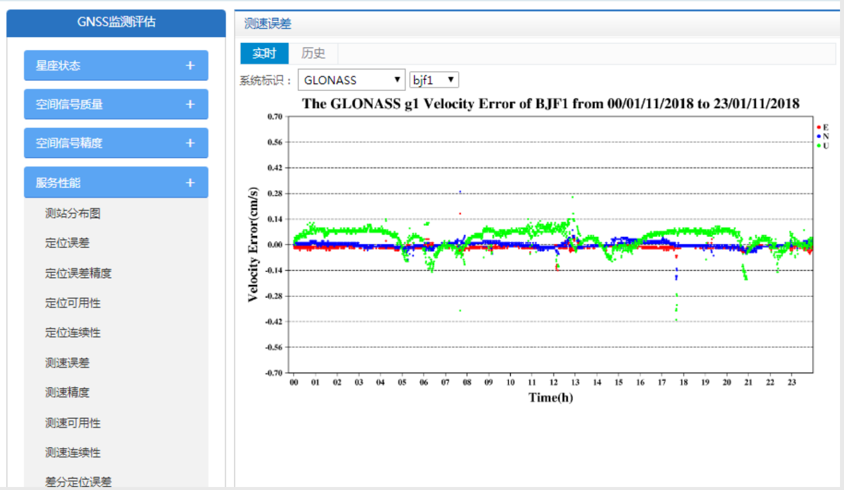
Demonstration/Velocity



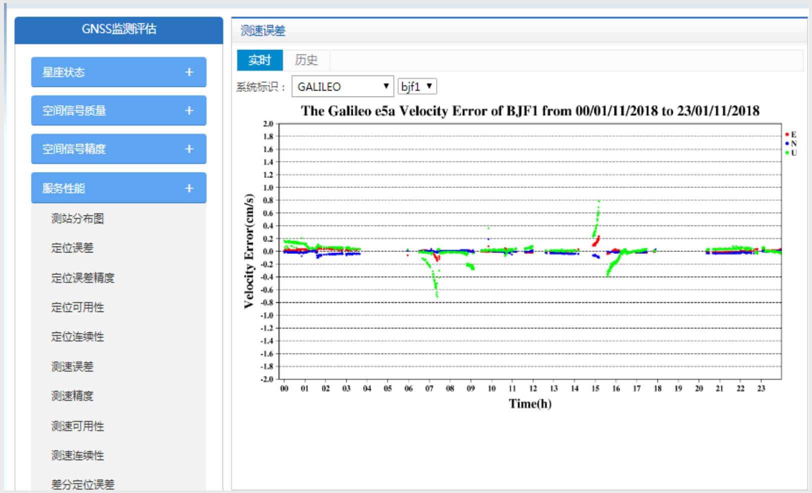
BDS



GPS



GLONASS



Galileo

05

Conclusion

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!

13th Meeting of the International Committee on Global Navigation Satellite Systems