Update of international GNSS Monitoring and Assessment System (iIGMAS)

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1. Background

- More navigation systems will provide services for users. The multi-GNSS era is coming.

- To ensure the GNSS service quality, realize the interoperation of OS signals, it is desirable to carry out GNSS monitoring and assessment.

- In June 2011, at Vienna ICG conference, the international GNSS Monitoring and Assessment services was proposed.
1. Background

- At 2011 ICG-6 in Tokyo, the decision was adopted to carry out the GNSS open services monitoring and assessment.
- The subgroup on International GNSS Monitoring and Assessment (IGMA) was formed at ICG-6.
1. Background

Several GNSS monitoring activities are under way,

- the long-term successful operation of IGS.
- The achievements in GNSS signal monitoring by Stanford University, DLR, IAC, MGA and others.
- Preliminary experience of GSC and future GRC
- For the realization and promotion of IGMA proposal, iGMAS has obtained great achievements led by China.
1. Background

2. iGMAS

3. Monitoring Results

4. Summary
2.1 Objective of iGMAS

Objective & tasks:

- **To promote** the sharing of global monitoring resource and provide better GNSS service for users.
- **To study** the related standards, the sharing mode of resources.
- **To develop** basic products as well as monitoring and assessment information.
- **To provide** service for monitoring and assessment, scientific research and various applications effectively.
2.2 iGMAS Construction

Architecture of iGMAS

- **3 Data Centers**: Wuhan, Xi’an, Changsha

- **7 Analysis Centers**: Analysis Center is responsible for the depth processing of the original observation, the formation of high-precision products, and provides products to Product Synthesis and Service Center.

- **30 Tracking Stations**: Orbit, Track station coordinates, Clock, ERP, Inter-frequency bias, Ionosphere simulation data, Ionosphere products, High-precision products

- **1 Monitoring and Evaluation Center**: Monitoring the operation status of the international GNSS monitoring and evaluation system, and issuing the instruction information according to the running state.

- **1 Operations Control and Management Center**: GNSS Builders, GNSS Operators, GNSS Users

- **Core Tasks**: To analyze the quality of the analysis center products, weighted process the results, form the final integrated products.

- **External services**: Releasing integrated products, monitoring and evaluation information, backup of products.

- **Product Synthesis and Service Center**: Original data, Basic data, Releasing integrated products, Monitoring products, Control instruction.


Milestones

- Sep. 2007, idea of iGMAS;
- Aug. 2010, requirements analysis and project approachment;
- Dec. 2012, iGMAS project approval;
- Jul. 2014, start of trial running and service.
- Jul. 2016, Most construction has been finished, open routine service started.
2.4 Development of iGMAS

(1) Tracking stations

Up to the Sept. 2016, 18 tracking stations have been built: 8 in China, 2 in polar regions, 8 abroad stations.
2.4 Development of iGMAS

(1) Tracking stations

Beijing  Shanghai  Wuhan  Kunming  Zhongshan station  Pakistan  Brazil  Germany

Xi’an  Lhasa  Changchun  Urumqi  Yellow River station  Canada  Argentina  Tahiti

South Africa  Nigeria
2.4 Development of iGMAS

(2) Data Center

- NUDT
- WHU
- NTSC
2.4 Development of iGMAS

(3) Analysis Center

- Wuhan University
- Shanghai Astronomical Observatory
- Xi’an Satellite Control Center
- Chang’an University
- Space Information Relay and Transmission Technology Research Center
- Institute of Geodesy and Geophysics
- Chinese Academy of Surveying & Mapping

Information Engineering University
Xian Institute of Surveying and Mapping
China University of Mining and Technology
Beijing Aerospace Control Center
National Time Service Center, CAS
……
2.4 Development of iGMAS

(4) Monitoring Analysis Center

Xi’an Institute of Surveying and Mapping

Monitoring Hall

Computer room

National Time Service Center

40 meter Antenna for signal monitoring

Radio Frequency signal monitoring equipments
2.4 Development of iGMAS

(5) Product Integration and Service Center

Product Integration Process

Website
2.4 Development of iGMAS

- (6) Operational Control and Management Center

System Monitor software

Operation information management system
2.5 Basic Service

(1) Original observations and Basic Products

- Orbit
- Clock
- Inter-frequency Biases
- Ionosphere
- Troposphere
- Ionospheric scintillation index
- Earth rotation parameters
- Geocentric coordinates of tracking station

Final: GNSS satellite related products
Rapid: Atmospheric Environment related products
Ultra-rapid: Tracking station related products
Real time:
2.5 Basic Service

(2) Monitoring and assessment information

Monitoring and Assessment Parameters

Constellation Status
- Single satellite work status
- Orbital parameters
- Constellation DOP

Navigation signal
- User-Received Signal Level
- Envelop Characteristic of Power Spectral Density
- Baseband Signal Waveform in Time Domain
- Sigal-In-Space Orthogonality Characteristics
- Sigal-In-Space Correlation Characteristics
- Ranging Stability
- Relative phase consistency between two ranging codes

Navigation Information
- Navigation message status
- Broadcast Clock Offset Accuracy
- Sigal-In-Space Signal Integrity
- Sigal-In-Space Availability
- User Ranging Acceleration Error (URAE)
- Coordinated Universal Time offset error (UTCOE)
- System Time Performance
- Satellite Clock Performance

Service Performance
- Broadcast Orbit Accuracy
- Sigal-In-Space User Ranging Error (SIS URE)
- Sigal-In-Space Continuity
- User Ranging Rate Error (URRE)
- Broadcast Ionosphere delay model accuracy
- TGD accuracy
- GNSS System Time Deviation

Positioning, Velocity and Timing (PVT) Accuracy
- PVT Continuity
- PVT Availability

IGMA-IGS Trial Project
3.1 Constellation Status

(1) Visible Satellite number

BDS

GPS

GLONASS

Galileo

30th June 2016
3.1 Constellation Status

(2) Healthy of Satellite

(\textcolor{blue}{blue:healthy}, \textcolor{red}{red:unhealthy}, 2016, doy1–181)

BDS

GPS

GLONASS

Galileo
3.2 Navigation Signal Quality

(1) Signal power envelope

BDS IGSO4-B1(2016-06-24)

GPS BIIRM-1-L1(2016-06-24)

GLONASS COSMOS-G1(2016-06-24)

Galileo GSAT0102-E1
3.2 Navigation Signal Quality

(2) Signal Correlation

- **BeiDou-03-B1Cp** (CL = -0.027715 dB)
- **GPS-03-L1CA** (CL = 0.19086 dB)
- **GLONASS-G1C A** (CL = 0.001987 dB)
- **Galileo-24-E1c** (CL = 0.3316 dB)

BDS M1-S-B1 (2016-05-10)

GPS BIIF-8-L1 (2016-06-24)

GLONASS COSMOS-G1 (2016-06-24)

Galileo GSAT0206-E1 (2016-06-25)
3.2 Navigation Signal Quality

(3) Signal constellation figure

BDS IGSO4-B1(2016-06-24)

GPS BIIF-8-L1(2016-06-24)

GLONASS COSMOS-G1(2016-06-24)

Galileo GSAT0206-E1(2016-06-24)
3.2 Navigation Signal Quality

(4) SCB profile

BDS IGSO4-B1(2016-06-24)

GPS BIIF-8-L1(2016-06-24)

GLONASS COSMOS-G1(2016-06-24)

Galileo GSAT0209-E1(2016-06-23)
3.3 Navigation information Accuracy

(1) Accuracy of broadcast orbit

- **BDS**
- **GPS**
- **GLONASS**
- **Galileo**

(2016 Jan – Sept)
3.3 Navigation information Accuracy

(2) Accuracy of broadcast clock

Clock Error Of Broadcast BDS (RMS)

Clock Error Of Broadcast GPS (RMS)

Clock Error Of Broadcast GLONASS (RMS)

Clock Error Of Broadcast Galileo (RMS)

BDS

GPS

GLONASS

Galileo
(3) User Range Error of Signal-in Space (SISURE)

### BDS (BDS)

- **Satellite Numbers:** C01, C02, C03, C04, C05, C06, C07, C08, C09, C10, C11, C12, C14, C15
- **Signal-In-Space User Ranging Error BDS (95%)**

### GPS (GPS)

- **Satellite Numbers:** G01, G02, G03, G05, G06, G07, G08, G09, G10, G11, G12, G13, G14, G15, G16, G17, G18, G19, G20, G21, G22, G23, G24, G25, G28, G29, G30, G31, G32
- **Signal-In-Space User Ranging Error GPS (95%)**

### GLONASS (GLONASS)

- **Satellite Numbers:** R01, R02, R03, R04, R05, R06, R07, R08, R09, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24
- **Signal-In-Space User Ranging Error GLONASS (95%)**

### Galileo (Galileo)

- **Satellite Numbers:** E08, E09, E11, E12, E14, E18, E19, E22, E24, E26, E30
- **Signal-In-Space User Ranging Error Galileo (95%)**
3.3 Navigation information Accuracy

(4) User Range Rate Error of Signal-in Space (SISURRE)

- **BDS**
  - User Ranging Rate Error BDS (95%)

- **GPS**
  - User Ranging Rate Error GPS (95%)

- **GLONASS**
  - User Ranging Rate Error GLONASS (95%)

- **Galileo**
  - User Ranging Rate Error Galileo (95%)
3.3 Navigation information Accuracy

(5) User Range Acceleration Error of Signal-in Space (SISURAE)

User Ranging Acceleration Error BDS (95%)

User Ranging Acceleration Error GPS (95%)

User Ranging Acceleration Error GLONASS (95%)

User Ranging Acceleration Error Galileo (95%)

Satellite Number

BDS

GPS

GLONASS

Galileo
3.3 Navigation information Accuracy

(6) Error of Broadcast Ionospheric model

<table>
<thead>
<tr>
<th>GNSS</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
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<tbody>
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<td>1.00</td>
<td>0.82</td>
<td>0.76</td>
<td>0.70</td>
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<td>0.59</td>
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<td>1.31</td>
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<td>1.73</td>
<td>1.84</td>
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<td>0.72</td>
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<td>0.45</td>
<td>0.58</td>
<td>0.57</td>
<td>0.58</td>
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</table>

Galileo
3.3 Navigation information Accuracy

(7) UTC(NTSC) - BDT

Clock difference (ns)

MJD

2016-01-01
2016-09-30
3.3 Navigation information Accuracy

(1) PDOP (≤6)

<table>
<thead>
<tr>
<th>GNSS</th>
<th>Jan</th>
<th>Feb</th>
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<th>May</th>
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<td>2.30</td>
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<tr>
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<td>2.34</td>
<td>2.23</td>
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</table>
3.4 Service Performance

(2) Positioning Accuracy

<table>
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<th>GLONASS</th>
</tr>
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<tbody>
<tr>
<td>bjfl</td>
<td>4.21</td>
<td>5.81</td>
<td>5.49</td>
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<tr>
<td>chu1</td>
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<td>lha1</td>
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<td>13.59</td>
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<tr>
<td>sha1</td>
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<td>8.25</td>
<td>4.58</td>
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<td>wuh1</td>
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<td>5.24</td>
</tr>
<tr>
<td>xia1</td>
<td>14.14</td>
<td>28.89</td>
<td>74.2</td>
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<tr>
<td>brch</td>
<td>23.06</td>
<td>36.01</td>
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</table>
3.4 Service Performance

(3) Velocity Accuracy

<table>
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<th>GPS</th>
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</tr>
</thead>
<tbody>
<tr>
<td>bjfl</td>
<td>0.19</td>
<td>0.1</td>
<td>0.14</td>
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<tr>
<td>chul</td>
<td>0.27</td>
<td>0.01</td>
<td>0.68</td>
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<td>gual</td>
<td>0.42</td>
<td>0.02</td>
<td>0.78</td>
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<tr>
<td>kunl</td>
<td>0.17</td>
<td>0.06</td>
<td>0.13</td>
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<tr>
<td>hala</td>
<td>0.22</td>
<td>0.11</td>
<td>0.17</td>
</tr>
<tr>
<td>shal</td>
<td>0.15</td>
<td>0.06</td>
<td>0.15</td>
</tr>
<tr>
<td>wuh1</td>
<td>0.19</td>
<td>0.1</td>
<td>0.15</td>
</tr>
<tr>
<td>xial</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
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<td>brch</td>
<td>1.82</td>
<td>0.07</td>
<td>0.21</td>
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<tr>
<td>elgy</td>
<td>0.03</td>
<td>0.08</td>
<td>0.09</td>
</tr>
<tr>
<td>cnyr</td>
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</tr>
<tr>
<td>zhon</td>
<td>1.46</td>
<td>0.09</td>
<td>0.09</td>
</tr>
</tbody>
</table>
3.4 Service Performance

(4) Time Service Accuracy

![BDS System's Time Accuracy Graph]

![GPS System's Time Accuracy Graph]

![GLONASS System's Time Accuracy Graph]

<table>
<thead>
<tr>
<th>GNSS</th>
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<th>June</th>
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</thead>
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<td>18.7</td>
<td>33.7</td>
<td>24.6</td>
<td>21.7</td>
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<tr>
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<td>2.74</td>
<td>5.08</td>
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<td>-2.8</td>
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<tr>
<td>GLO</td>
<td>12.3</td>
<td>9.6</td>
<td>-0.2</td>
<td>-3.2</td>
<td>-17.2</td>
<td>-11.8</td>
</tr>
</tbody>
</table>
3.5 Result Distribution

The GNSS monitoring and assessment results are distributed through the website and mobile terminals:

- Website
- Mobile Terminal (APP)
The APP of Mobile Terminal can publish the results of iGMAS Monitoring and Assessment, include four types: Constellation Status, Signal Quality, Signal Accuracy, Service Performance.

- Display in English and Chinese
- Facilitate users anytime and anywhere.
1. Background

2. iGMAS

3. Monitoring Results

4. Summary
Summary

- It has been an international consensous to develop a GNSS monitoring and assessment system with resource sharing and open service.

- iGMAS is promoted smoothly and started service in July 2014. It has provided various observations, basic products, monitoring and assessment information.

- iGMAS was designed with an open architecture. Tracking stations and analysis centers worldwide are welcomed to take part in the system.

- Products from other systems or projects are also welcomed to be compared with these from iGMAS.
Thanks!

Welcome to the Website:
http://124.205.50.178/