GLONASS: PRESENT AND FUTURE

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GLONASS current status

Some problems with GLONASS

GLONASS visibility under constrain condition

NavIC/ IRNSS Constellation Status and availability from India

Probable solutions by introducing NavIC/ IRNSS
GLONASS constellation status and observation from India

GLONASS current constellation status as on 31/05/2019

GLONASS visibility from India (Observed data)

Number of always available satellites in different GNSS operation modes (Burdwan)

<table>
<thead>
<tr>
<th>Visible satellites</th>
<th>Usable satellites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max</strong></td>
<td><strong>Min</strong></td>
</tr>
<tr>
<td>GPS</td>
<td>GLO</td>
</tr>
<tr>
<td>10</td>
<td>08</td>
</tr>
</tbody>
</table>

11-Jul-19

United Nations/ Fiji Workshop 24 - 28 June, 2019
GLONASS: continuous study from INDIA

As an active alternative of GPS, usefulness of GLONASS as a stand alone GNSS or as a component of Multi-GNSS GLONASS has been studied from India

After the revitalization of GLONASS in late 2011, it became the only alternative to GPS and such study continued

While studying GLONASS in its fully operational condition, few problems was noticed and those are being presented here, with discussion on the remedies in view of the operation of IRNSS/NavIC

GLONASS Satellite geometry

GLONASS satellites over the sky from IAC, Russia (left) and increased PDOP values for eastern side of the globe from IAC, Russia (10/01/2019; 8:20:00 IST) (right)

Variation of GLONASS only observations from Burdwan, India

➢ PDOP values sometimes shoots up above 3.0 for stand-alone GLONASS
GLONASS satellite unavailability for more than 60° elevation angle
(Observation Time: March 2006- March 2011, 25-26 April, 2019 Location: Burdwan, India)

- GLONASS satellites are unavailable sometimes above 60° elevation mask
- It is repeated thrice a day
GLONASS satellite availability with 30° and 45° masking angle
(Observation date: 10/06/2019, Location: India)

GLONASS Visibility and Usability across the country for different masking angles

<table>
<thead>
<tr>
<th>Elevation Mask (deg)</th>
<th>Location</th>
<th>GLONASS sats in use (Total usable above 5° cut off)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Chennai</td>
<td>04 (09)</td>
</tr>
<tr>
<td></td>
<td>Balasore</td>
<td>04 (06)</td>
</tr>
<tr>
<td></td>
<td>Pilani</td>
<td>04 (09)</td>
</tr>
<tr>
<td></td>
<td>Burdwan</td>
<td>05 (09)</td>
</tr>
<tr>
<td>45</td>
<td>Chennai</td>
<td>02 (10)</td>
</tr>
<tr>
<td></td>
<td>Balasore</td>
<td>04 (09)</td>
</tr>
<tr>
<td></td>
<td>Dehradun</td>
<td>03 (09)</td>
</tr>
<tr>
<td></td>
<td>Burdwan</td>
<td>01 (08)</td>
</tr>
</tbody>
</table>

- Number of GLONASS sometimes fall short and could not provide stand-alone solutions under constrain condition
GLONASS satellite availability with 20° masking angle and support from NavIC
(Observation date: 10/06/2019, Location: Burdwan, India)

- Limited satellite visibility from high elevation angles during some parts of the day from India is observed for GLONASS
- In restricted visibility conditions from lower elevation angles simultaneous absence of GLONASS from higher elevation angles may pose serious threat for seamless navigation
GLONASS only operation in urban canyon

Real Life data collection location

GLONASS skyplot when GLONASS alone could not provide position solution (10/01/2019; 6:36:05 IST)

Solution Coordinates under constraint condition (within urban canyon);
10 January, 2019; one-hour data at 1 Hz rate, Burdwan, India

➢ In cases, GLONASS fails to provide solution
IRNSS (NavIC) Constellation

➢ IRNSS/NavIC is a regional system developed by ISRO, India

➢ NavIC operates in L5 (1176.45 MHz) and S bands (2492.08 MHz)

IRNSS (NavIC) available with all 7 satellites in constellation and is fully operational

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Launch Date</th>
<th>Type</th>
<th>Location (Longitude)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRNSS 1A</td>
<td>01 July, 2013</td>
<td>GSO</td>
<td>55° E</td>
</tr>
<tr>
<td>IRNSS 1B</td>
<td>04 April, 2014</td>
<td>GSO</td>
<td>55° E</td>
</tr>
<tr>
<td>IRNSS 1C</td>
<td>16 October, 2014</td>
<td>GEO</td>
<td>83° E</td>
</tr>
<tr>
<td>IRNSS 1D</td>
<td>28 March, 2015</td>
<td>GSO</td>
<td>111.75° E</td>
</tr>
<tr>
<td>IRNSS 1E</td>
<td>20 January, 2016</td>
<td>GSO</td>
<td>111.75° E</td>
</tr>
<tr>
<td>IRNSS 1F</td>
<td>10 March, 2016</td>
<td>GEO</td>
<td>32.5° E</td>
</tr>
<tr>
<td>IRNSS 1G</td>
<td>28 April, 2016</td>
<td>GEO</td>
<td>131.5° E</td>
</tr>
<tr>
<td>IRNSS 1H</td>
<td>31 August, 2017</td>
<td>GSO</td>
<td>55° E</td>
</tr>
<tr>
<td>IRNSS 1I</td>
<td>12 April, 2018</td>
<td>GSO</td>
<td>55° E</td>
</tr>
</tbody>
</table>
Visibility of NavIC under 30° elevation

➢ Except from some parts of India Minimum number of IRNSS lies above 04
GLONASS+ NavIC operation in urban canyon

GLONASS+ IRNSS Skyplot (urban canyon)

Solution Coordinates in constraint condition (urban canyon) in GLONASS+NavIC operation

Variation of 2D position solution in GLONASS+NavIC solution; 5 February, 2019; one-hour data @1 Hz rate, Burdwan, India

- Uninterrupted and less scattered solutions are possible using GLONASS+IRNSS
- Solution accuracies ~ 2m (Horizontal), 6m (vertical)
Obtained results for deep foliage (Observation date: 07/06/2019, Location: Shibpur Forest, West Bengal, India)

Real life observation under deep foliage

- **GLONASS** stand-alone solutions are frequently interrupted under deep foliage
- **IRNSS** stand-alone solutions are less scattered and uninterrupted
- **GLONASS+ IRNSS** always provide uninterrupted, less scattered position solutions
GLONASS position solution errors (open sky); 10 January, 2019; one-hour data at 1 Hz rate, Burdwan, India. Dark lines indicate the reference coordinates

- Solution accuracies ~ 6m (Horizontal), 11m (vertical) for GLONASS
- Solution accuracies ~ 2m (Horizontal), 7m (vertical) for IRNSS/NavIC
- NavIC Solution accuracies are less than GLONASS

IRNSS position solution errors (open sky); 27 January, 2019; one-hour data at 1 Hz rate, Burdwan, India. Dark lines indicate the reference coordinates
## Location for the study at permanent station

<table>
<thead>
<tr>
<th>Monitoring Site</th>
<th>Approx. Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>The University of Burdwan</td>
<td>23° 15.27’ N</td>
</tr>
<tr>
<td>Burdwan</td>
<td>87° 50.81’ E</td>
</tr>
<tr>
<td></td>
<td>45.781 Meters</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
\text{Error}_{2d} & = \sqrt{(1852 \cdot \Delta L_t \cdot \cos(La_0))^2 + (1852 \cdot \Delta La)^2} \\
\text{Error}_{3d} & = \sqrt{\Delta h^2 + (1852 \cdot \Delta L_t \cdot \cos(La_0))^2 + (1852 \cdot \Delta La)^2}
\end{align*}
\]
When IRNSS (NavIC) is introduced sequentially along with all 09 available GLONASS......

<table>
<thead>
<tr>
<th>Date</th>
<th>IRNSS (NavIC)</th>
<th>Average 2d Error (m)</th>
<th>Average 3d Error (m)</th>
<th>Jitter of 2d Error (m)</th>
<th>Jitter of 3d Error (m)</th>
<th>Average PDOP (GLONASS + IRNSS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.03.2019</td>
<td>0</td>
<td>2.24974</td>
<td>9.18358</td>
<td>0.21035</td>
<td>0.51472</td>
<td>2.39825</td>
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<tr>
<td></td>
<td>1</td>
<td>2.25894</td>
<td>8.26388</td>
<td>0.1763</td>
<td>0.58825</td>
<td>2.13886</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.15223</td>
<td>5.08486</td>
<td>0.20974</td>
<td>1.41167</td>
<td>1.90659</td>
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<tr>
<td></td>
<td>3</td>
<td>2.06958</td>
<td>2.72817</td>
<td>0.77477</td>
<td>1.41952</td>
<td>2.10586</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1.13443</td>
<td>1.64645</td>
<td>0.127</td>
<td>0.27502</td>
<td>1.78423</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1.2145</td>
<td>1.62606</td>
<td>0.25723</td>
<td>0.51574</td>
<td>1.63448</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1.68656</td>
<td>2.01506</td>
<td>0.32204</td>
<td>0.42103</td>
<td>1.51979</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>1.16875</td>
<td>3.91652</td>
<td>0.17125</td>
<td>0.35066</td>
<td>1.54218</td>
</tr>
</tbody>
</table>
When IRNSS is introduced sequentially along with all 09 available GLONASS

Variation of average errors and standard deviation of error with increasing number of IRNSS/ NavIC satellites with all available 09 GLONASS satellites (Date: 28/03/2019; Location: Burdwan)

➢ Error values are decreasing with the introduction of IRNSS
Improvement of Satellite geometry in GLONASS+NavIC hybrid operation

Variation of average PDOP values with increasing number of IRNSS satellites with 09 GLONASS satellites (Date: 28/03/2019; Location: Burdwan)

➢ PDOP values are decreasing with introduction of IRNSS
GLONASS is fully operational

NavIC is fully operational

GLONASS solutions are frequently interrupted under constrain condition

NavIC can mitigate this problem when used together with GLONASS within its operation region

Use of NavIC showcases the benefits of GNSS+RNSS hybrid operation
THANK YOU

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