GLONASS: PRESENT AND FUTURE

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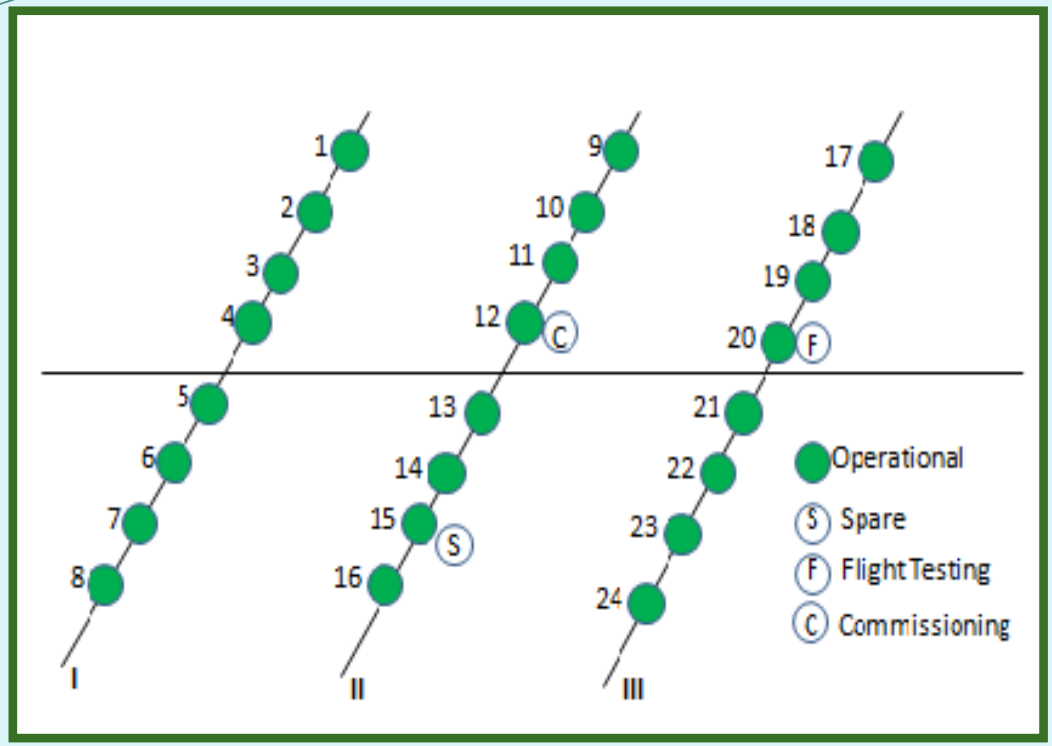
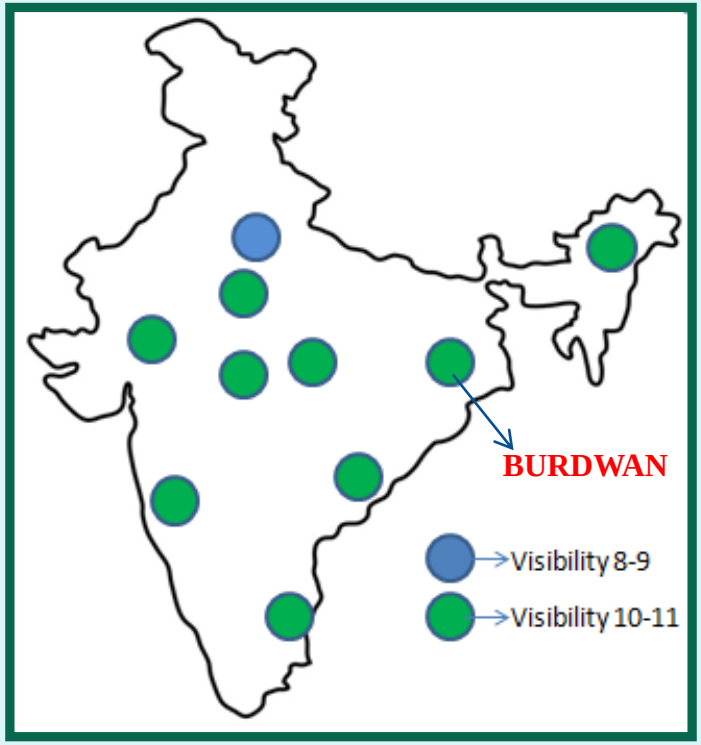
Content

- 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)

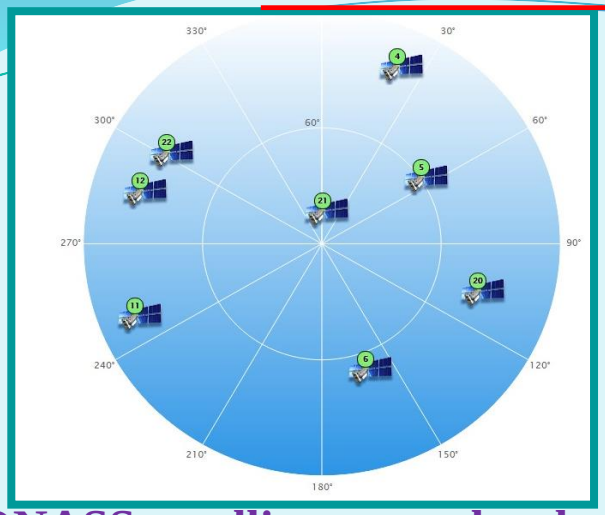
Number of always available satellites in different GNSS operation modes (Burdwan)												
Visible satellites						Usable satellites					
Max			Min			Max			Min		
GPS	GLO	MIX	GPS	GLO	MIX	GPS	GLO	MIX	GPS	GLO	MIX
10	08	20	08	03	12	09	07	16	02	02	06

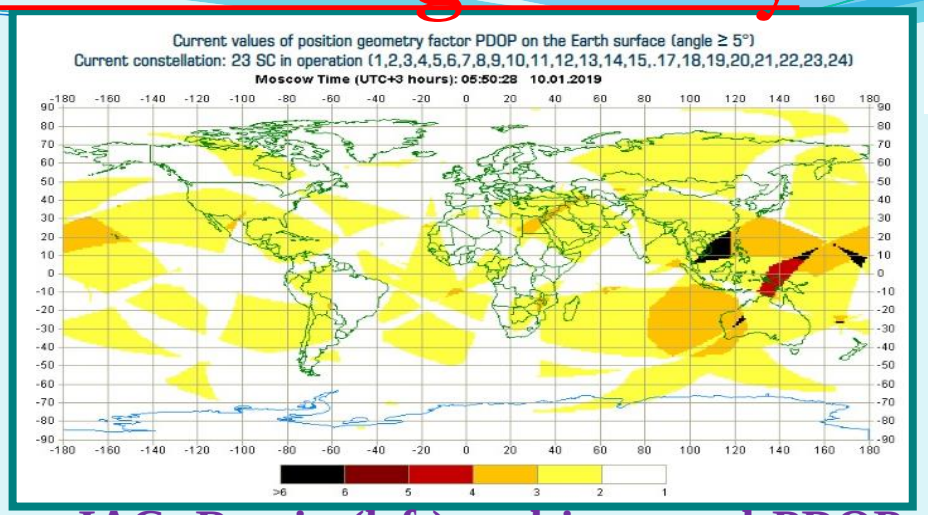
GLONASS: continuous study from INDIA

- **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**

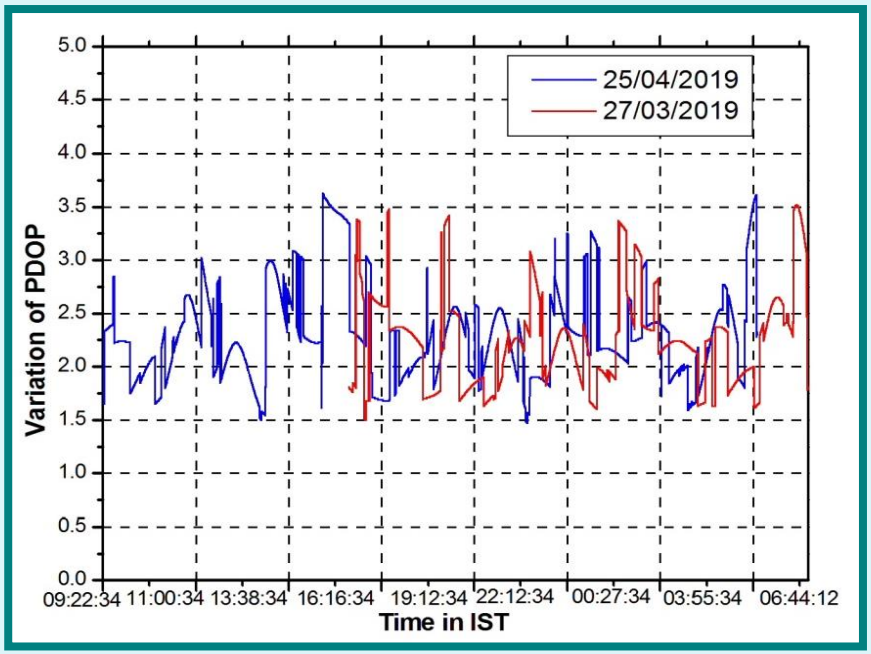
- Revitalized GLONASS Constellation Status in mid 2010, Anindya Bose and Shreya Sarkar, *European Journal of Navigation*, Vol 8, No 2, August 2010, pp 45 – 46
- Studies on revitalized GLONASS from India, Anindya Bose, Shreya Sarkar, Keka Hazra, Debipriya Dutta and A Bhattacharya, *Coordinates*, Vol XI, Issue 5, May 2015, pp 37 – 42
- Studies on Solution Accuracy of GLONASS from India, S Sarkar and A Bose, *Gyroscopy and Navigation*, Vol 7, No 1, Jan 2016, pp 39-49
- ·Lifetime Performances Of Modernized GLONASS Satellites: A Review, Shreya Sarkar and Anindya Bose, Artificial Satellites, Vol. 52, No. 4-2017, pp 85-97
- ·A review of 36 years of GLONASS service from India, Shreya Sarkar, P Banerjee and Anindya Bose, *Gyroscopy and Navigation*,Vol 9, No 4, April 2018, pp 298- 309

GLONASS Satellite geometry





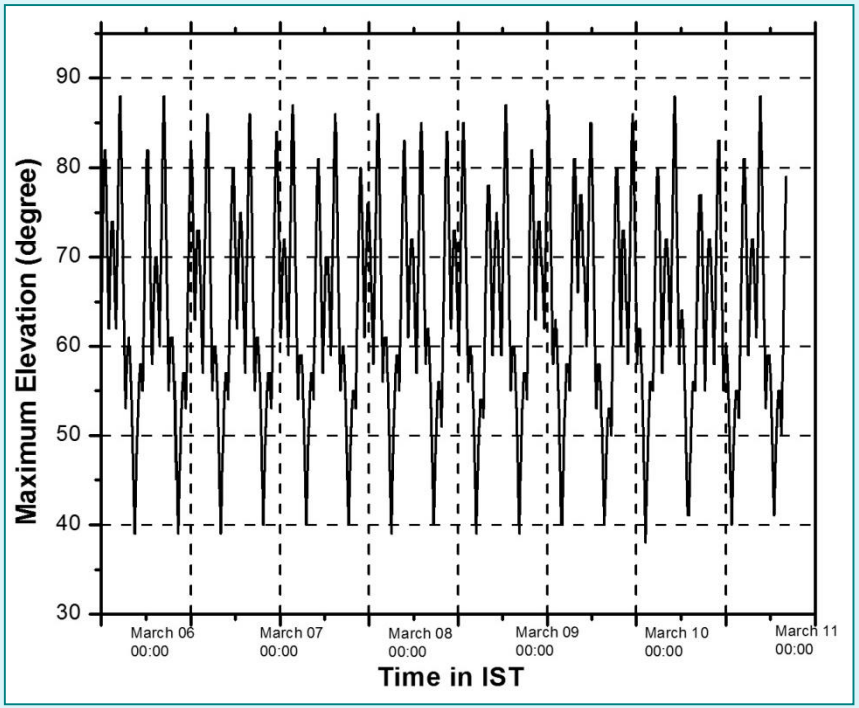
GLONASS satellites over the sky from IAC, Russia (left) and increased PDOP values for eastern side of the globe from IAC, Russia (10/01/2019; 8:20:00 IST) (right)

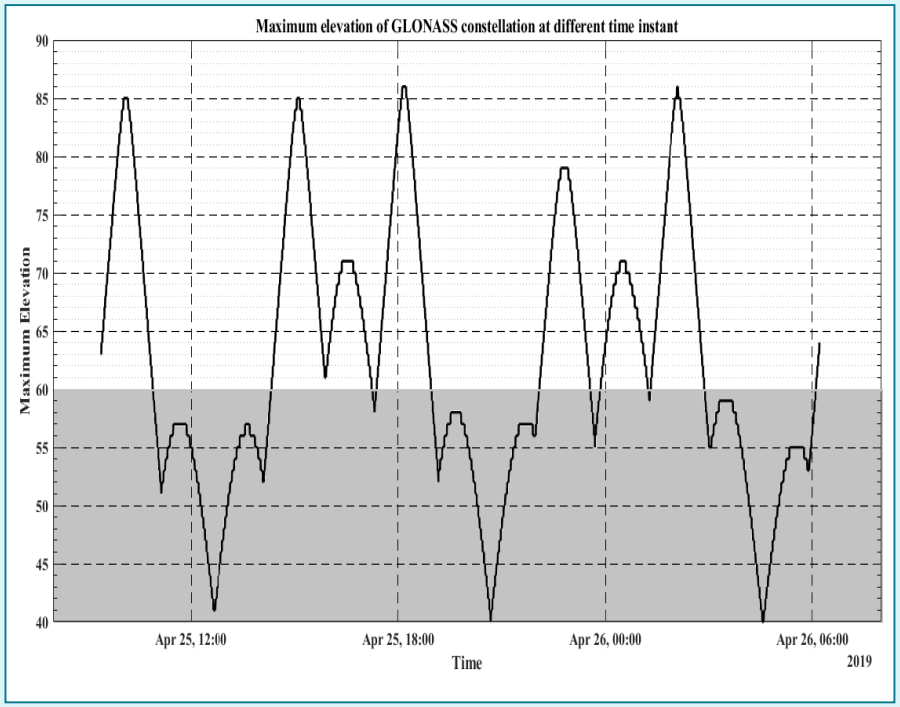


Variation of GLONASS only observations from Burdwan, India

- **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)





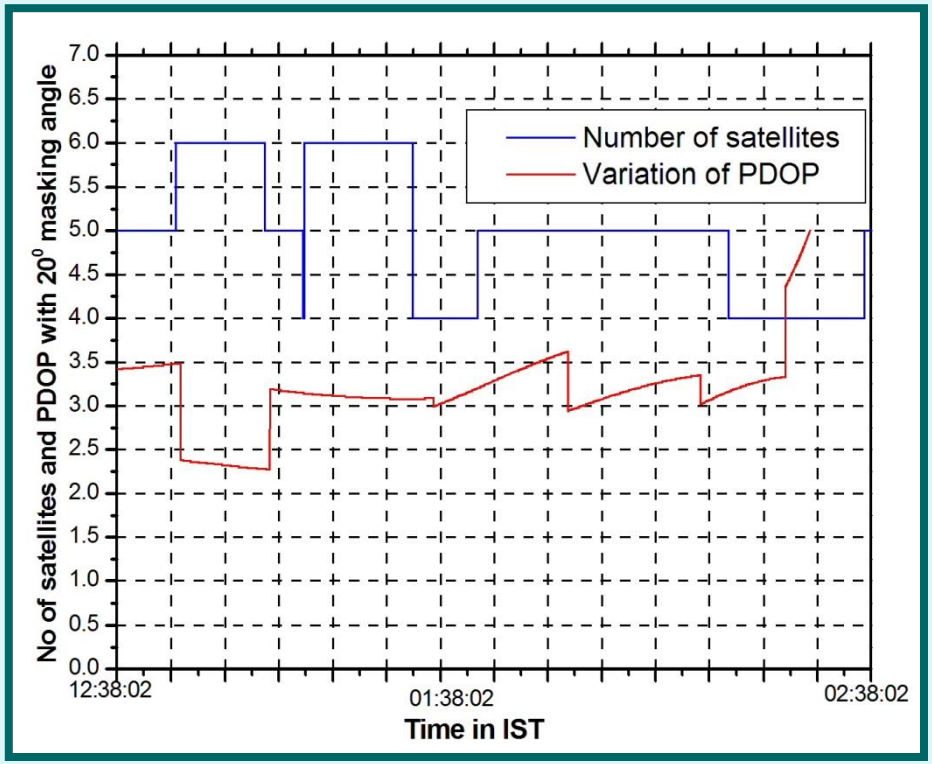
- GLONASS satellites are unavailable sometimes above 60^0 elevation mask
- It is repeated thrice a day

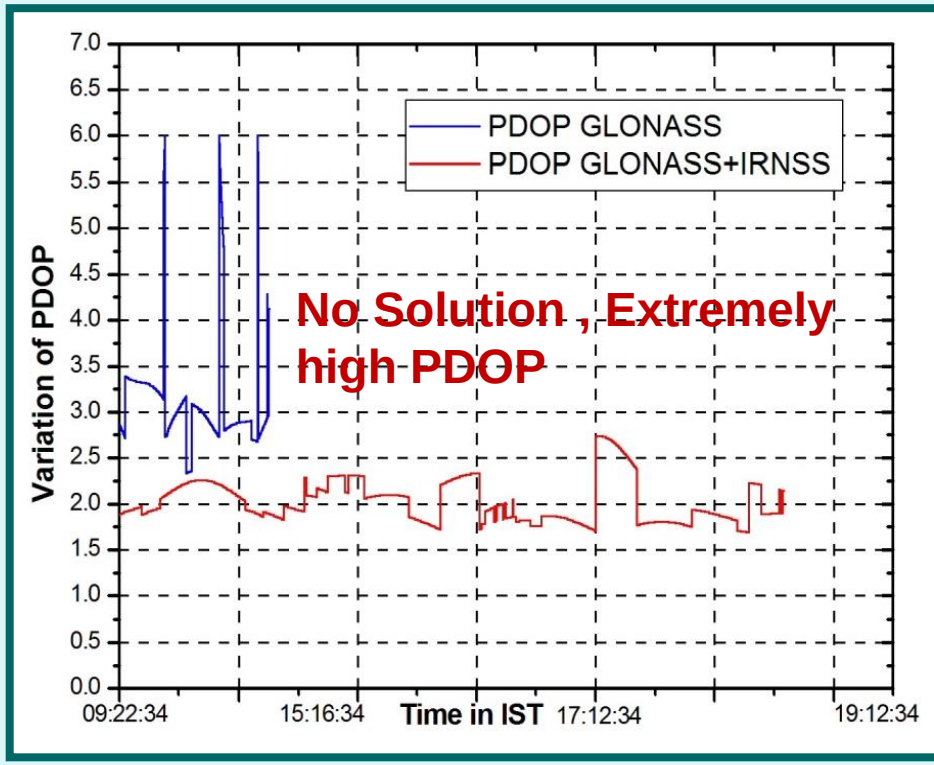
GLONASS satellite availability with 30° and 45 ° masking angle (Observation date: 10/06/2019, Location: India)

GLONASS Visibility and Usability across the country for different masking angles		
Elevation Mask (deg)	**Location**	**GLONASS sats in use (Total usable above 5° cut off)**
30	Chennai	04 (09)
	Balasore	04 (06)
	Pilani	04 (09)
	Burdwan	05 (09)
45	Chennai	02 (10)
	Balasore	04 (09)
	Dehradun	03 (09)
	Burdwan	01 (08)

- **Number of GLONASS sometimes fall short and could not provide stand- alone solutions under constrain condition**

GLONASS satellite availability with 20º masking angle and support from NavIC (Observation date: 10/06/2019, Location: Burdwan, India)

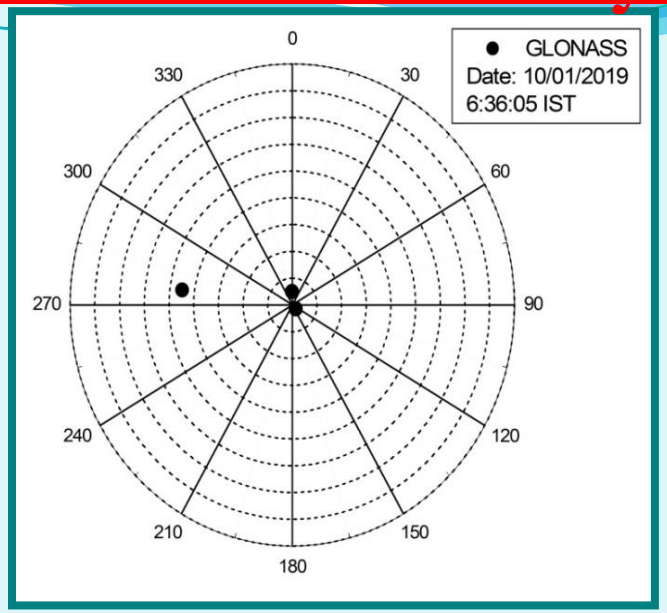




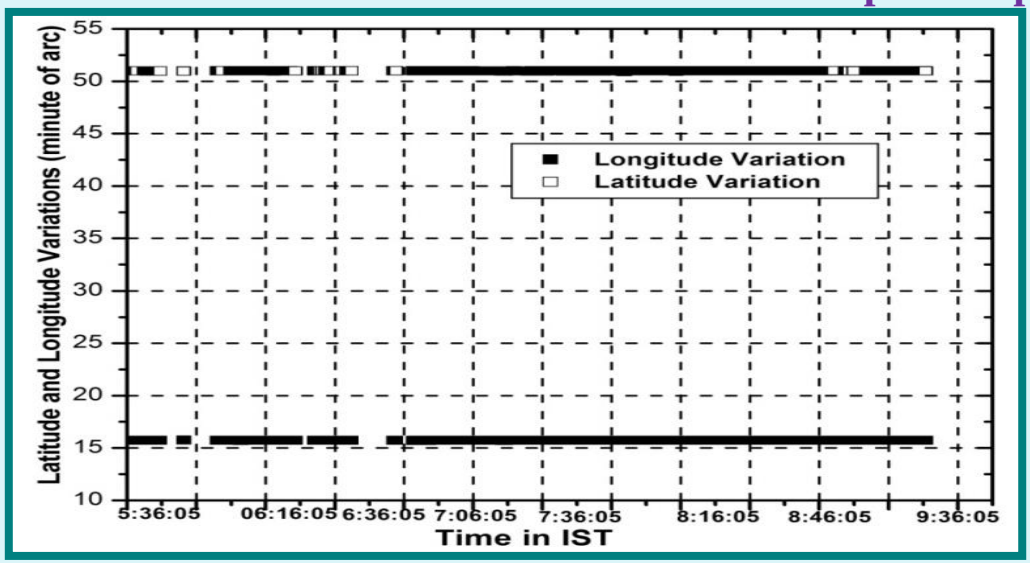
- Limited satellite visibility from high elevation angles during some parts of the day from India is observed for GLONASS
- In restricted visibility conditions from lower elevation angles simultaneous absence of GLONASS from higher elevation angles may pose serious threat for seamless navigation

GLONASS only operation in urban canyon

Real Life data collection location



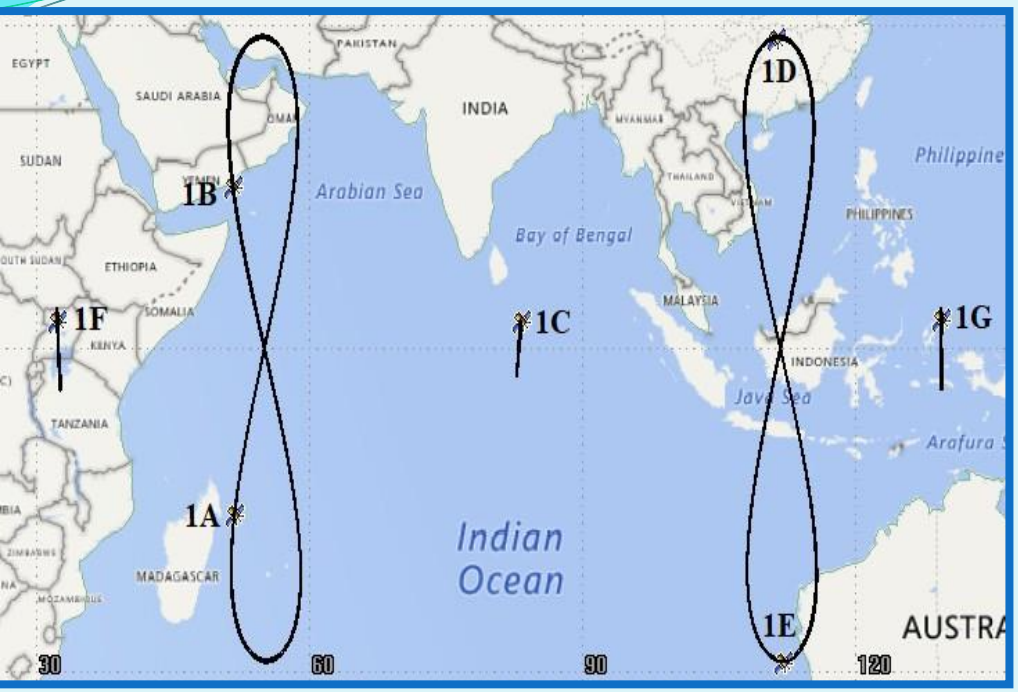
GLONASS skyplot when GLONASS alone could not provide position solution (10/01/2019; 6:36:05 IST)



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

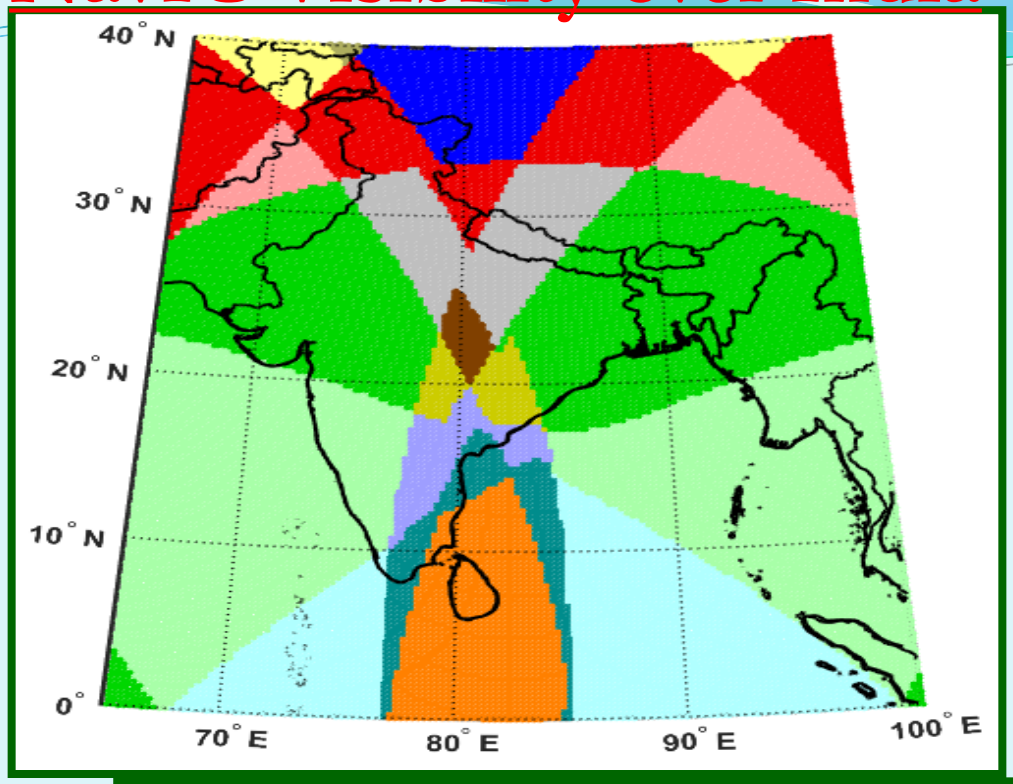


- IRNSS/ NavIC is a regional system developed by ISRO, India
- NavIC operates in L5 (1176.45 MHz) and S bands (2492.08 MHz)

NavIC Satellites			
Satellite	**Launch Date**	**Type**	**Location (Longitude)**
IRNSS 1A	01 July, 2013	GSO	55° E
IRNSS 1B	04 April, 2014	GSO	55° E
IRNSS 1C	16 October, 2014	GEO	83° E
IRNSS 1D	28 March, 2015	GSO	111.75° E
IRNSS 1E	20 January,2016	GSO	111.75° E
IRNSS 1F	10 March, 2016	GEO	32.5° E
IRNSS 1G	28 April, 2016	GEO	131.5° E
IRNSS 1H	31 August, 2017	GSO	55° E
IRNSS 1I	12 April, 2018	GSO	55° E

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

NavIC Visibility over India



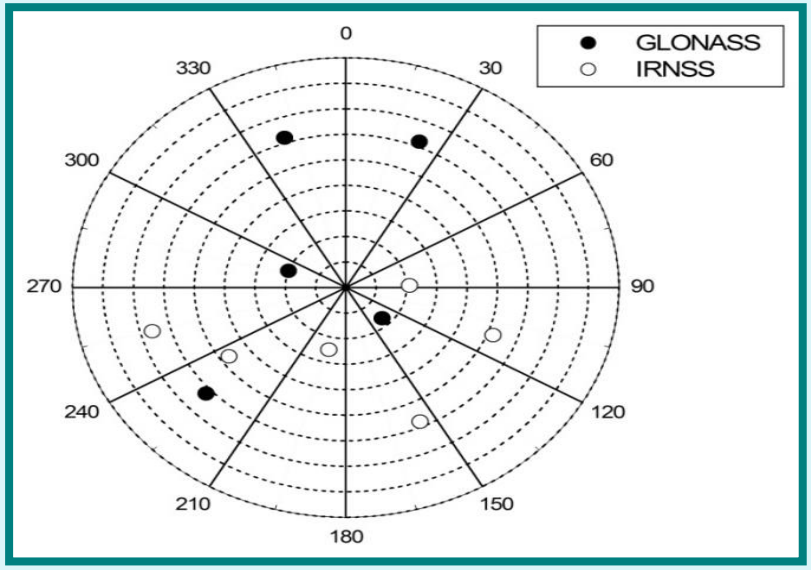
Visibility of NavIC under 30 ^{0} elevation

Colour Code	Maximum No. of Satellite	Minimum No. of Satellite
	7	6
	7	5
	7	4
	7	3
	6	5
	6	4
	6	3

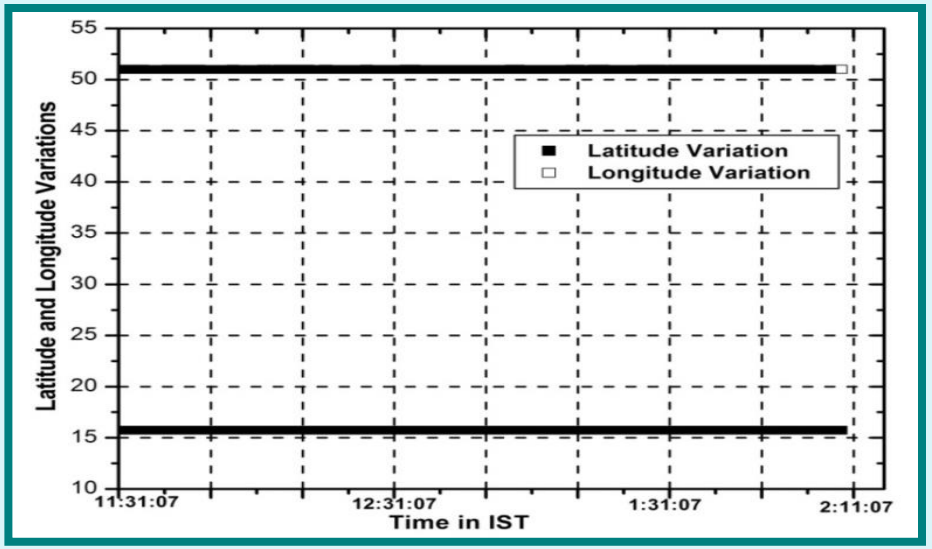
Colour Code	Maximum No. of Satellite	Minimum No. of Satellite
	5	4
	5	3
	5	2
	4	3
	4	2
	Always 7	
	Always 6	

- **Except from some parts of India Minimum number of IRNSS lies above 04**

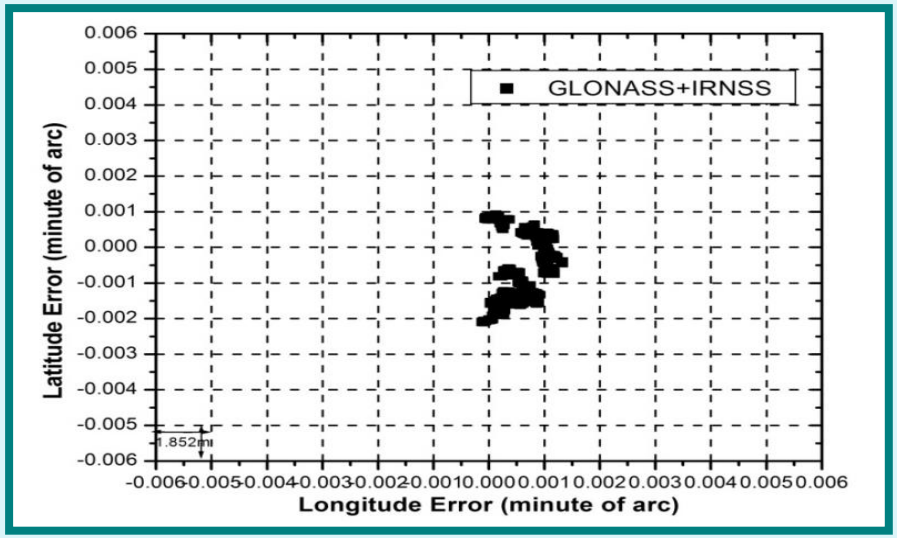
GLONASS+ NavIC operation in unban canyon



GLONASS+ IRNSS Skyplot (urban canyon)



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

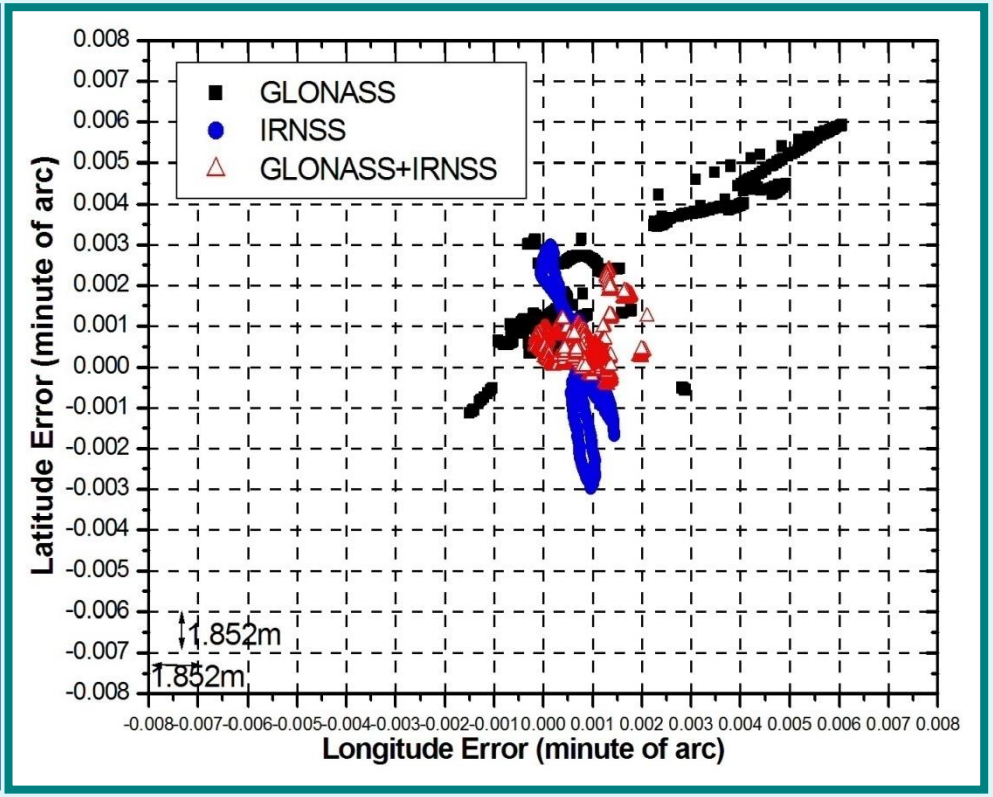


Variation of 2d position solution in GLONASS+NavIC solution; 5 February, 2019; one- hour data @1 Hz rate, Burdwan, India

- 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)

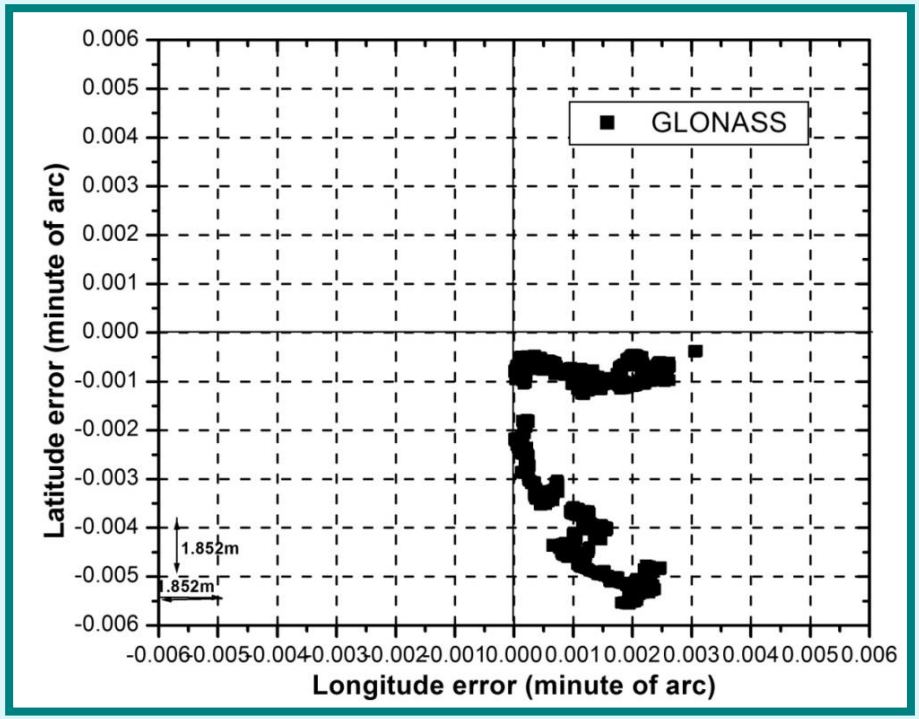
Real life observation under deep foliage



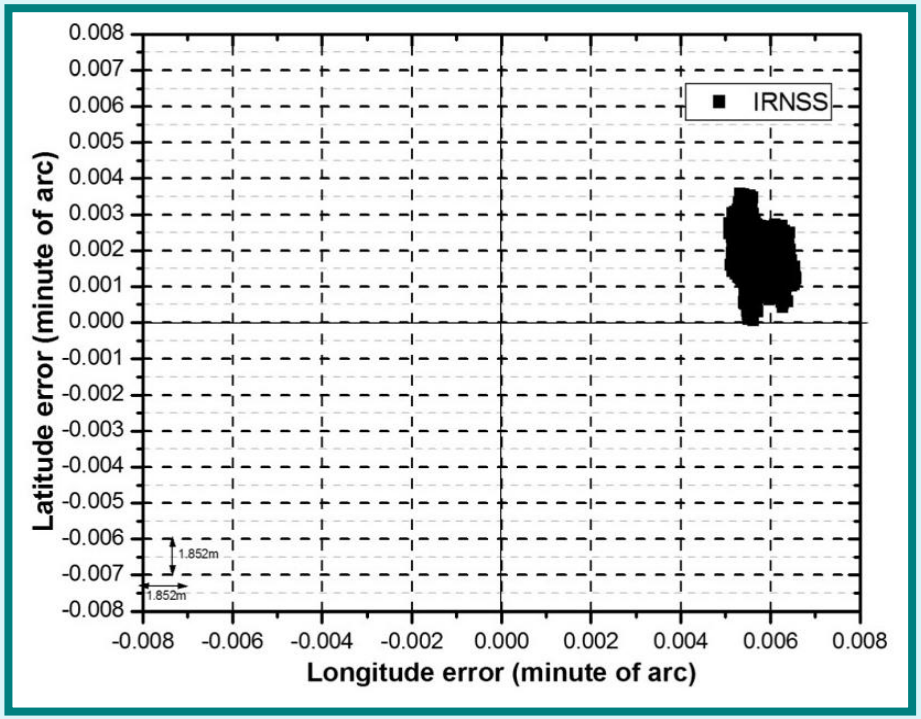
Solution Errors for GLONASS, IRNSS and GLONASS+IRNSS

- 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

Solution Error Comparison



GLONASS position solution errors (open sky); 10 January, 2019; one- hour data at 1 Hz rate, Burdwan, India. Dark lines indicate the reference coordinates



IRNSS position solution errors (open sky); 27 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

Location for the study at permanent station

Monitoring Site	Appox. Location
The University of Burdwan Burdwan	23^0 15.27′ N 87^0 50.81′ E 45.781 Meters

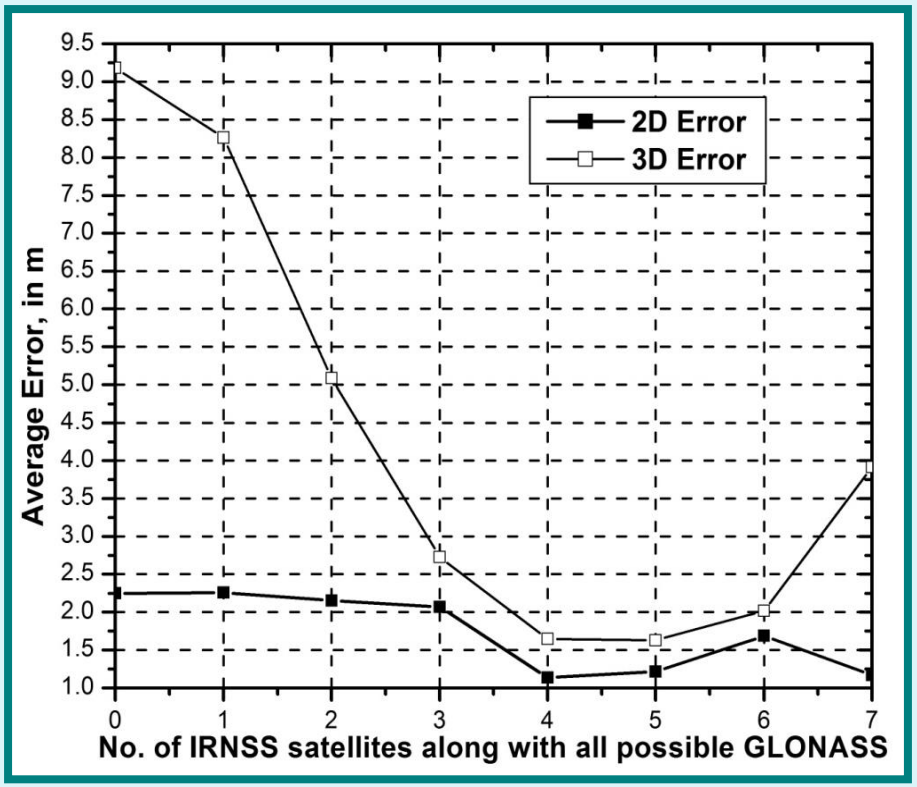
$$Error_{2d} = \sqrt{(1852 \,.\, \Delta Lt \,.\, \cos(La_0))^2 + (1852 \,.\, \Delta La)^2}$$

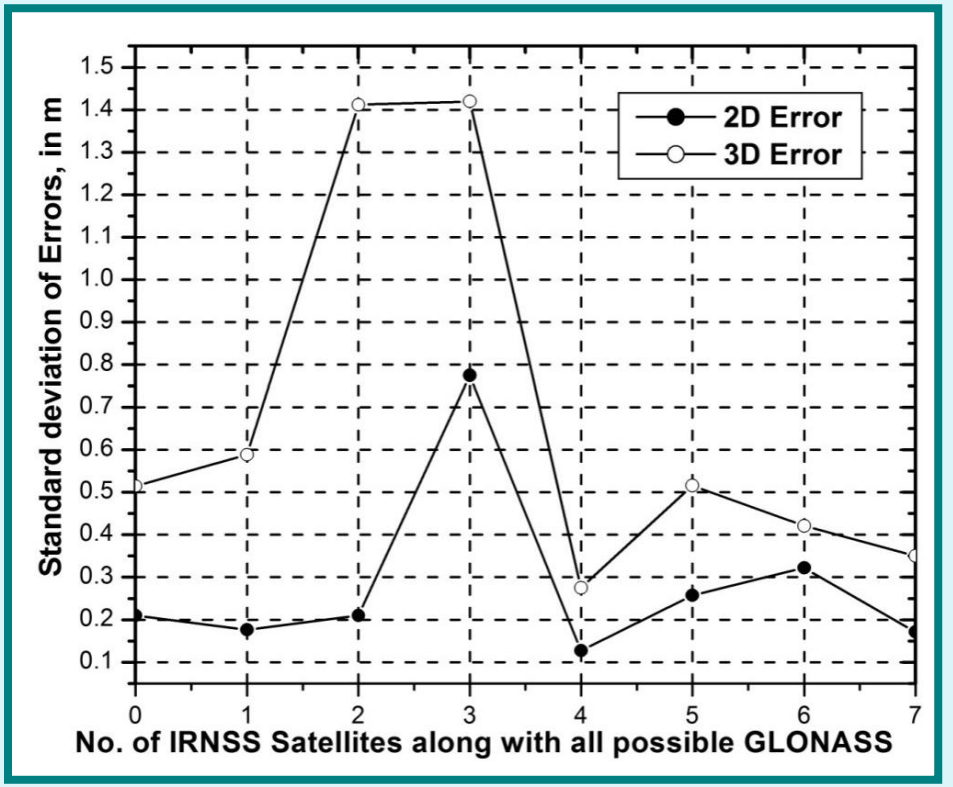
$$Error_{3d} = \sqrt{\Delta h^2 + (1852 \,.\, \Delta Lt \,.\, \cos(La_0))^2 + (1852 \,.\, \Delta La)^2}$$

When IRNSS (NavIC) is introduced sequentially along with all 09 available GLONASS……

Average errors and jitter (standard deviation) of errors with increasing number of IRNSS used with all available GLONASS satellites for solution						
Date	**IRNSS (NavIC)**	**Average 2d Error (m)**	**Average 3d Error (m)**	**Jitter of 2d Error (m)**	**Jitter of 3d Error (m)**	**Average PDOP (GLONASS + IRNSS)**
28.03.2019	0	2.24974	9.18358	0.21035	0.51472	2.39825
	1	2.25894	8.26388	0.1763	0.58825	2.13886
	2	2.15223	5.08486	0.20974	1.41167	1.90659
	3	2.06958	2.72817	0.77477	1.41952	2.10586
	4	1.13443	1.64645	0.127	0.27502	1.78423
	5	1.2145	1.62606	0.25723	0.51574	1.63448
	6	1.68656	2.01506	0.32204	0.42103	1.51979
	7	1.16875	3.91652	0.17125	0.35066	1.54218

When IRNSS is introduced sequentially along with all 09 available GLONASS

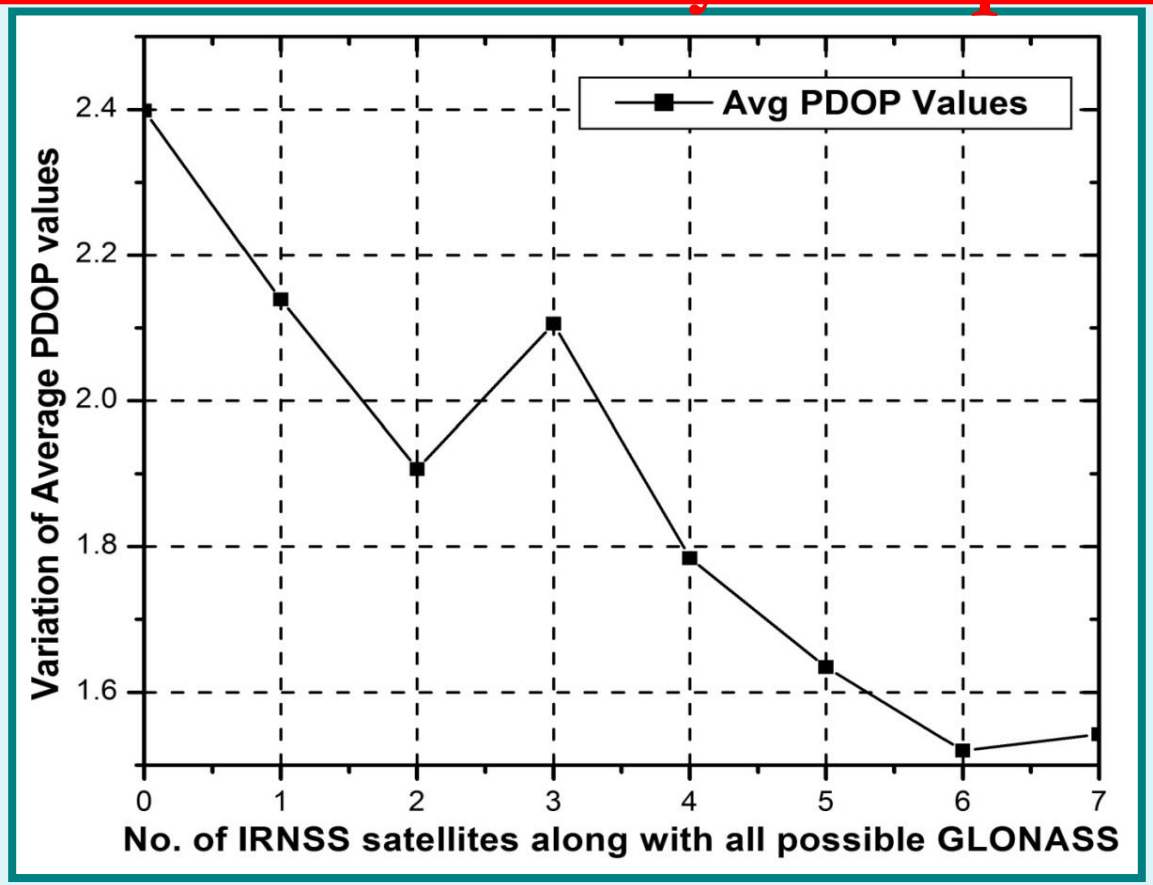




Variation of average errors and standard deviation of error with increasing number of IRNSS/ NavIC satellites with all available 09 GLONASS satellites (Date: 28/03/2019; Location: Burdwan)

- **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**

Summary

- 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

Acknowledgment

THANK YOU

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