GLONASS from India: review of the revitalised system performances

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Presentation outline

- **About GNSS activity Group, BU**
- **Revitalized GLONASS – current scenario**
- **Experimental set up: Hardware, Data monitoring point**
- **Results:** GLONASS Visibility in India

  Multi-GNSS and satellite geometry

  GLONASS in limited satellite visibility

  Multi-GNSS & stand-alone solution accuracy

  GPS-GLONASS Interoperability

  Experience with GALILEO
- **Conclusion and Scopes**

GNSS Activity Group, BU

(Lat 23.2545^0 N, Lon 87.8468^0 E)

- GNSS activity group in The Department of Physics, BU is engaged in R&D activities in the filed of GNSS with focus towards:

  1) Exploration of Multi-GNSS environment for use in India
  2) Development of cost-effective applications and solutions
  3) Capacity Building in the Field of GNSS

- Sponsored Projects from Govt of India consultancy projects on GNSS, Provide support to R&D efforts of other academic Institutions, Data sharing

- Established links with International agencies – (e.g. Member, Multi-GNSS Asia (MGA) [http://multignss.asia], GNSS-Asia

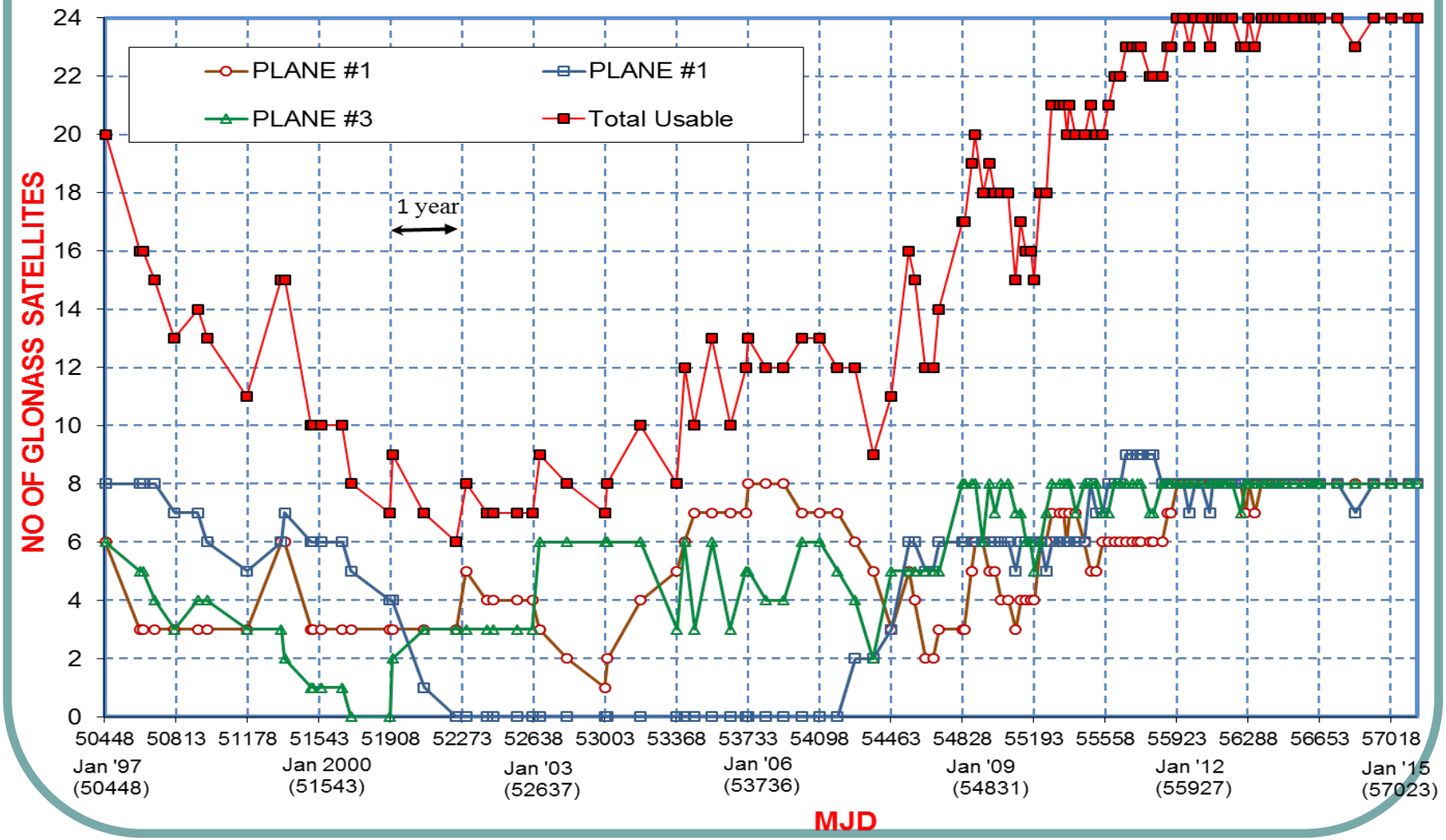
- Collaboration with Industry for improved solution development using our expertise and competencies to address the market needs

GLONASS development plan and implementation

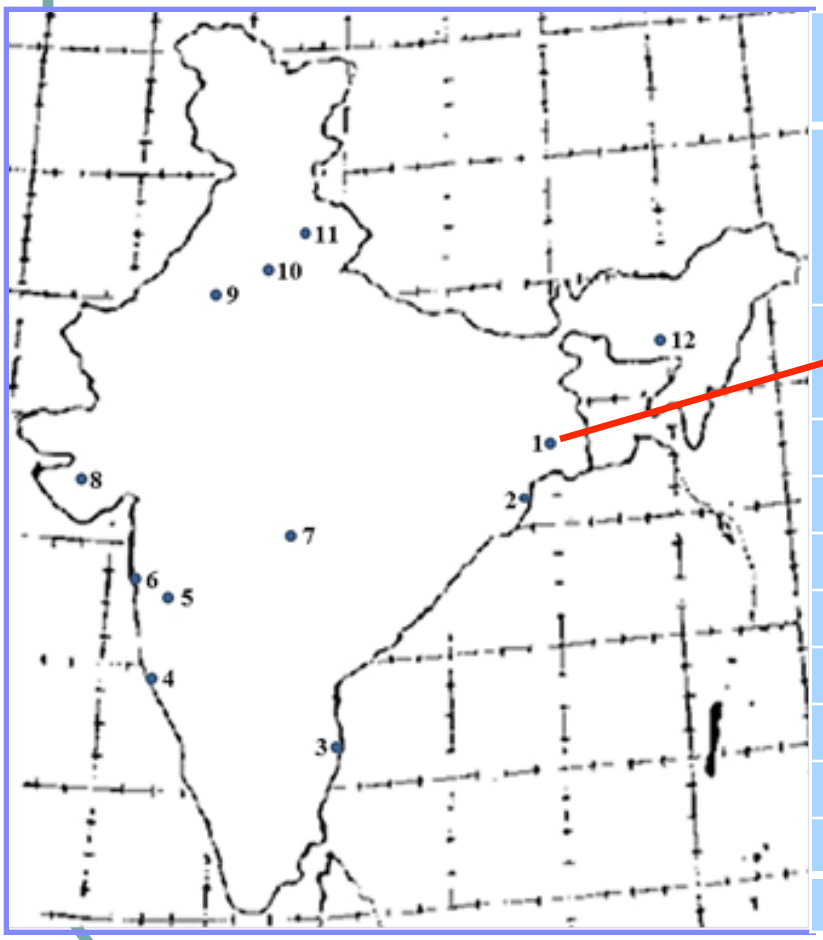
- **Fully operating GLONASS during late 1990s had shown the advantagess of using GLONASS from India- specially with SA present in GPS signal***
- **GLONASS degraded since 2001 and became unusable**
- **GLONASS modernization plan was declared in 2004; 24 fully operating and improved GLONASS satellites was promised by 2010.**
- **Between December, 2004 and December 2014, GLONASS satellites launched: 40 (through 17 launches)**
- **Revitalized GLONASS was declared fully operational since October end, 2011**
- **It was interesting to study the availability and usability of GLONASS once again from India**
- **As of 11 May, 2015 : 28 GLONASS satellites in the constellation- 24 fully operational, 02 under check by contractor and 02 in Flight Testing phase.**

*"The usefulness of GLONASS for positioning in the presence of GPS in Indian subcontinent", P Banerjee, Anindya Bose and Ashish Dasgupta, *Navigation*, *J Instt of Navigation*, (UK), Vol 55, No 3, September 2002, pp 463 – 475

GLONASS constellation variation with time (1997 – May, 2015)



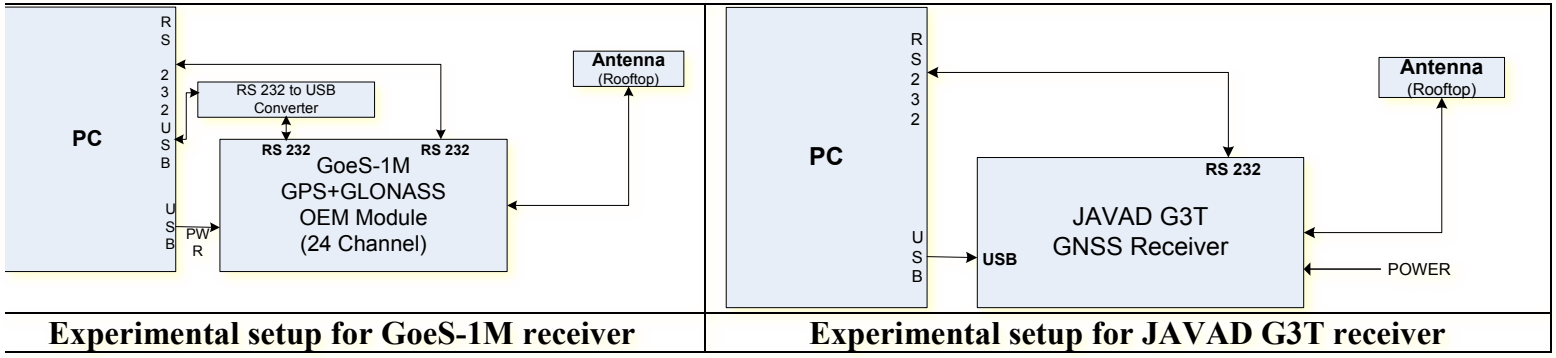
GLONASS data monitoring plan



Location No	Location	Comment
1	Burdwan	Permanent station (GoeS-1M, G3T)
2	Balasore	Data recorded for 2-4 days at each data monitoring point during August, 2012 – November, 2012. (GoeS-1M)
3	Chennai	
4	Goa	
5	Pune	
6	Panvel	
7	Nagpur	
8	Rajkot	
9	Pilani	
10	Noida	
11	Dehradun	
12	Shillong	

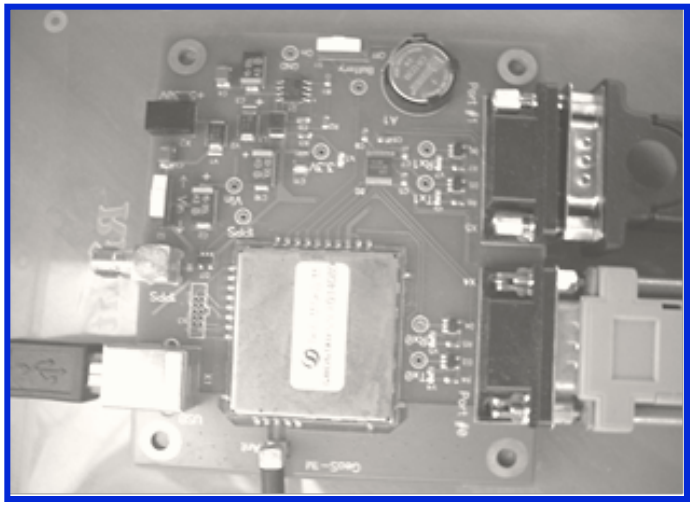
Ref: "Experiment to Study Revitalized GLONASS Signal Availability from India", **Anindya Bose**, Shreya Sarkar, Keka Hazra, Avik Mukherjee and Sourav Nandi, Proc. National Conference on Electronics Technologies (NCET 2K12), Govt Engineering College, Ponda, Goa, 13 – 14 April, 2012, pp 79 – 84

Hardware



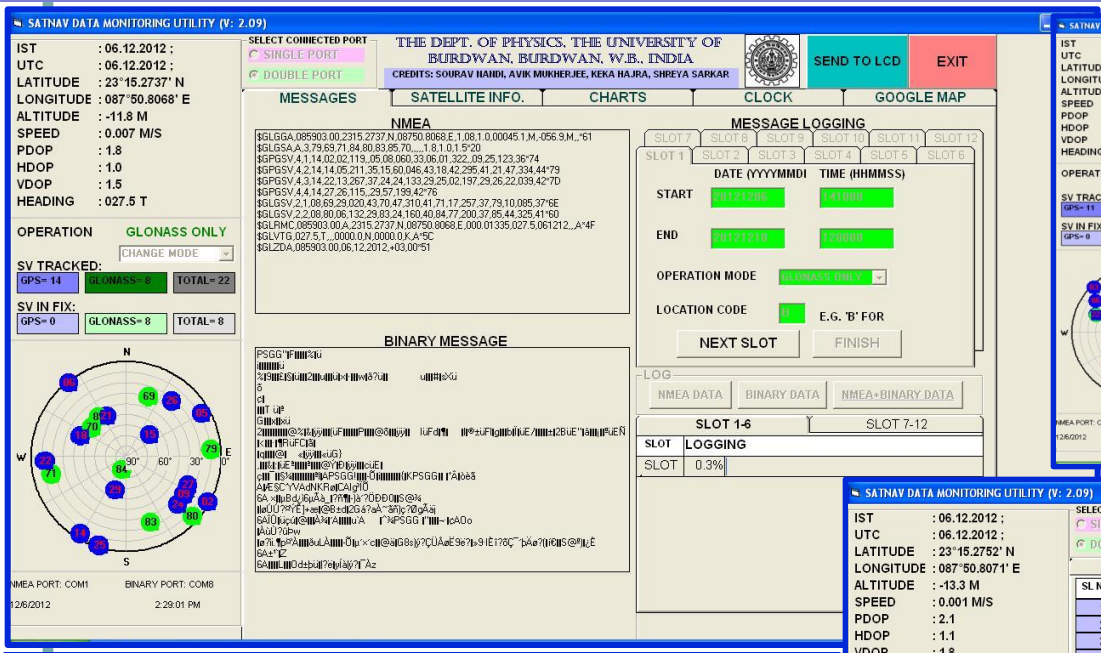
Experimental setup for GoeS-1M receiver

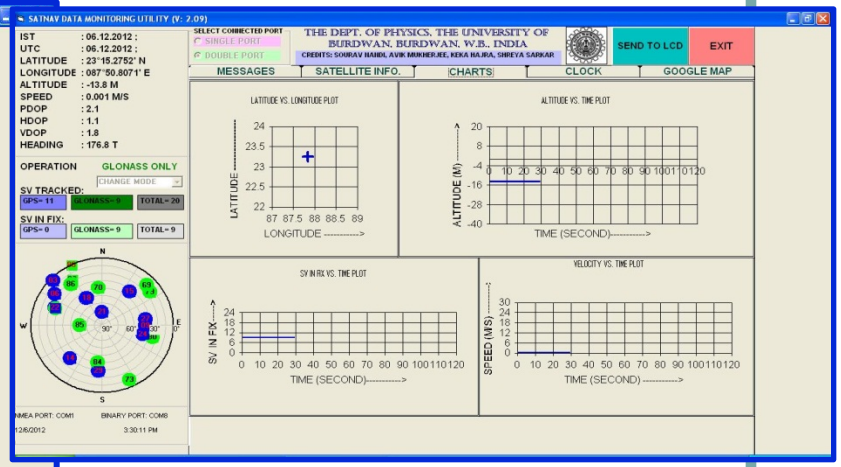
Experimental setup for JAVAD G3T receiver

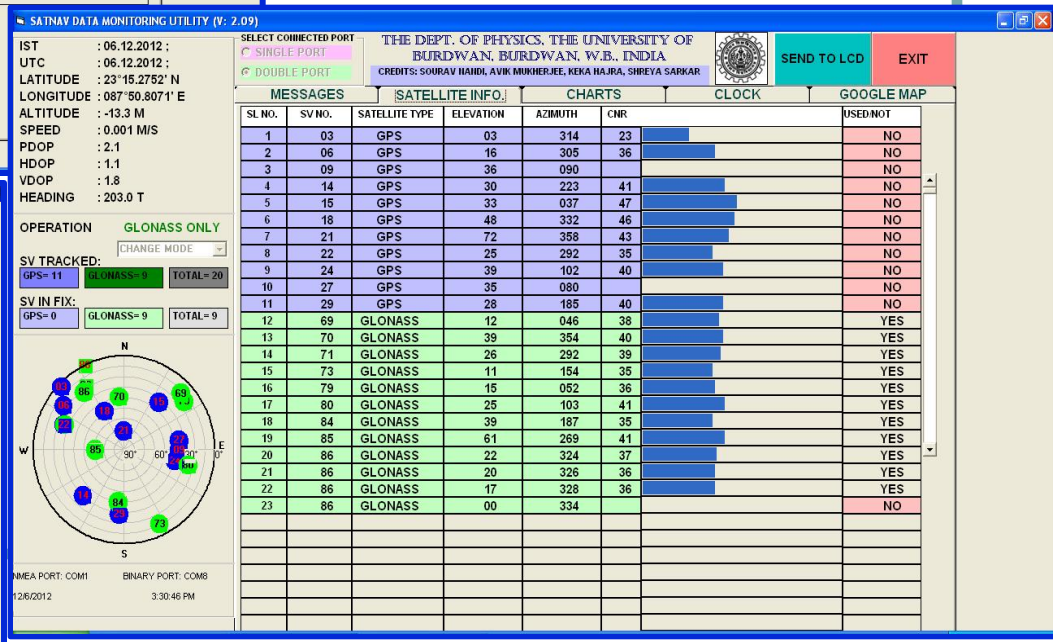


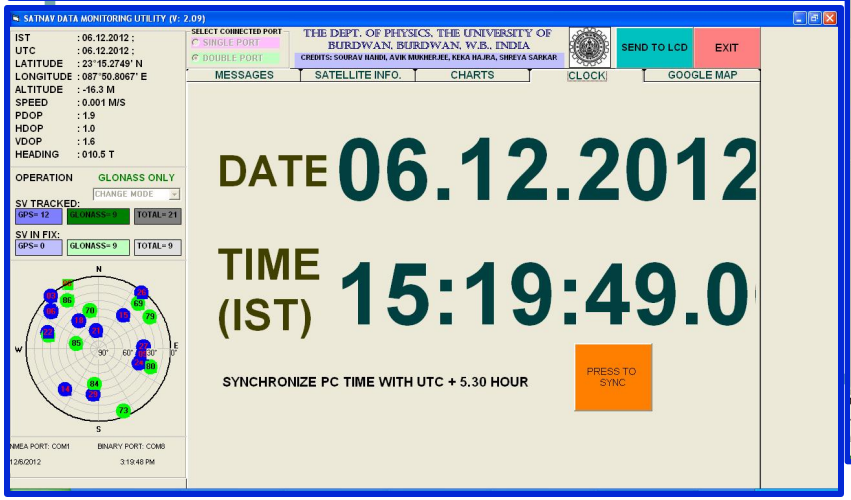
Data output: NMEA @1Hz; Cable length: 10m

Software (GoeS-1M)- in house developed







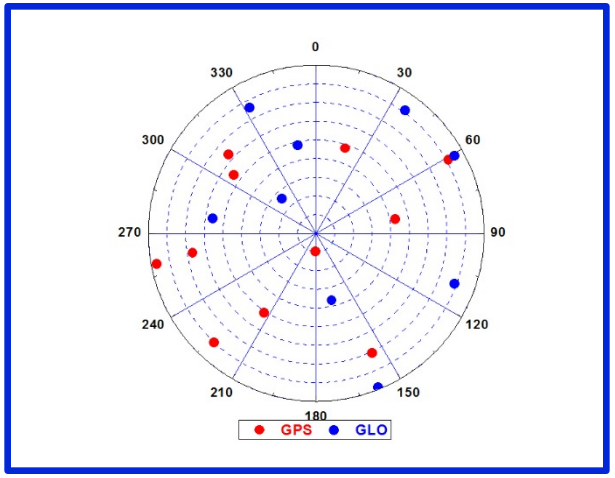


GLONASS Visibility and usability

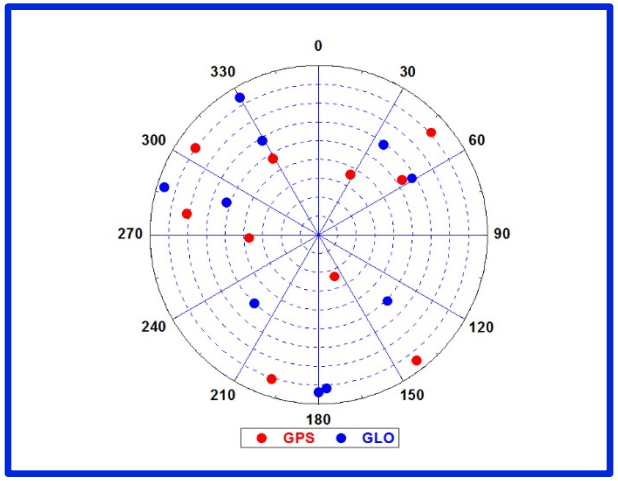
Place	Satellites in View			Satellites used		
	Max	Min	Avg	Max	Min	Avg
Burdwan	12	05	8.41	11	03	7.38
Balasore	12	08	9.45	11	06	8.57
Chennai	11	06	8.57	10	04	7.25
Goa	11	06	8.46	09	04	5.47
Pune	10	05	8.08	08	03	5.33
Panvel	11	06	7.69	09	04	6.19
Nagpur	11	05	8.81	10	05	7.48
Rajkot	11	05	8.79	11	05	7.83
Pilani	11	05	8.34	10	04	7.15
Noida	12	05	8.05	10	04	6.92
Dehradun	12	09	10.09	11	07	8.79
Shillong	12	07	8.21	10	04	8.09

- Except for transient time periods, at least 04 GLONASS are available for use
- Maximum 8 - 11 GLONASS are available for use above 5^0 elevation
- On an average, 7 to 9 GLONASS may be expected to be visible, out of which 05 or more may be used for solution

GLONASS satellite Visibility "Skyplots"



07/09/2012, 13;55:24 IST, Nagpur (West part), Rx #1



02/01/2015, 13:10:32 IST Burdwan, Rx #1

Elevations shown radially with zenith at the center and azimuth along the circumference of the circle, top indicating north

- In GPS+GLO mode, signals are available for use from all quadrants of the sky
- Total 14 – 22 satellites are available for use

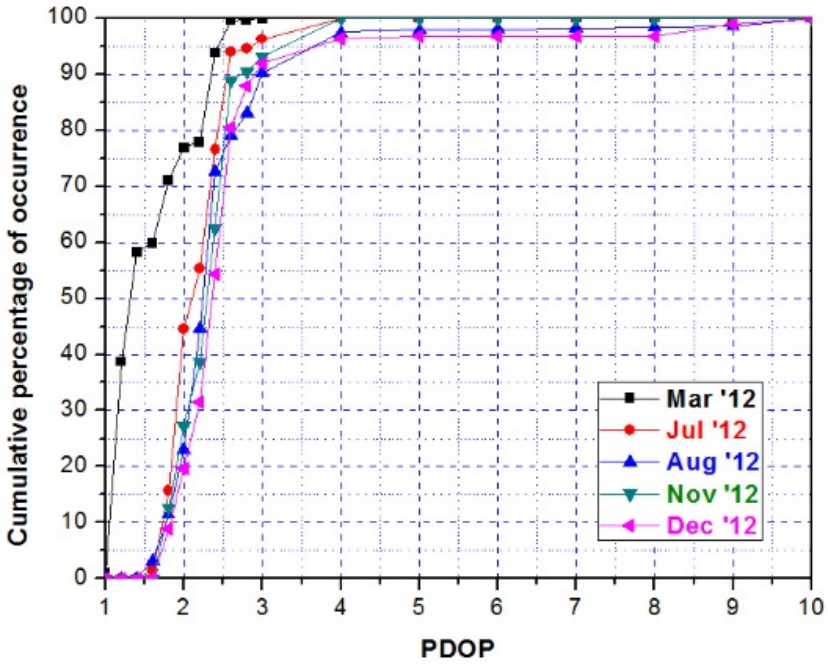
Result: Advantage of GPS+GLONASS

Data recorded with intentional degraded elevation mask angle

Elevation Mask Angle (deg)	Location	GPS satellite nos in use (Available GPS sats)	GLONASS sat. Nos in use (Available GLONASS sats)
30	Chennai	5 (12)	4 (9)
	Balasore	5 (13)	4 (6)
	Pilani	5 (10)	4 (9)
	Burdwan	7 (12)	3 (9)
45	Chennai	3 (13)	2 (10)
	Balasore	2 (12)	4 (9)
	Shillong	4 (12)	2 (9)
	Dehradun	3 (12)	3 (9)
	Burdwan	4 (14)	2 (9)

- In limited satellite visibility conditions (urban canyons or Deep foliage, simultaneous 04 satellite may be available only using GPS and GLONASS together

GLONASS and satellite geometry



Satellite geometry plays a significant role in accuracy of solution

PDOP is a quantitative measure of satellite geometry related to 3d solution

Data for a month are grouped together and the PDOP values are subdivided into 'range bins' of variable width (higher class widths for higher PDOP values).

Percentage and cumulative percentages are calculated and plotted against higher value of the range bin

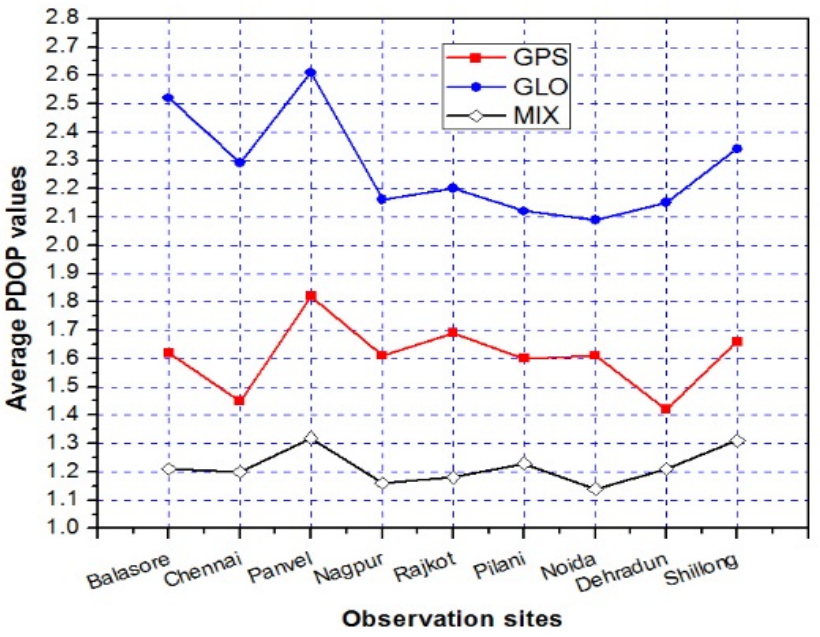
For 90% cases, GLONASS-only PDOP is below 3.0

GLONASS contribution in Multi-GNSS satellite geometry

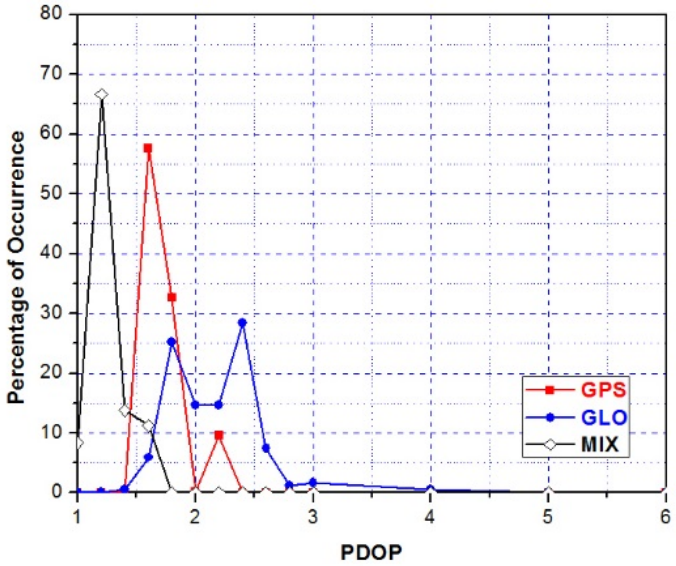
Month	Max PDOP			Min PDOP			Mean PDOP		
	GLO	GPS	MIX	GLO	GPS	MIX	GLO	GPS	MIX
Nov '11	2.8	1.6	1.6	1.5	1.1	1.2	2.34	1.52	1.45
Dec '11	2.3	2.4	2.3	2.2	1.1	1.1	2.28	2.36	1.65
Jan '12	2.0	1.4	1.2	1.6	1.0	1.0	1.89	1.38	1.04
Feb '12	2.4	1.4	1.4	1.6	1.1	1.0	1.89	1.37	1.25
Mar '12	3.0	1.5	3.2	1.5	1.7	1.0	1.84	1.37	1.25
Apr '12	1.4	1.3	1.3	1.0	1.0	1.0	1.51	1.21	1.16
May '12	1.8	1.3	1.3	1.6	1.0	1.0	1.89	1.53	1.32
July '12	3.0	1.3	1.3	1.6	1.0	1.0	2.09	1.87	1.50
Aug '12	3.5	1.3	1.3	1.6	1.0	1.0	2.15	1.75	1.47
Sep '12	2.4	1.7	1.6	1.6	1.3	1.0	2.12	1.62	1.25

PDOP variation for different GNSS modes, Burdwan, Rx #1

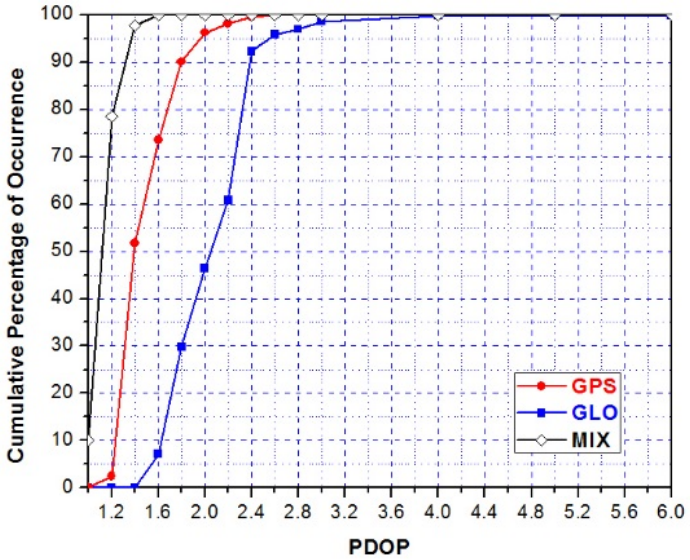
Average PDOP variation for different GNSS modes, Various places, Rx #1



GLONASS contribution in Multi-GNSS satellite geometry



PDOP distribution, Sept 2012, Burdwan, Rx #1

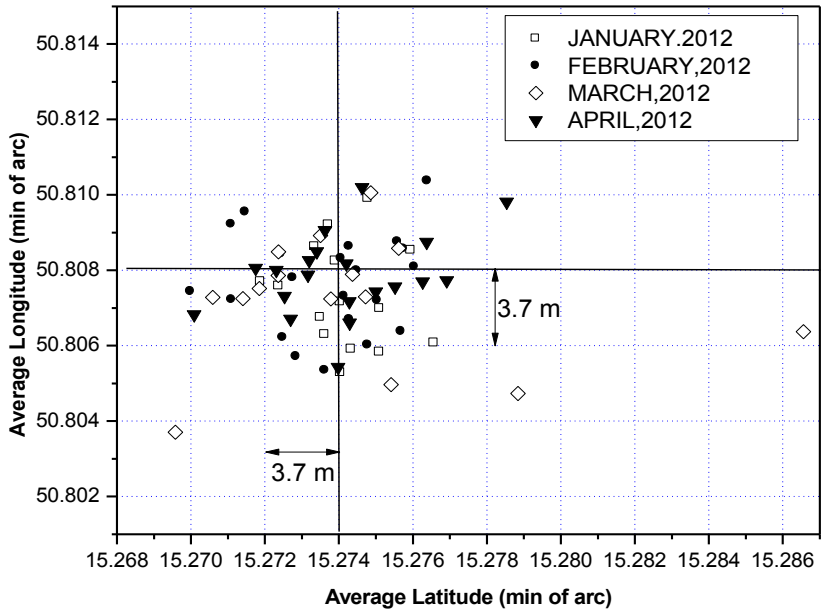


PDOP distribution, Feb 2012, Burdwan, Rx #1

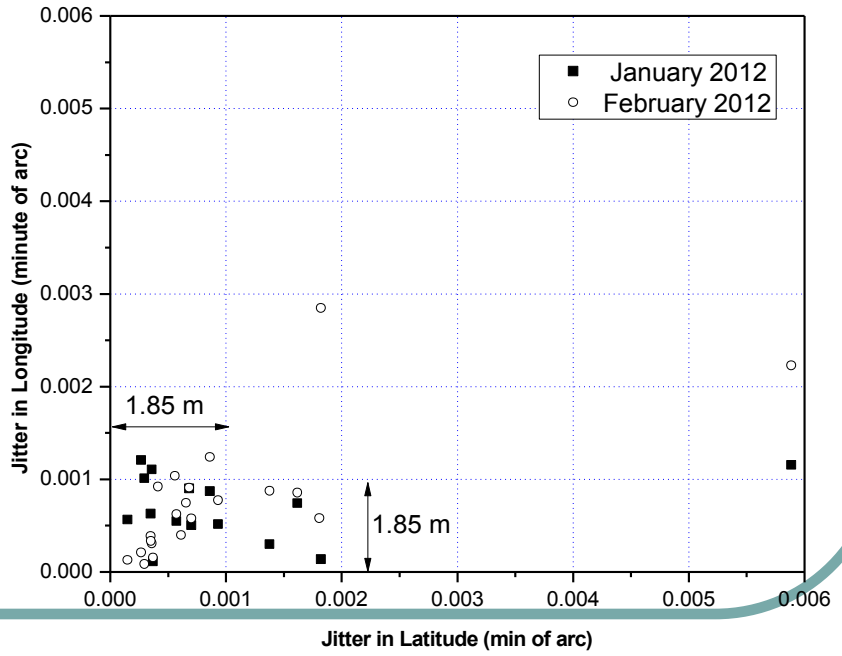
- GLONASS alone seems to provide worse satellite geometry in comparison to GPS but helps to obtain best geometries in GPS +GLONASS mode

Ref: A Study on Satellite Geometry Variation for Multi-GNSS from India, Anindya BOSE, (Ms) Keka Hazra and (Ms) Shreya Sarkar, *International Journal of Engineering Research*, Vol 3, Issue 10, October 2014, pp 575-579,

Result: Accuracy using GLONASS (Standalone, Burdwan)



Values for each nominal day of observation is plotted w.r.t. average GPS location as reference



GLONASS Stand-alone solution Accuracy

- **Collected data are categorized for a month for analysis**
- **Reference point for each antenna location is calculated averaging large number of GPS-only solution for each antenna location**
- **Coordinate Errors 2-d (2 dimensional) or 3d 3 dimensional) errors are calculated using the following formulas:**

$$\text{Latitude error } \Delta La \text{ (in meters)} = (L_i - L_0) \times 1852 \quad (1)$$

$$\text{Longitude error } \Delta Lo \text{ (in meters)} = (LO_i - LO_0) \times 1852 \times \cos(L_0) \quad (2)$$

$$Error_{2d} = \sqrt{\Delta Lo^2 + \Delta La^2} \quad (3)$$

$$Error_{3d} = \sqrt{\Delta h^2 + \Delta Lo^2 + \Delta La^2} \quad (4)$$

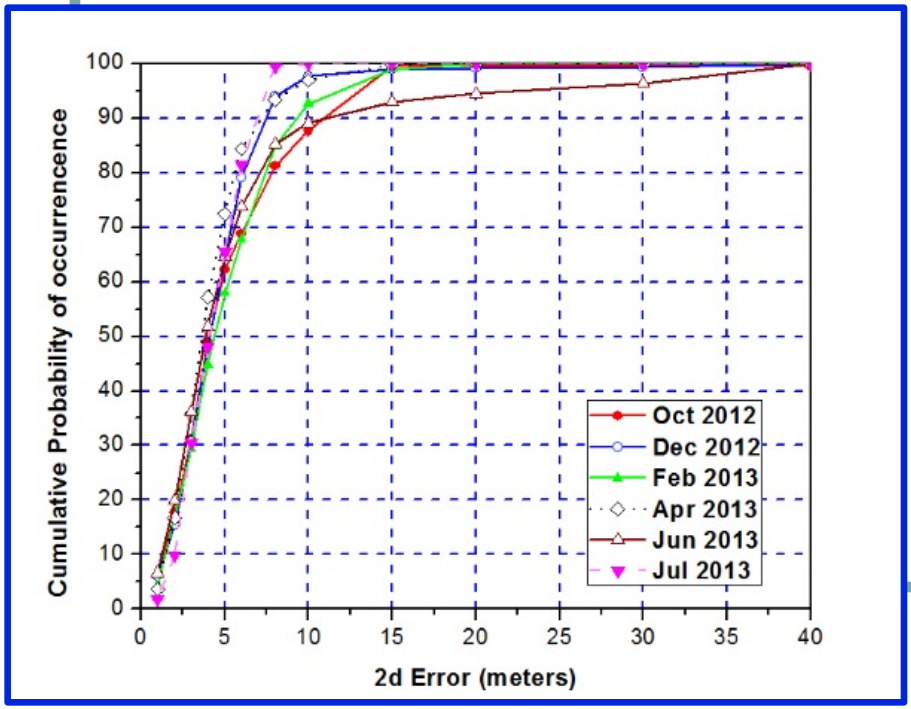
where, **L_0, and LO_0 are reference Latitude and Longitude of antenna**.
L_i and LO_i are instantaneous position solutions
***Δh is* Instantaneous height error in meters**

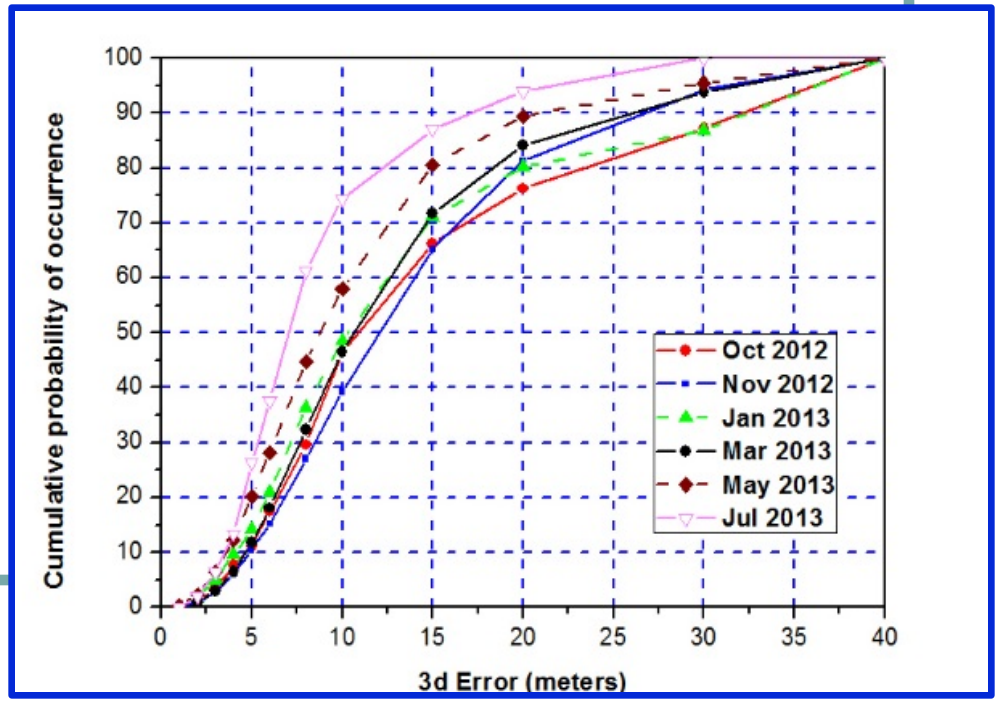
GLONASS solution Accuracy (Goes-1M)

Observation Month	Average Error (meters)		Standard Deviation of Error (meters)	
	2d	3d	2d	3d
Mar 2012	9.128	16.292	3.336	8.007
Sep 2012	4.818	9.275	2.295	5.007
Dec 2012	4.570	11.541	4.015	11.567
Apr 2013	4.078	9.697	2.357	5.925
Jul 2013	4.174	8.493	1.739	5.029
Apr 2014	3.545	6.707	2.861	2.901
May 2014	5.093	9.431	1.650	3.141

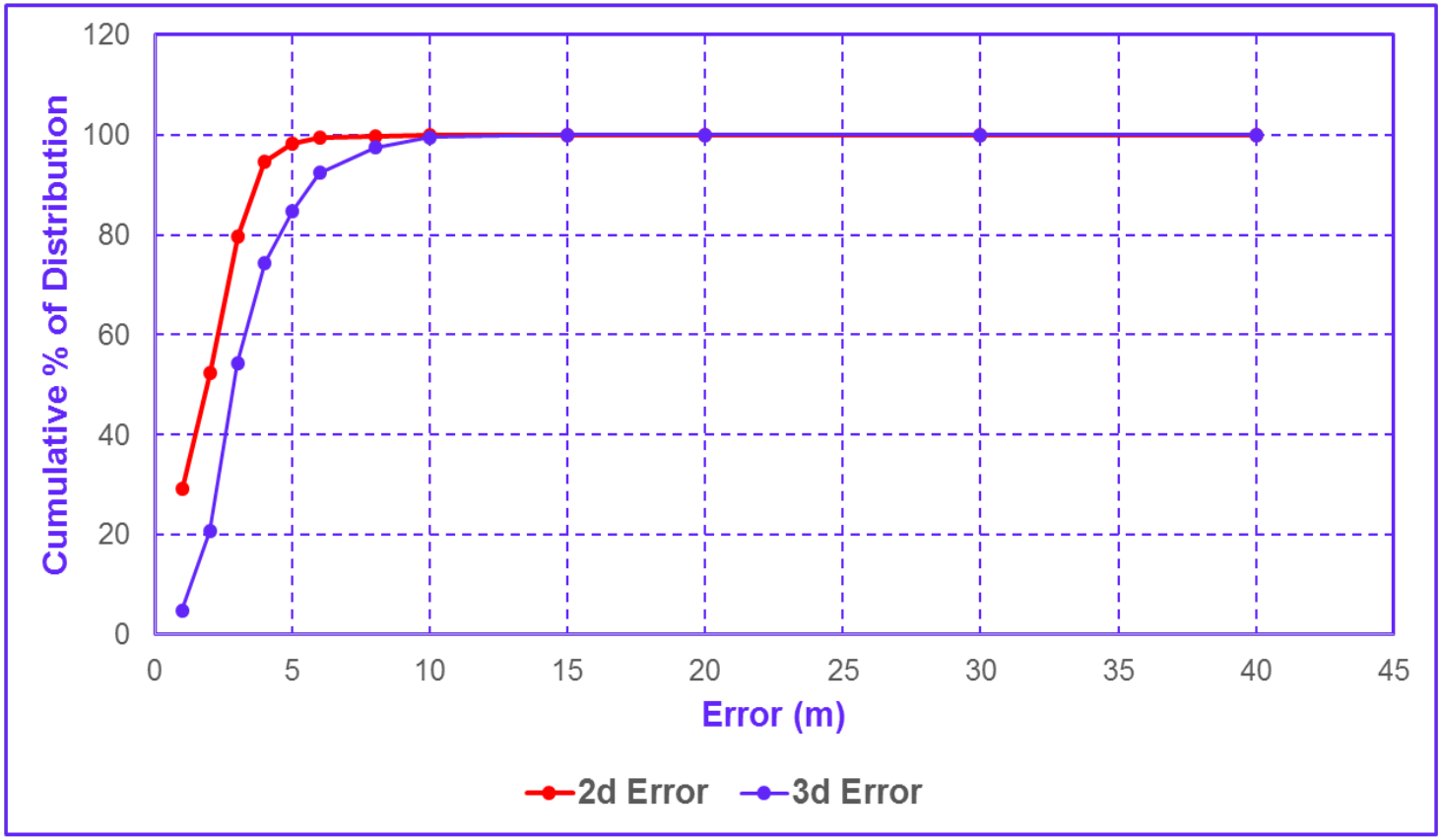
Data for a month is collected together and analyzed for 2d and 3d errors.

Data then divided into "error range bins" and cumulative occurrence % calculated



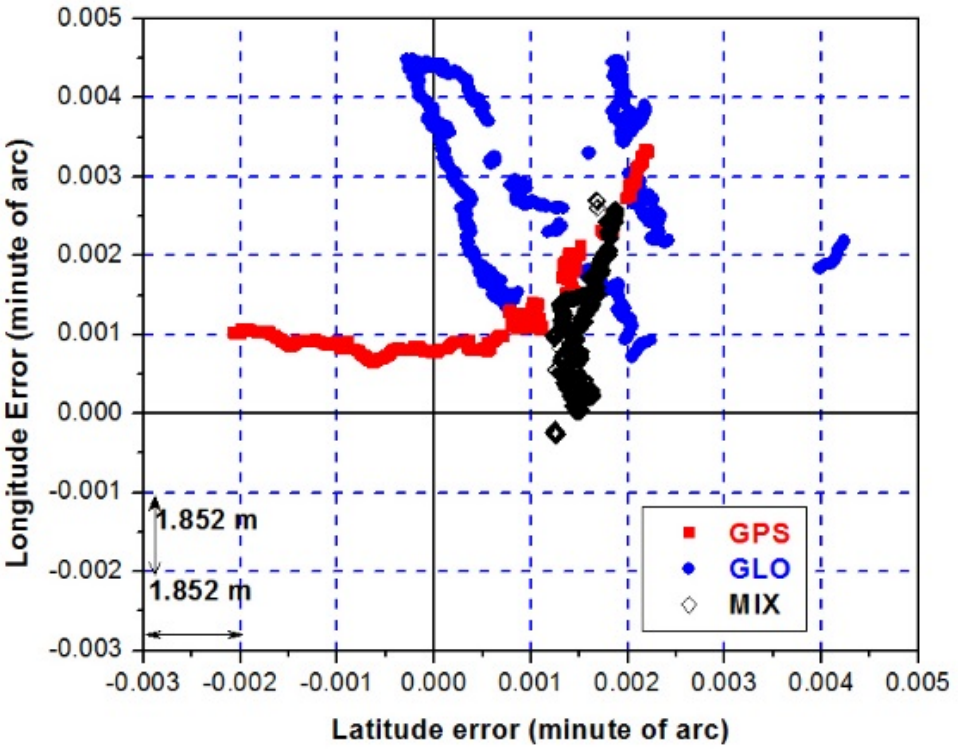


GLONASS only solution Errors



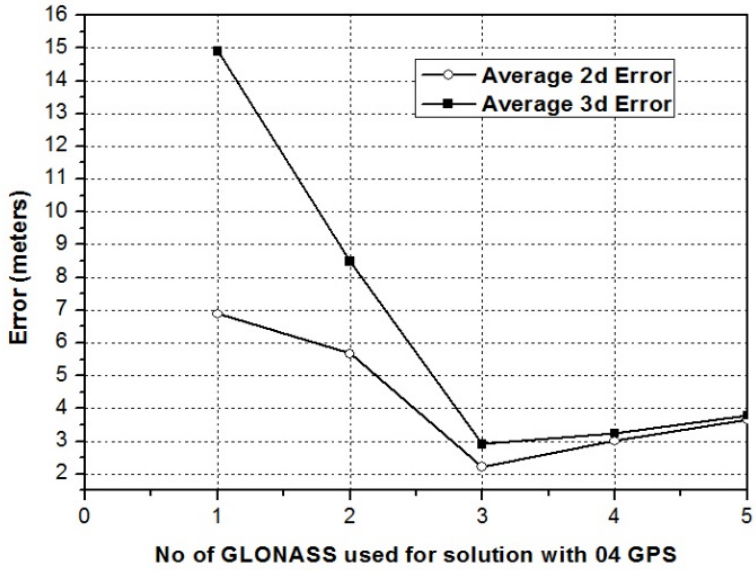
Javad G3T (with 0.2 mm GLONASS dynamic calibration, multi-frequency) November 2012, GLONASS only

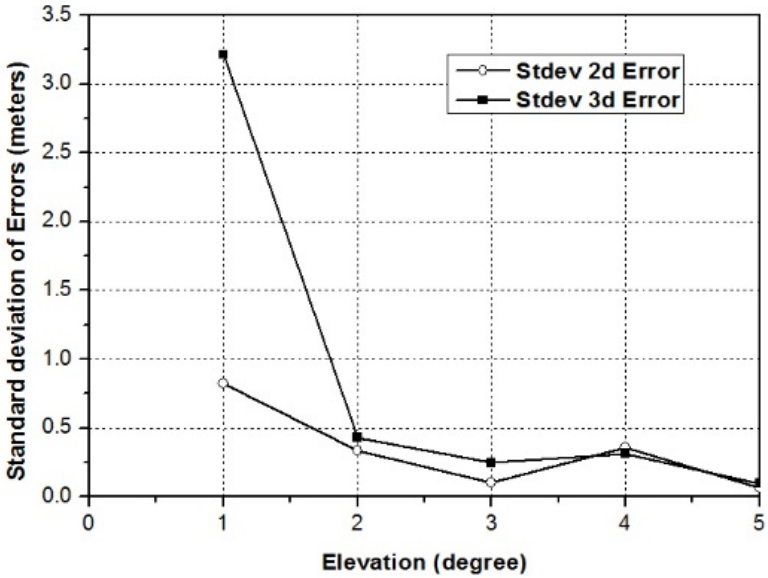
GPS-GLONASS Combined operation
Instantaneous Solution in different modes



1 hour data @1 Hz each for GPS, GLONASS, GPS+GLONASS
08/04/14, GoeS-1M

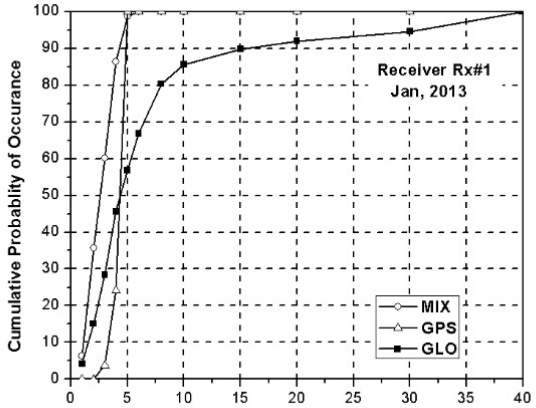
Effect of introducing increasing GLONASS with 04 GPS (27/05/2014: GoeS-1M)

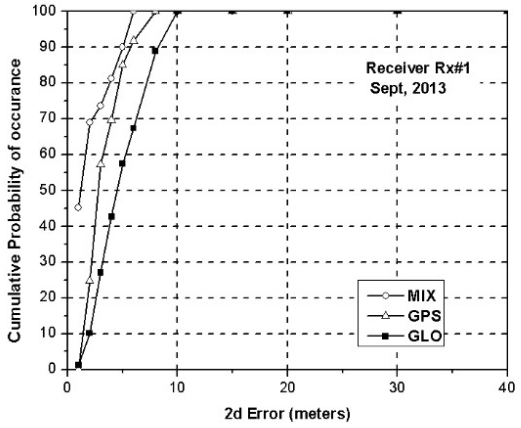




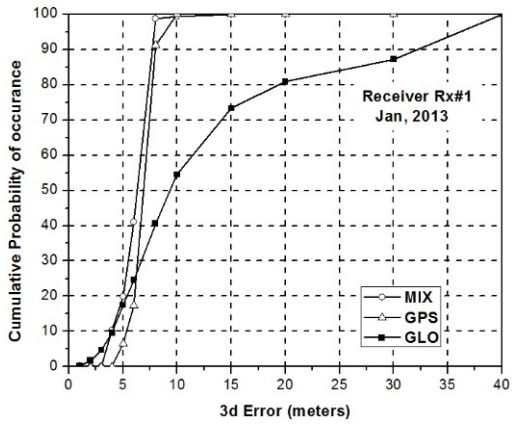
- Increasing GLONASS satellites (01 to 05) are introduced with 04 GPS satellites with modest geometry for solution
- 10-15 minutes data @ 1Hz are collected for each case
- Increasing GLONASS shows proportionally increasing solution

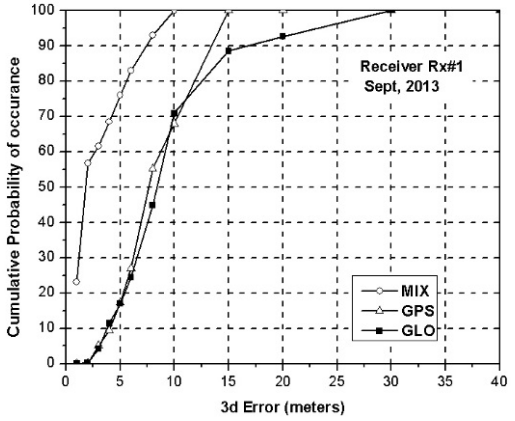
GLONASS contribution in Multi-GNSS operation





2 d errors





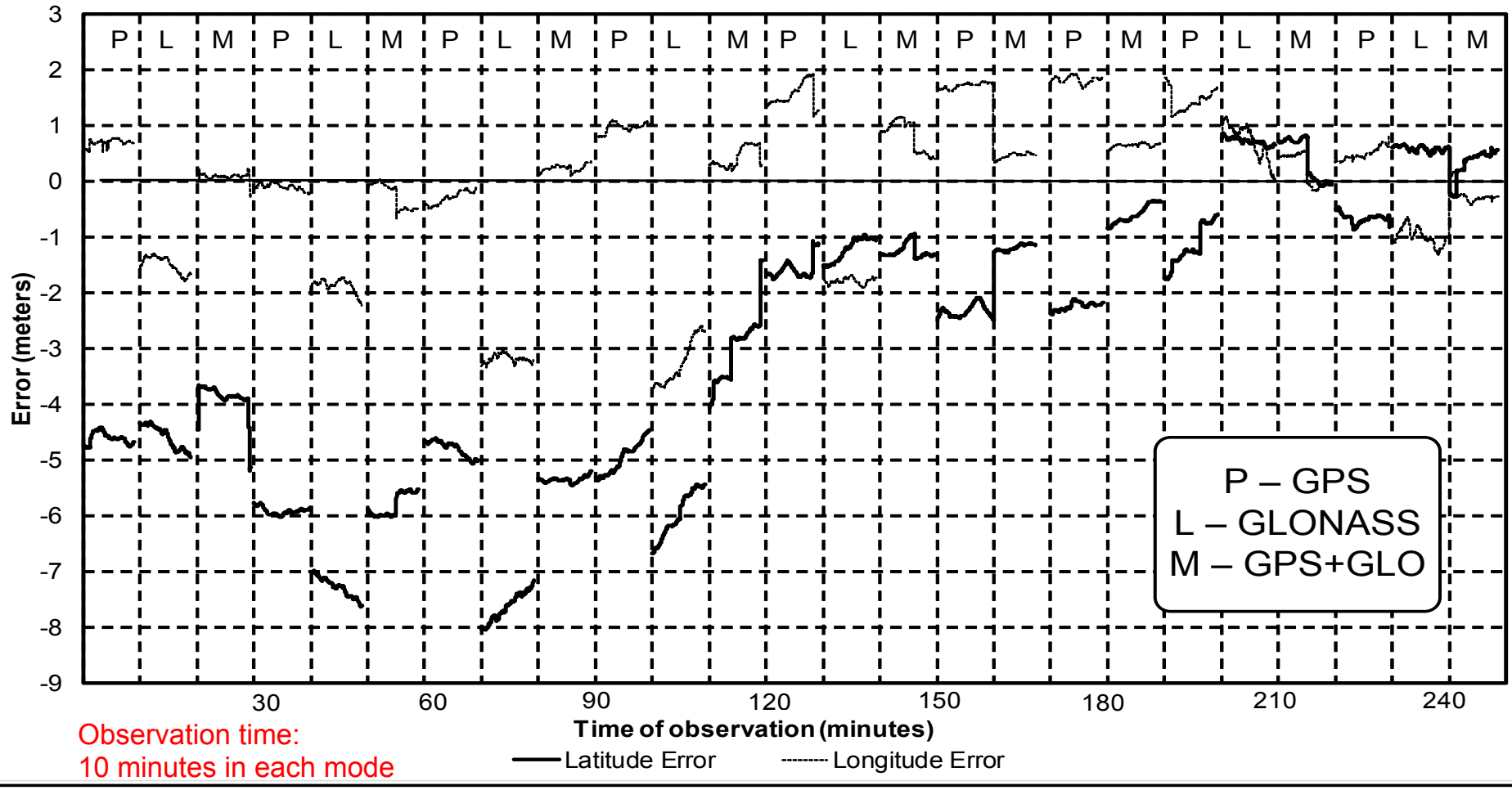
3d errors

GLONASS only mode shows worse solution accuracy than GPS

GLONASS strongly helps MIX operation providing best accuracy

GPS-GLONASS Interoperability
Solution Error (Receiver used: Javad G3T)

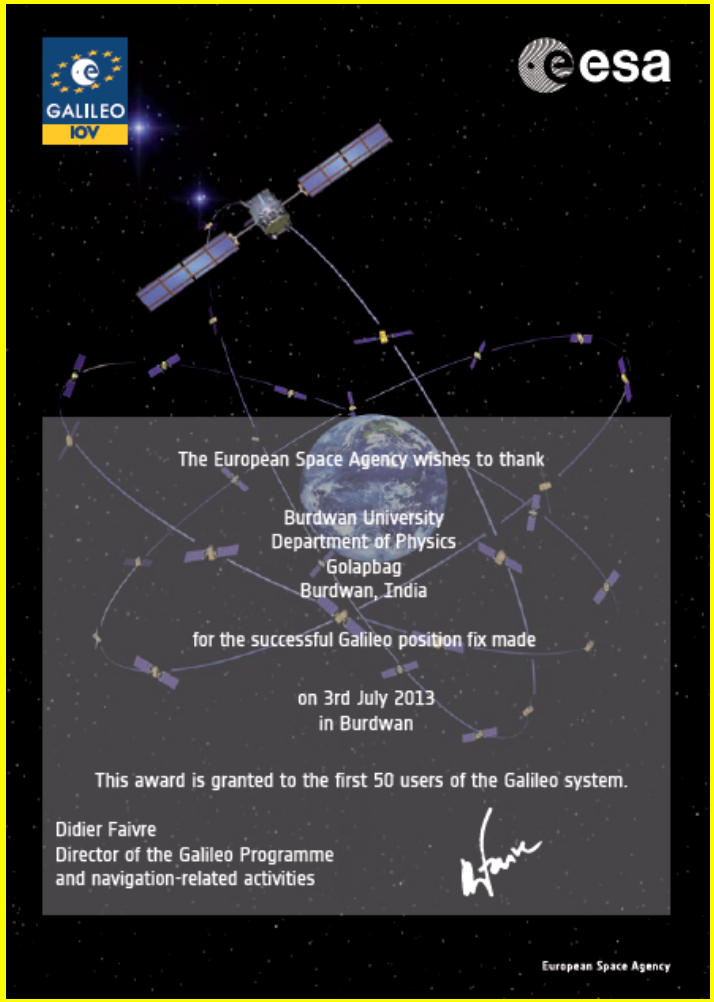
Instantaneous Error in latitude (in meters) = $(L_i - L_0) \times 1852$
Instantaneous Error in longitude (in meters) = $(LO_i - LO_0) \times 1852 \times \cos(L_0)$



Observation time:
10 minutes in each mode

GALILEO from India: our experience

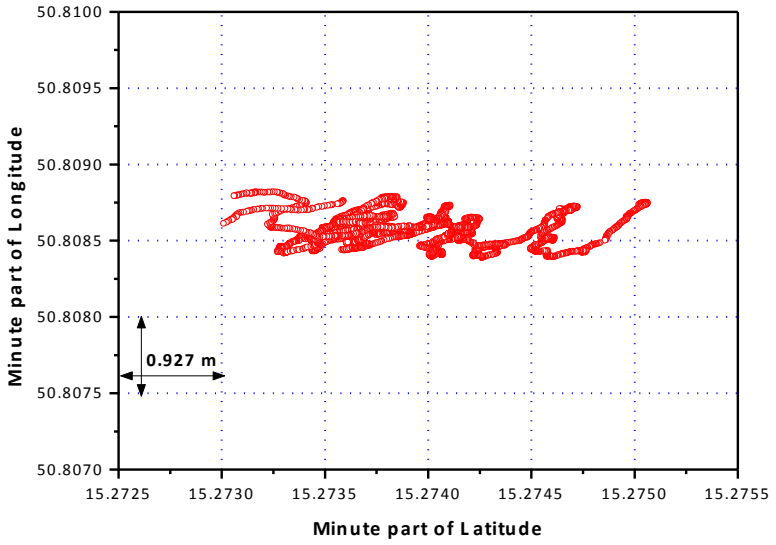
(Lat 23.2545^0 N, Lon 87.8468^0 E)



GALILEO-only Position Fix from India: First Experience

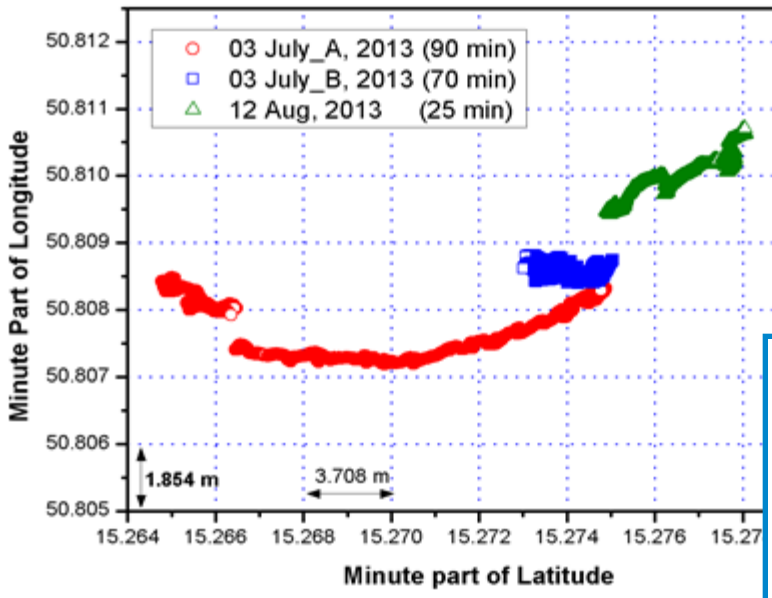
This paper reports the first successful Galileo-only 3-dimensional position solution obtained from Burdwan, India on 03 July, 2013. The paper also presents the initial observations of solutions obtained using one or more Galileo satellites with GPS and/ or GLONASS

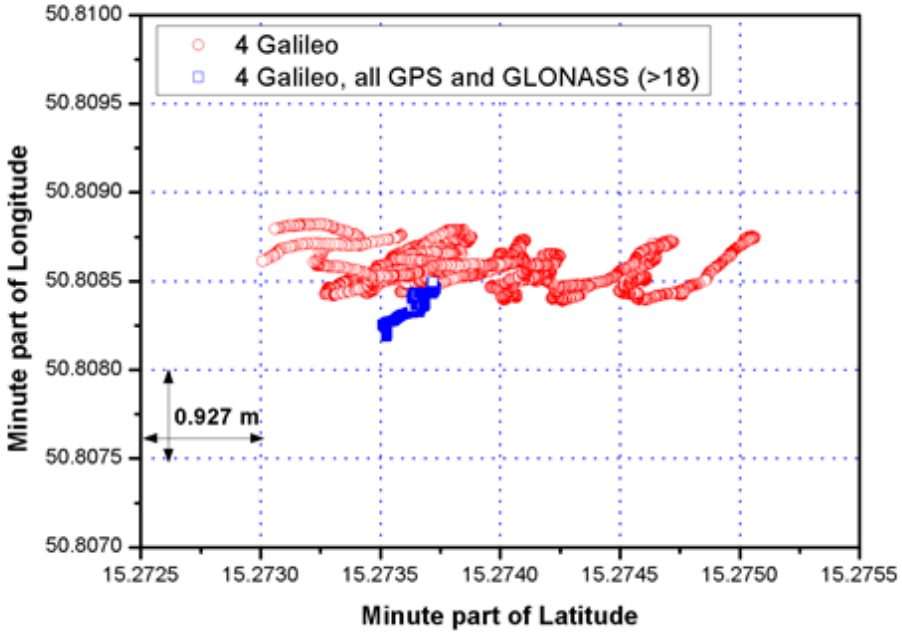
03 July, 2013



Ref: "GALILEO-only Position Fix from India: First Experience", **Anindya BOSE**, Saikat Das, Rakesh Malik and Debipriya Dutta, *Coordinates,* Vol IX, Issue 9, September 2013, pp 37 -41

GALILEO- stand alone and integrated solutions





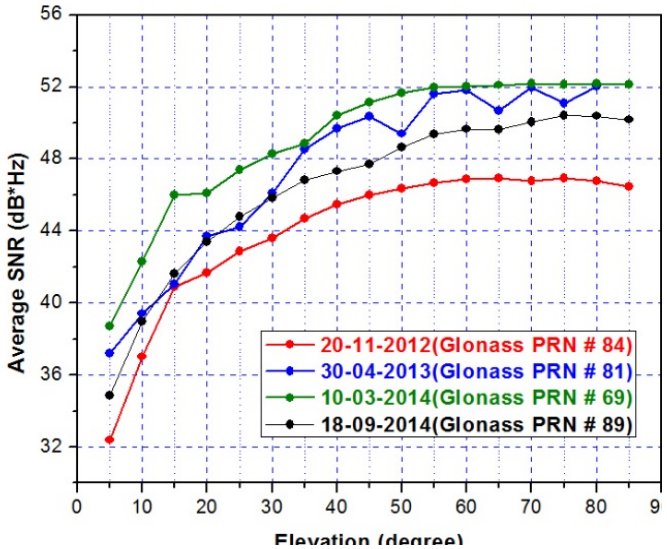
GALILEO- in Multi-GNSS Solutions

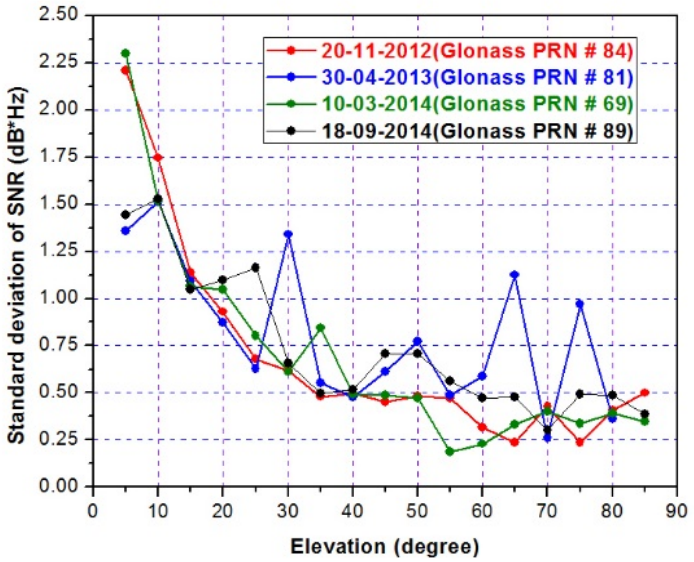
- **G=Galileo, P=GPS, L=GLONASS satellites; 1/2/3/4 = No of satellites used for a constellation,**
  A=all satellites in a constellation; σ denotes standard deviation of observation.

Constell-ation* used	No of Samples	Variation of (mt)						Mean PDOP	Remarks GPS/GLO sats)
		Latitude		Longitude		Altitude			
		σ	Max	σ	Max	σ	Max		
1G AP AL	3524	0.21	1.04	1.20	4.20	1.45	5.06	1.33	P=11; L=6
1G AP AL	2586	0.50	2.04	0.80	2.81	0.57	2.67	1.27	P=9;L=6
2G AP AL	4082	0.40	2.43	0.39	1.85	2.35	9.53	1.05	P=11;L=7
3G AP AL	1979	0.46	2.99	0.90	2.54	0.67	3.18	1.08	P=10; L=7
4G AP AL	739	0.09	0.41	0.11	0.58	0.26	0.82	1.06	P+L>18

GALILEO+GPS+GLONASS solutions

GLONASS Signal strength



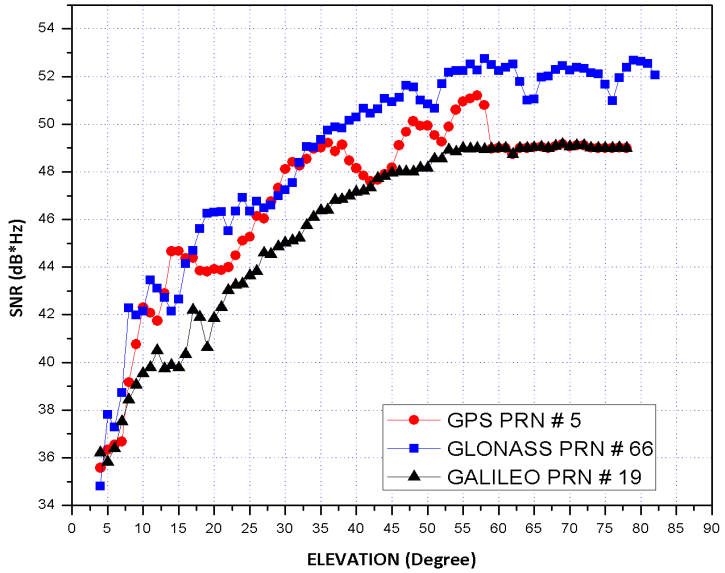


L1 Signal strengths for GLONASS is shown

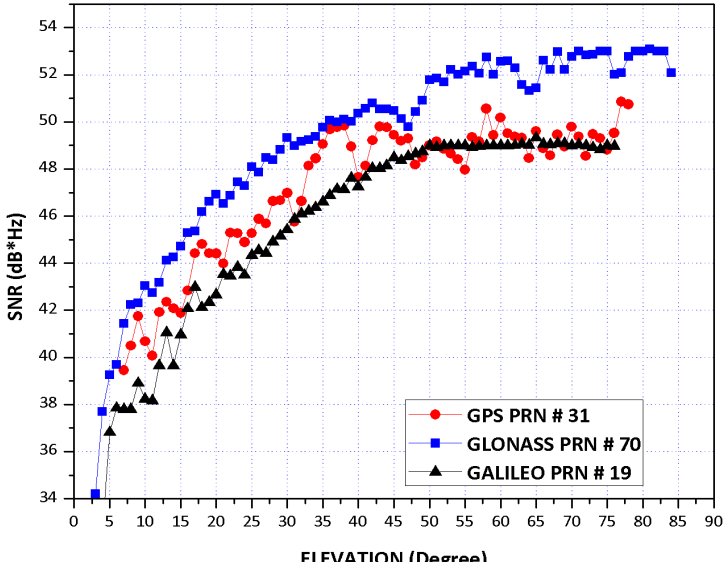
Signal strength increases with elevation, jitter decreases

Signal strength >40 db*Hz above 20^0 and saturates ~48 dB*Hz for elevation> 60^0

GLONASS and other GNSS signal strengths



19/09/14, Burdwan



17/02/15, Burdwan

GLONASS shows higher and stable (than GPS) signal strengths- may be useful for TTFF considerations during solution developments

"Studies on GNSS signal strengths from India", Debipriya Dutta, Shreya Sarkar and **Anindya BOSE**, *Proc. NSCMLC 2015,* Burdwan, India, 27–28 February, 2015, p 57

Conclusion

- GLONASS is now an attractive and the only fully operating GNSS alternative other than GPS from India with sufficient number of usable satellites.
- GLONASS can be used both as an independent system with slightly degraded accuracy and as a complementary system to GPS in GPS+GLONASS modes of operation.
- More satellites scattered over the sky may help in minimizing the problem of limited satellite visibility from certain locations and for mitigating atmospheric effects – all these point towards the advantages of use of Multi-GNSS for cost effective solution developments.
- GPS-GLONASS INTEROPERABILITY IS AN IMPORTANT ISSUE

Issues

- India is a potentially large market for GNSS and LBS – where use of GLONASS may help all stakeholders and in development of mass-market solutions
- Not much information/ awareness about GLONASS and potentials in comparison to GPS
- Low-cost, good quality GLONASS enabled devices/ Boards/ Chipsets are not readily available in Indian market
  - Efforts for system study using several low-cost devices from multiple manufacturers was impaired
  - Experience with some products (from other countries) is not good – that may negatively affect the GLONASS popularity
- For enhanced confidence level on GLONASS, information about the measures taken to mitigate any future system failure risk need to be properly propagated among the stakeholders

Scopes

- Awareness enhancement on GLONASS and other future systems
- Need of channels for easy distribution of GLONASS enabled hardware for mass-market product development
- GNSS Activity Group, BU looks forward to use our experience and expertise in promoting the use of Multi-GNSS for the Indian users through
  - International Collaboration, and Interaction with Industries/ Solution Developers
  - Assessment and validation of GNSS Hardware performances from the Indian region– we welcome any interested entity for joint activity
  - Data sharing



THANK YOU



http://bugnss.webs.com/

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