Initial Results of IRNSS Standalone and Hybrid Operations

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GNSS Activity Group, BU

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

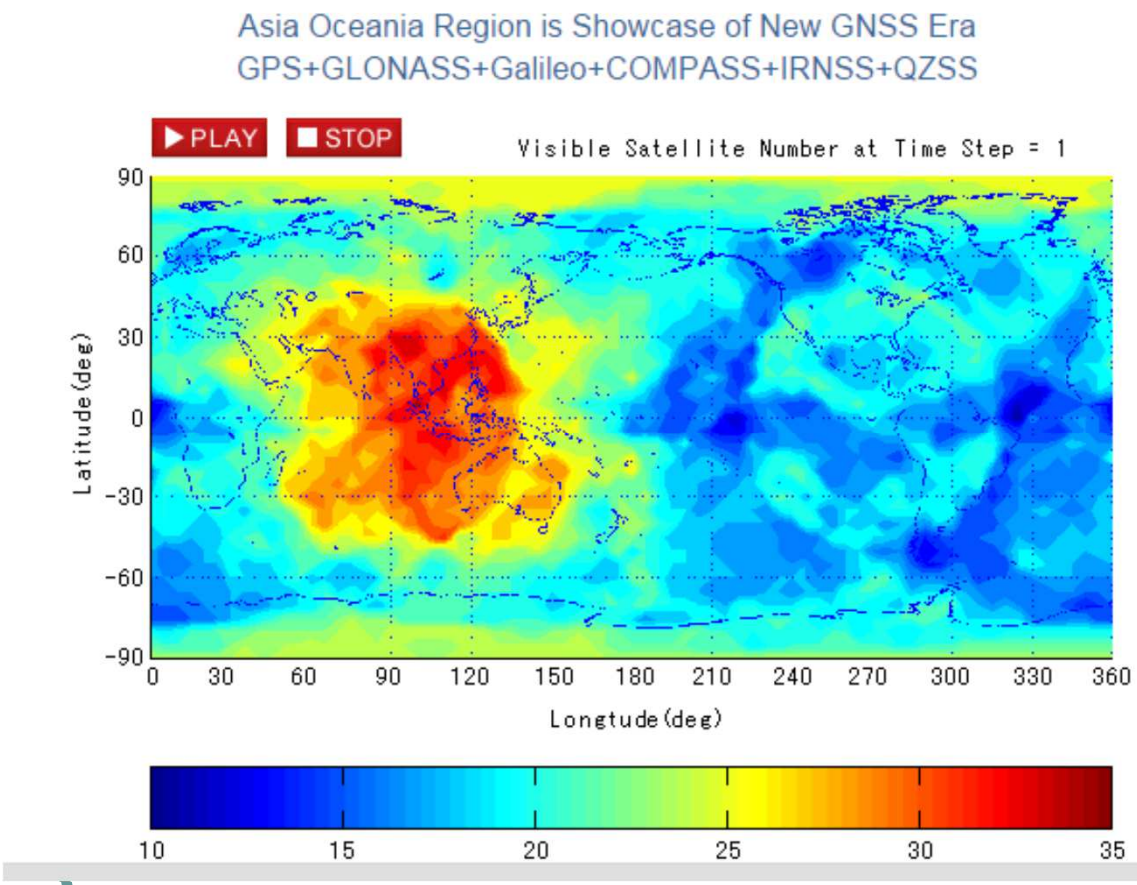
- GNSS activity group, The University of Burdwan, India is engaged in R&D activities on GNSS with focus towards:

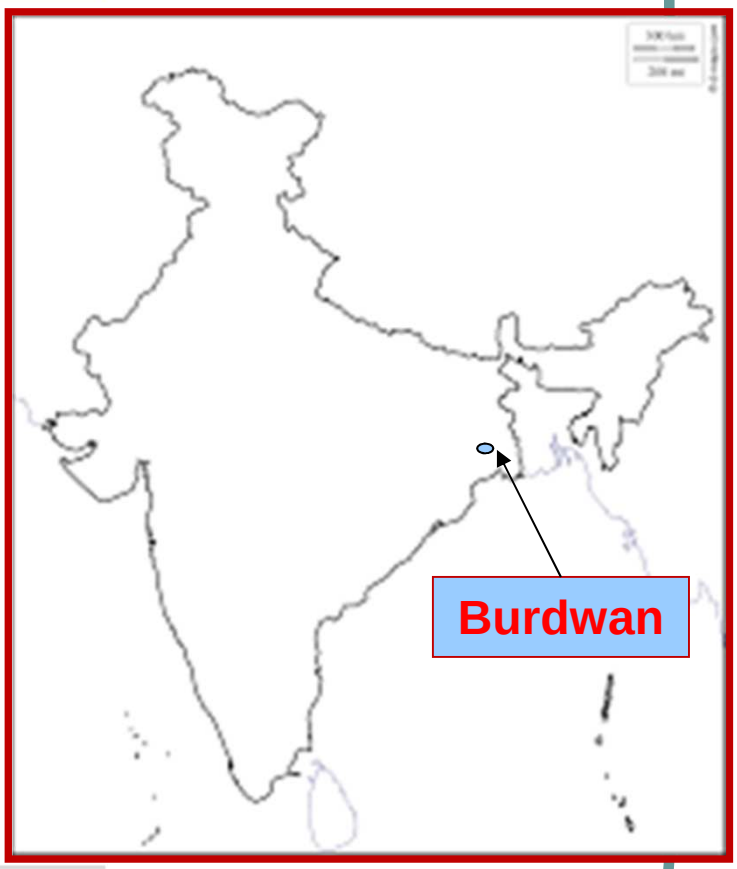
  1) Exploration of the Multi-GNSS environment from India
  2) Development of cost-effective applications and solutions
  3) Capacity Building

- Sponsored Projects from Govt of India
- Support to R&D efforts of other academic Institutions, Data sharing
- Member, Multi GNSS Asia (MGA)
- Collaboration with Industry
- **We look forward for Cross-border Collaborations**

Contents

India: advantages for Multi-GNSS





- Use of multi-GNSS would be available for the users of the region
- IRNSS enhances the scope

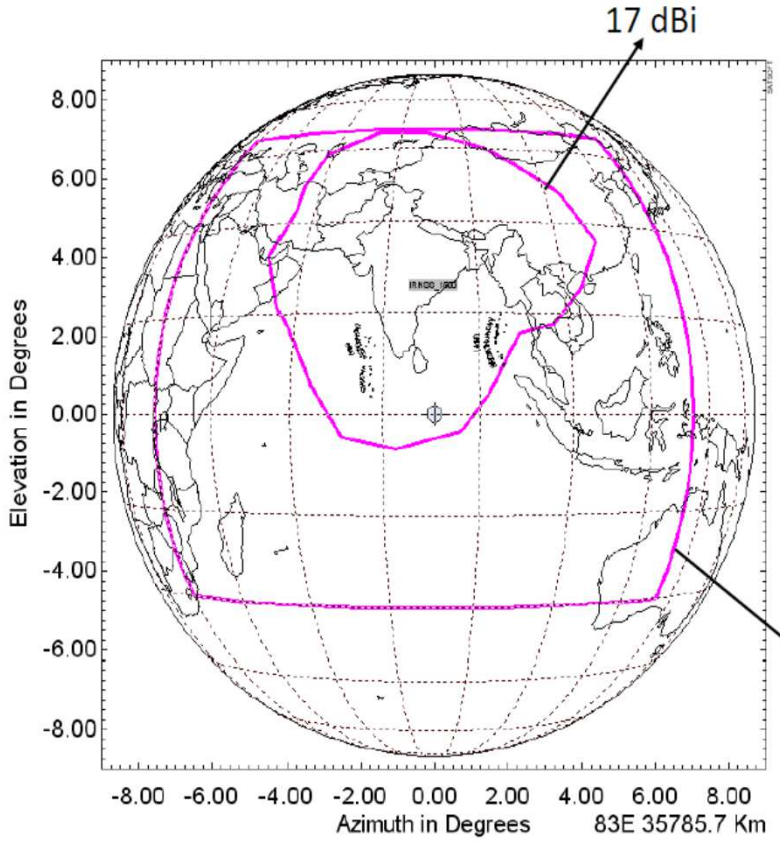
Source: http://www.multignss.asia/campaign.html

IRNSS: Introduction

- **IRNSS (or NAVIC) is a Regional satellite based navigation system** developed by ISRO to provide PVT information for the Indian and the surrounding region.
- **In April 2016**, ISRO successfully completed launched all the **07 IRNSS** satellites using the Indian launcher PSLV.
- Among these, **03 satellites are located in GEO** and the rest **04 satellites are located in GSO** with an **inclination of 29°**
- Arrangement ensures continuous radio visibility of all the 07 satellites from the operational zones.
- Expected to provide position accuracy of **better than 20 meters** over India and a region extending outside the land mass up to **about 1,500 kilometers**.

IRNSS: Primary and Secondary Coverage Areas

IRNSS Coverage



Primary Service Region Polygon for IRNSS-1C:

India mainland and surrounding 1500 km

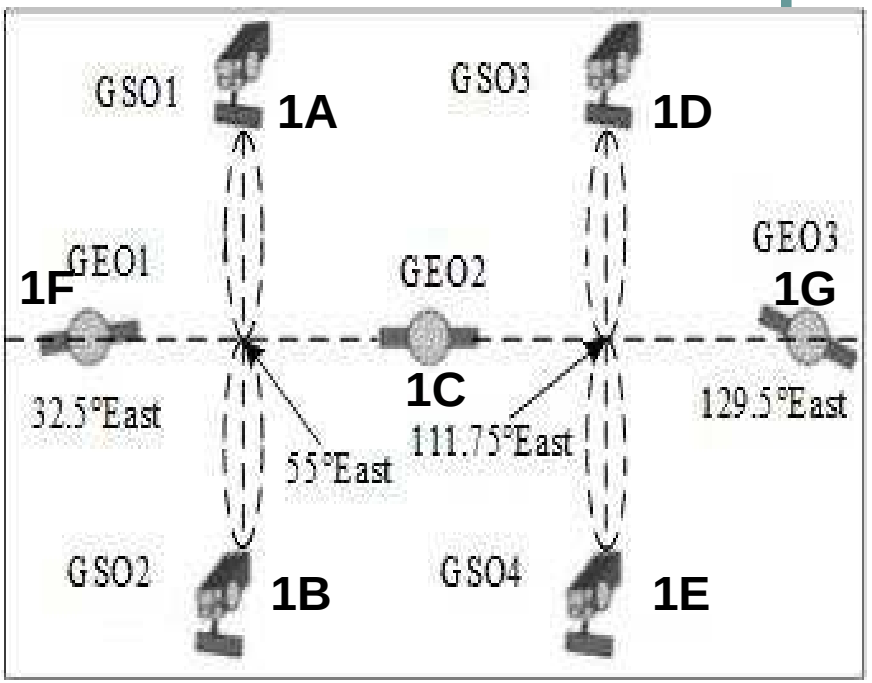
Extended service Region Polygon:

Long. 30° E to 130° E,

Lat. 30° S to 50° N

IRNSS: Launch History, Constellation Plan

Satellite	Launch Date	Placed in	Location (Long)	Expected Lifetime (Mission Life), years
IRNSS 1A	01 July, 2013	GSO	55^0 E	>10.0
IRNSS 1B	04 April, 2014	GSO	55^0 E	
IRNSS 1C	16 October, 2014	GEO	83^0 E	
IRNSS 1D	28 March, 2015	GSO	111.75^0 E	
IRNSS 1E	20 January, 2016	GSO	111.75^0 E	
IRNSS 1F	10 March, 2016	GEO	32.5^0 E	
IRNSS IG	28 April, 2016	GEO	129.5° E	



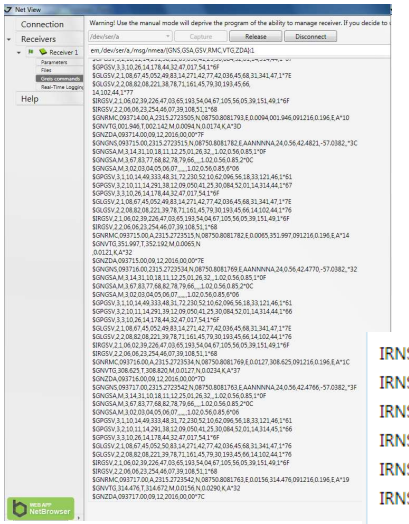
IRNSS constellation plan

IRNSS: Features

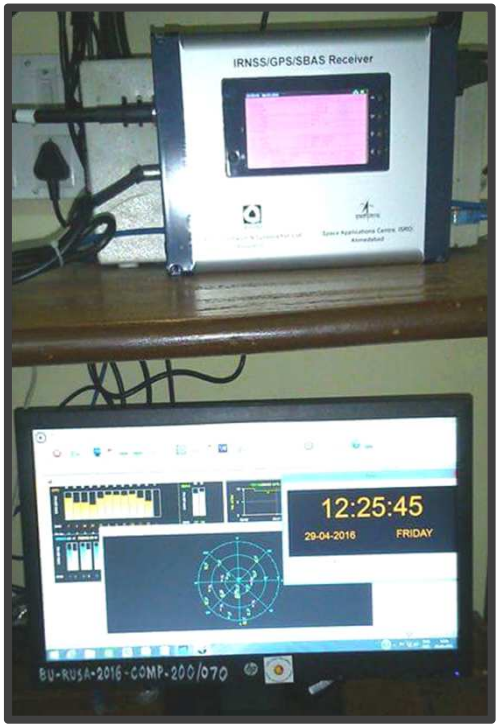
- Transmit signals in L (1164.45 – 1188.45 MHz) and S band (2483.5-2500 MHz)
- Provision for text message transmission

IRNSS SIS ICD FOR STANDARD POSITIONING SERVICE, *VERSION 1.0,* ISRO SATELLITE CENTRE, INDIAN SPACE RESEARCH ORGANIZATION, BANGALORE, June 2014

Experimental Set up at UoB



IRNSS	5	38	152	49	>18h	45	/
IRNSS	2	39	226	50	>18h	45	/
IRNSS	3	65	194	53	>18h	45	/
IRNSS	6	23	254	42	>18h	45	/
IRNSS	4	67	104	55	>18h	45	/
IRNSS	7	39	108	50	>18h	45	/



- ✓ Data from the IRNSS-GPS-SBAS (IGS) receiver at 1 Hz frequency are recorded (IRNSS L5 and S1),GPS(L1) and SBAS (GAGAN) since May, 2016.
- ✓ NMEA Data from the JAVAD DELTA receiver @1 Hz frequency are recorded (L5 only, GPS(L1) since November 2016.

Data Collection Plan

IGS Rx (GPS L1, IRNSS L5, S, SBAS)

In built data recording and output generation

Solution Files in .csv format

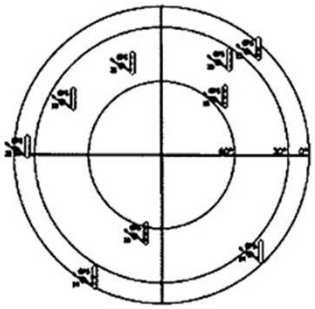
JAVAD Rx (GPS L1, IRNSS L5)

NMEA data recording using updated firmware

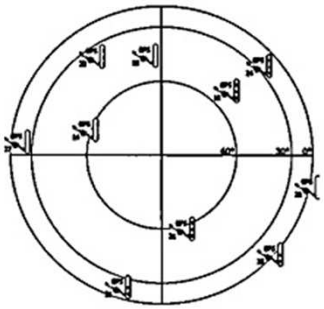
NMEA data extraction utility

ASCII data for further processing

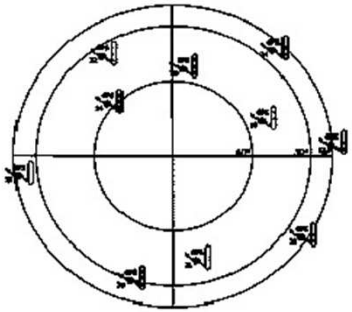
IRNSS: helping Multi-GNSS availability



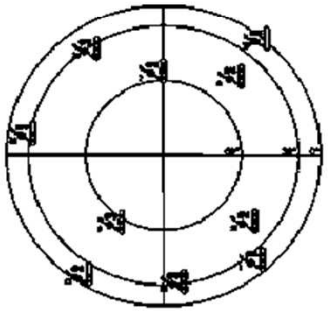
27 August, 2015



30 December, 2015

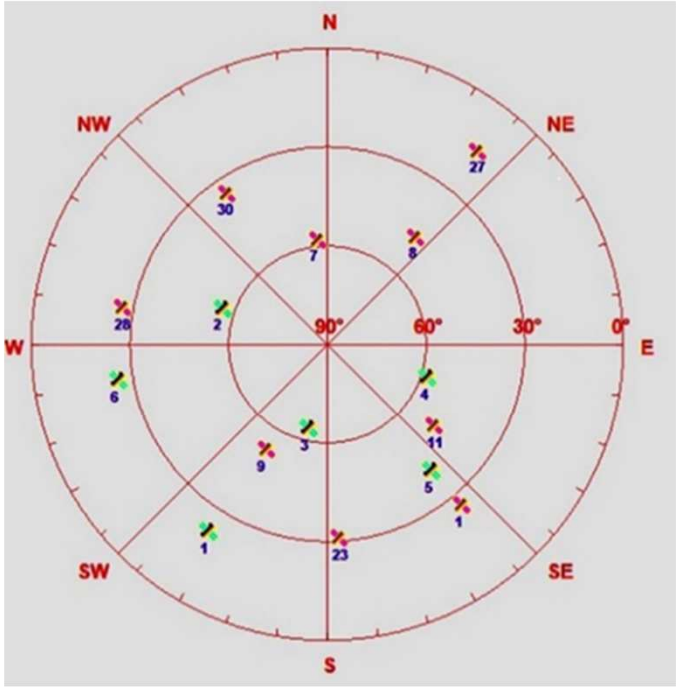


13 January, 2016



08 February, 2016

Absence of GPS satellites above 60^0 elevation angle observed from UoB (Javad DELTA G3T)



All GPS satellites lie below 60^0 elevation and IRNSS 1C above it, observed from UoB, 28 April, 2016, 14:00 hrs IST (IRSO-ACCORD IGS receiver)

This situation may create problem for cases where the lower elevation angles are obstructed

IRNSS visibility: a theoretical study

Approximate elevation and azimuth angles for IRNSS GEO at 83° E (IRNSS-1C) from different locations of India

Place	Approximate location		Look angle for IRNSS 1C	
	Lat (°N)	Lon (°E)	Elevation (degree)	Azimuth (deg)
(North)	(l_e)	(L_e)	(EL)	(AZ)
Jammu	32.73	74.86	50.9	165.2
Delhi	28.61	77.21	56.0	168.0
Allahabad	25.44	81.84	60.2	177.3
Burdwan	23.26	87.96	62.1	192.4
Nagpur	21.15	79.10	64.8	169.3
Bangalore	12.97	77.59	73.5	157.1
Kanyakumari (South)	8.09	77.54	78.5	145.8

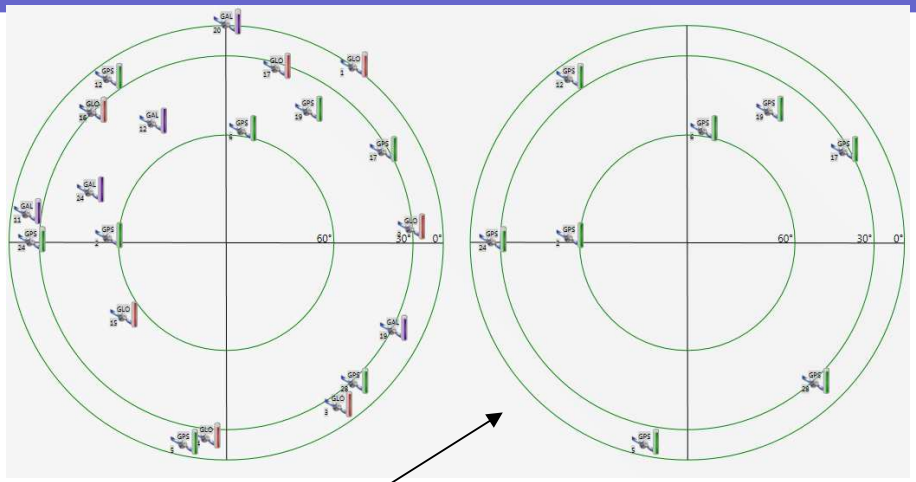
1. Susch, H. P., 'Calculating antenna bearing for geostationary satellites', Ham Radio, May 1978, pp 67-69, available online at www.setileague.org/articles/ham/geosynch.pdf
2. Ayansola,O. D., Yinusa, A. A., 'Mathematical Model of Antenna Look Angle of Geostationary Communications Satellite Using Two Models of Control Stations', International J. Advanced Computer Science, 2012, 2, (9), pp. 348-351

Satellite geometry in GPS-IRNSS hybrid mode (simulations)

Satellite Geometry for all GPS Satellites below 60^0 elevation, UoB, INDIA			
Observation Date	Time IST	No. of used GPS Satellites	PDOP
27 August, 2015	18:41	9	1.42
30 December, 2015	12:52	10	1.62
13 January , 2016	12:11	10	1.57
8 February, 2016	18:15	10	1.72

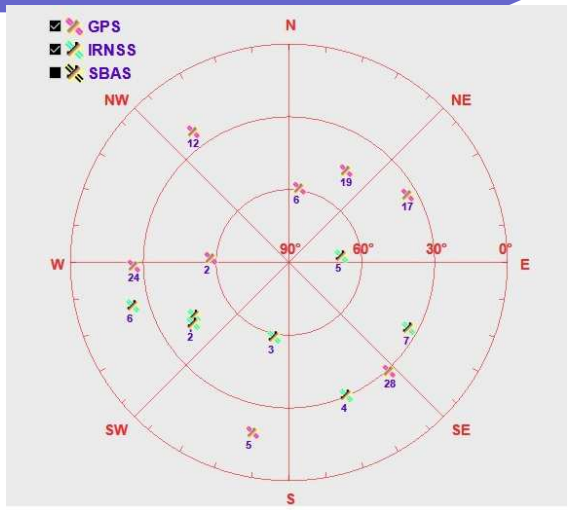
Satellite Geometry for GPS Satellites below 60^0 elevation in hybrid operation with IRNSS satellites from UoB				
Date and Time (IST)	PDOP values for 10 GPS satellites below 60^0 elevation angles operating with			
	No IRNSS (GPS only)	01 IRNSS (1C)	02 IRNSS (1A, 1C)	03 IRNSS (1A, 1C, 1D)
08/02/2016, 18:15	1.72	1.56	1.49	1.48
08/02/2016, 18:22	1.75	1.58	1.52	1.49

IRNSS: Augmenting satellite visibility at higher elevation angles

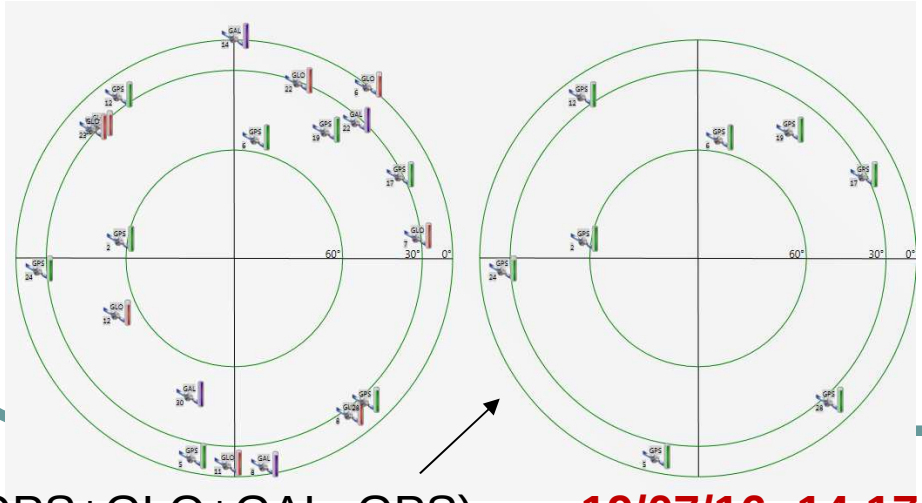


(GPS+GLO, GPS)

14/07/16: 14:30 IST

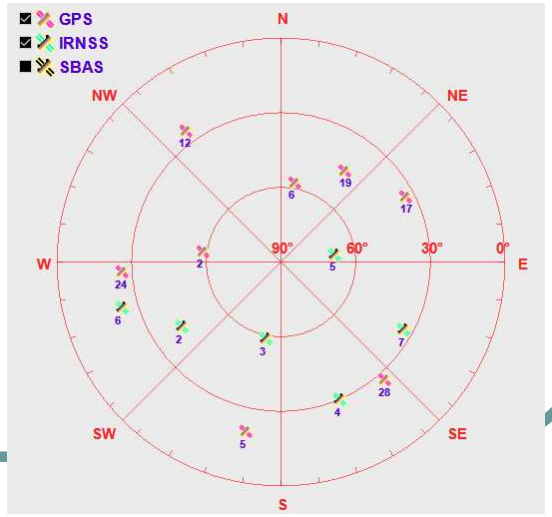


(GPS+IRNSS)



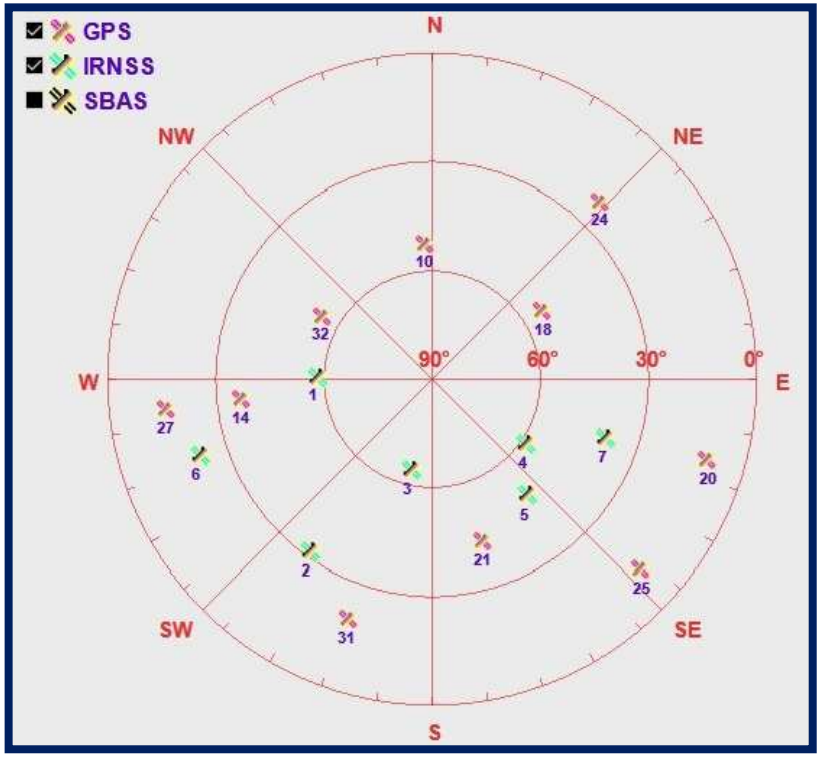
(GPS+GLO+GAL, GPS)

19/07/16: 14:17 IST

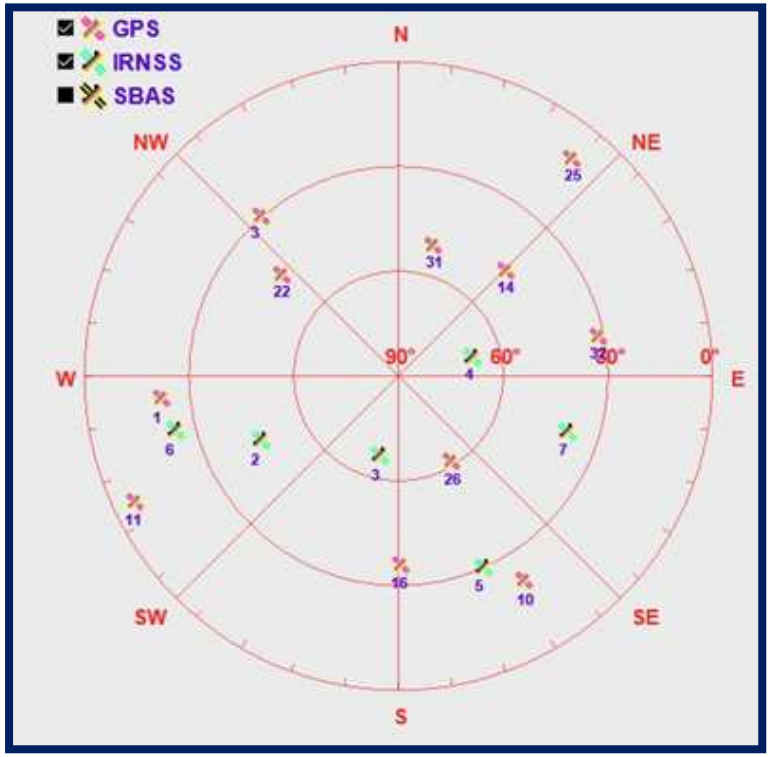


(GPS+IRNSS)

Examples (IGS Rx)



20/09/16; 18:50 IST

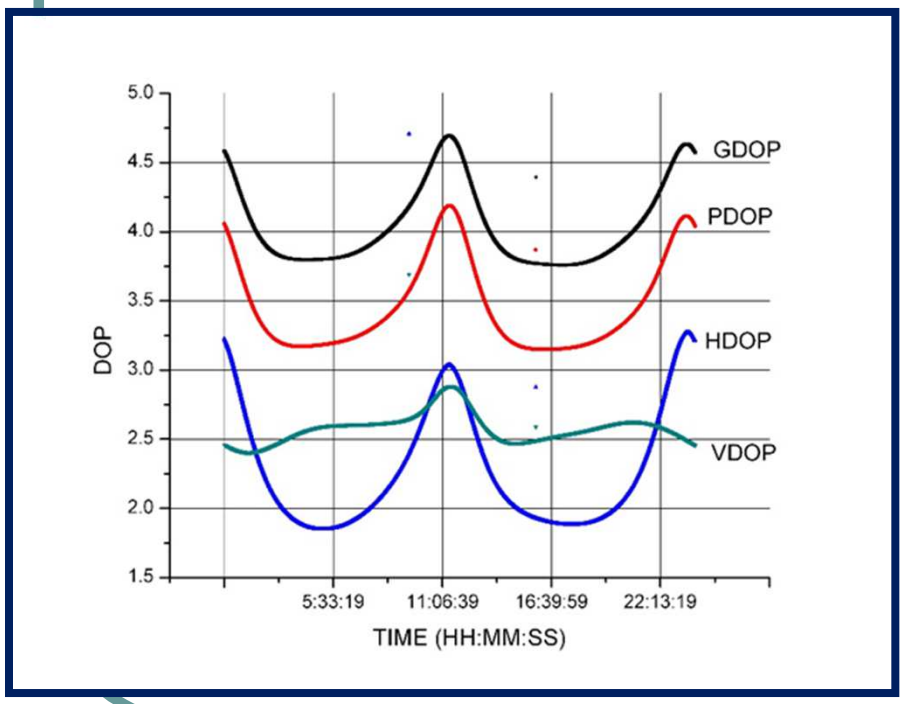


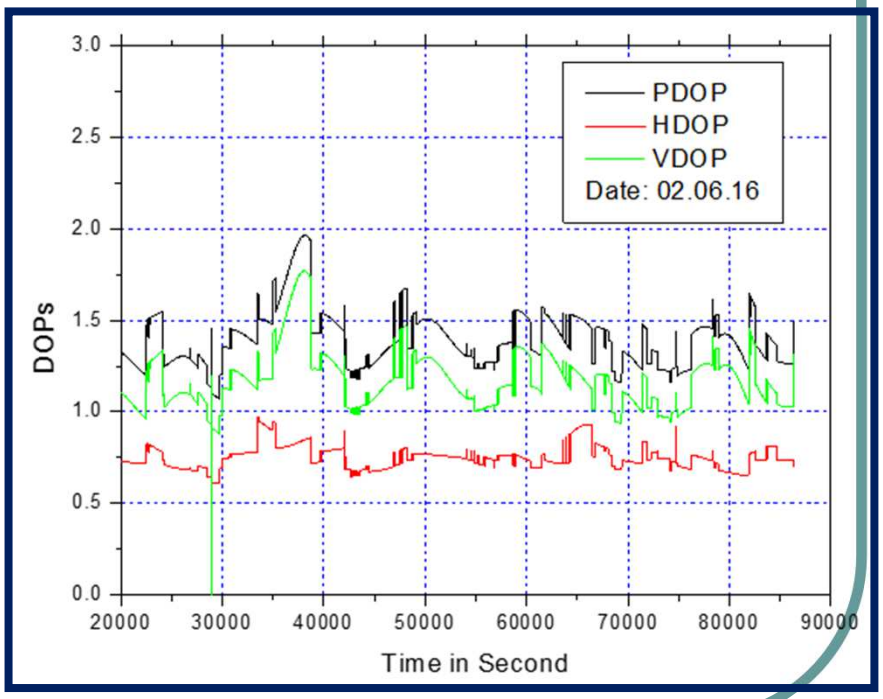
29/11/16; 17:37 IST

IRNSS visibility and satellite geometry: Observations

	1A	1B	1D	1E	1C	1F	1G
Max	58.4	58.9	68.7	68.4	65.9	25.6	35.7
Min	21.1	20.2	24.2	25.5	64.9	25.5	37.7

IRNSS satellite elevation variation, 13/09/2016; UoB, INDIA

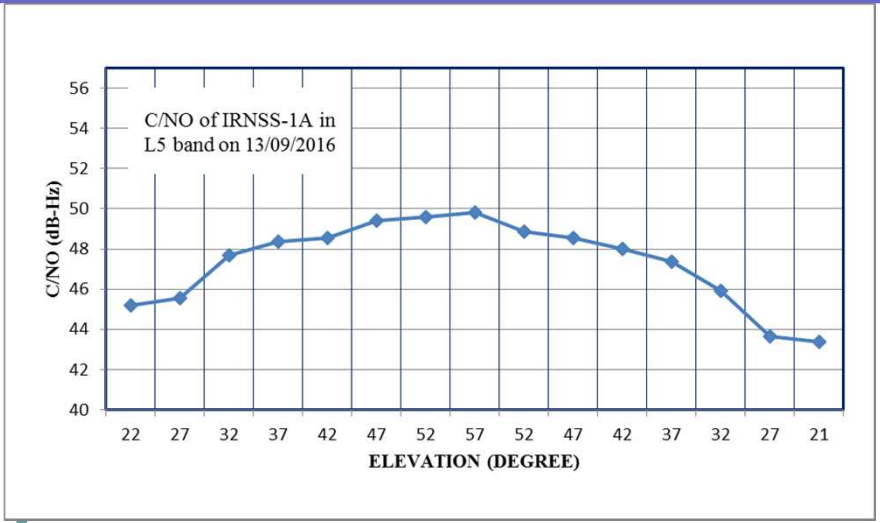


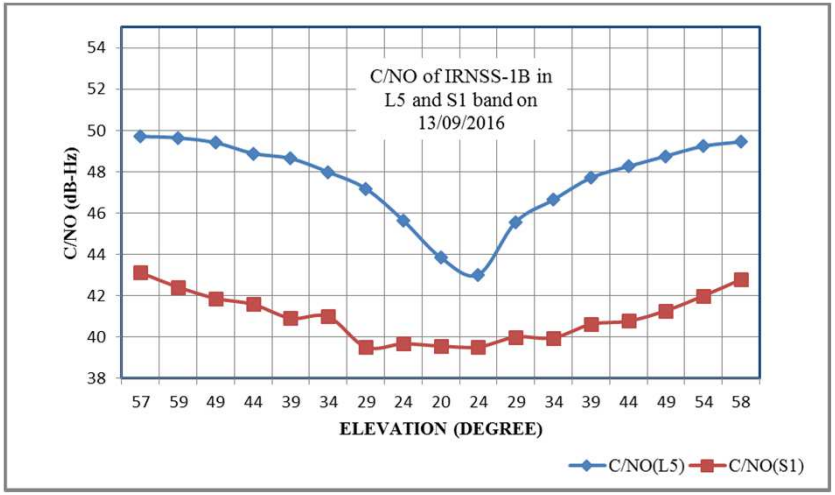


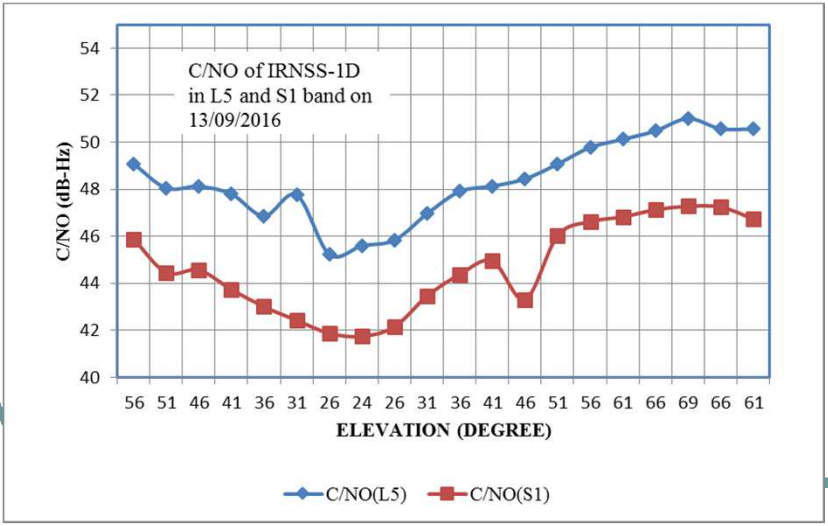
IRNSS, 12/10/2016

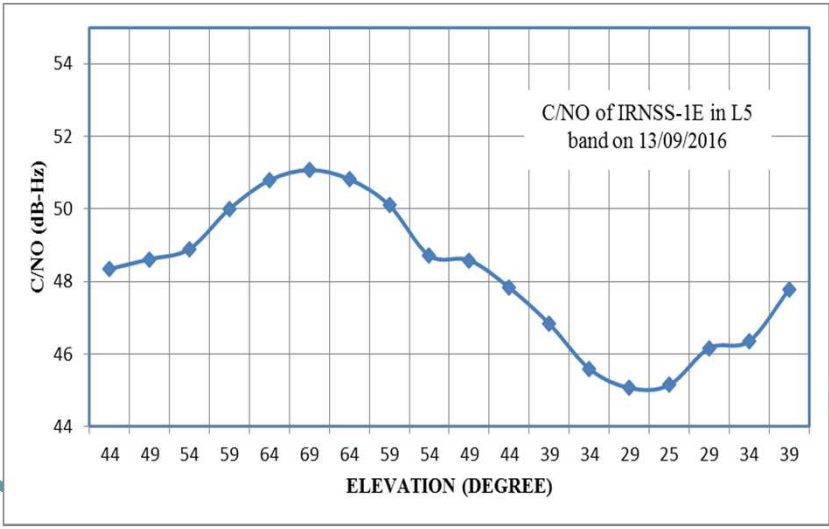
IRNSS + GPS, 02/06/16

IRNSS satellite signal strength variation (GSOs)

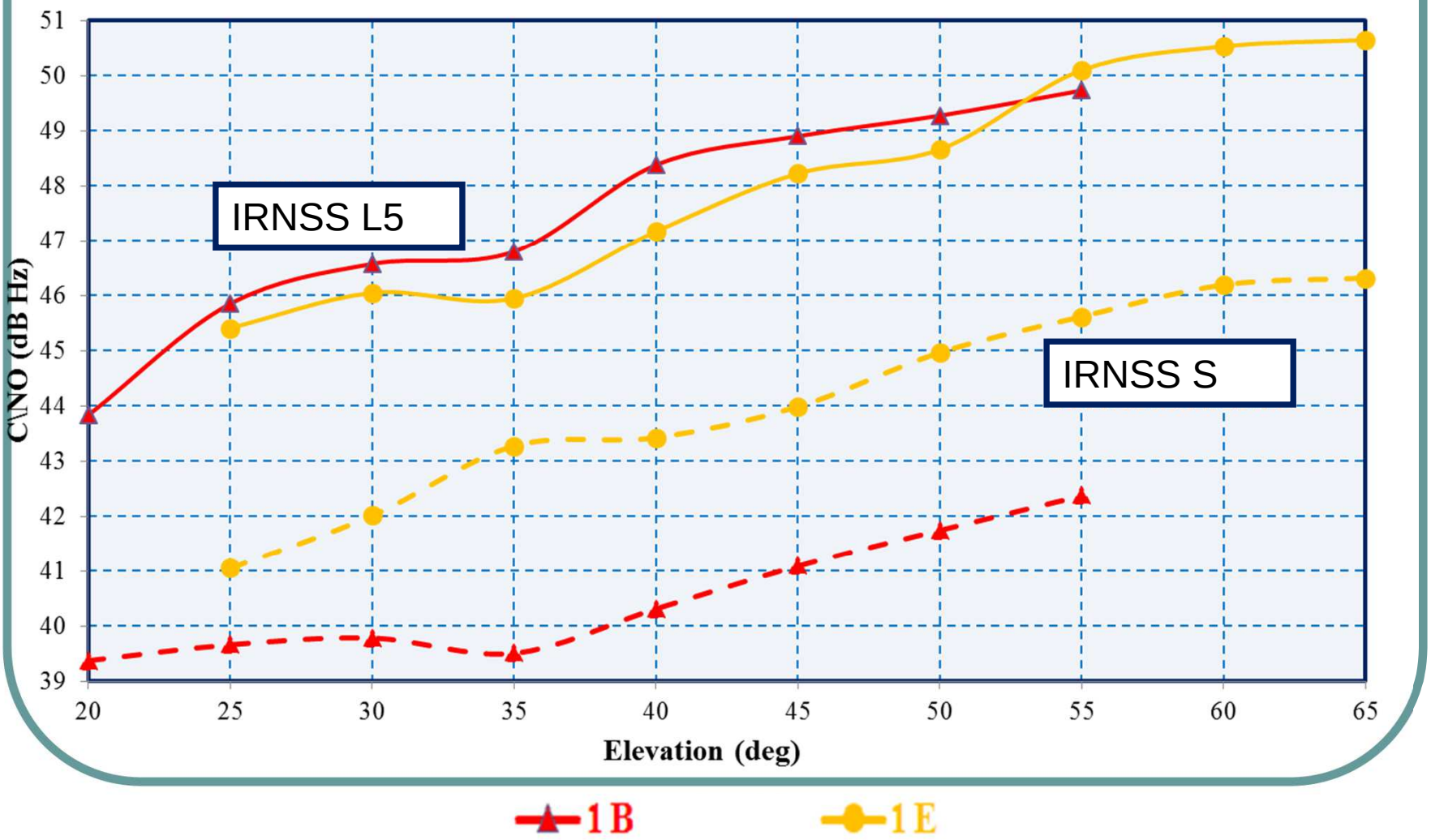




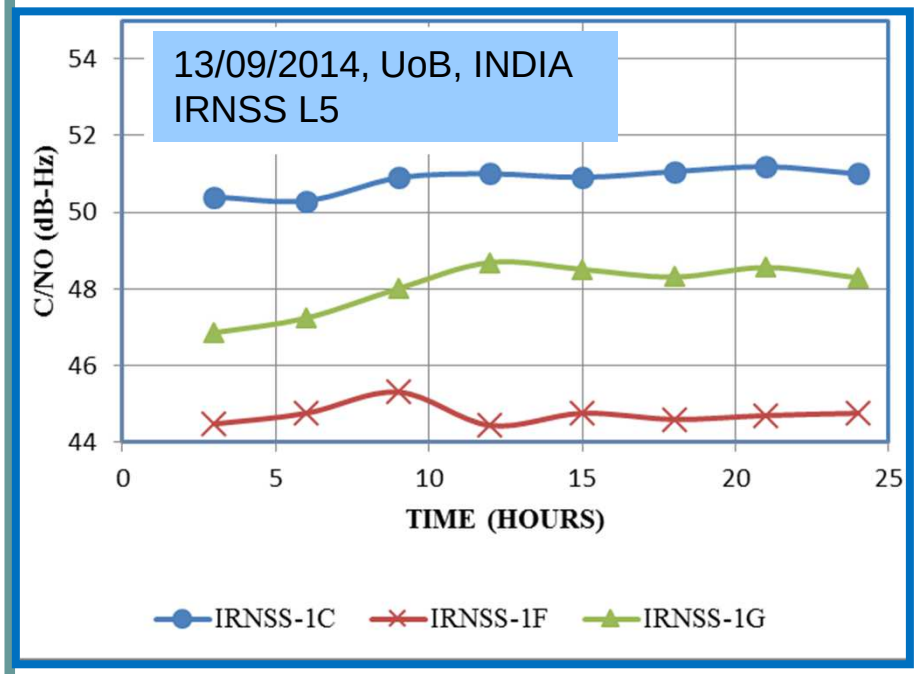


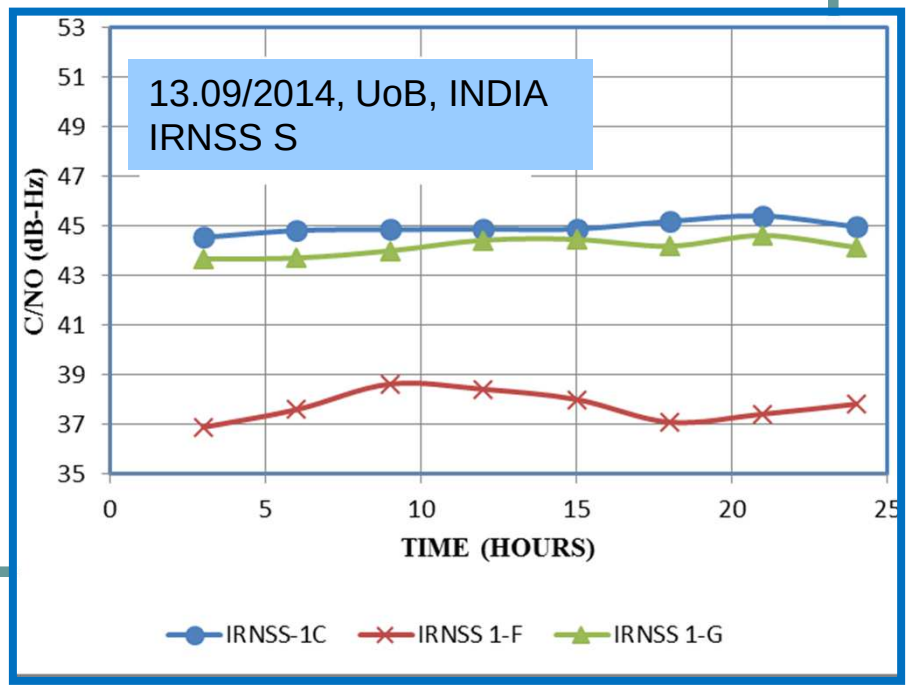


IRNSS satellite signal strength variation (GSOs), 29/11/2016

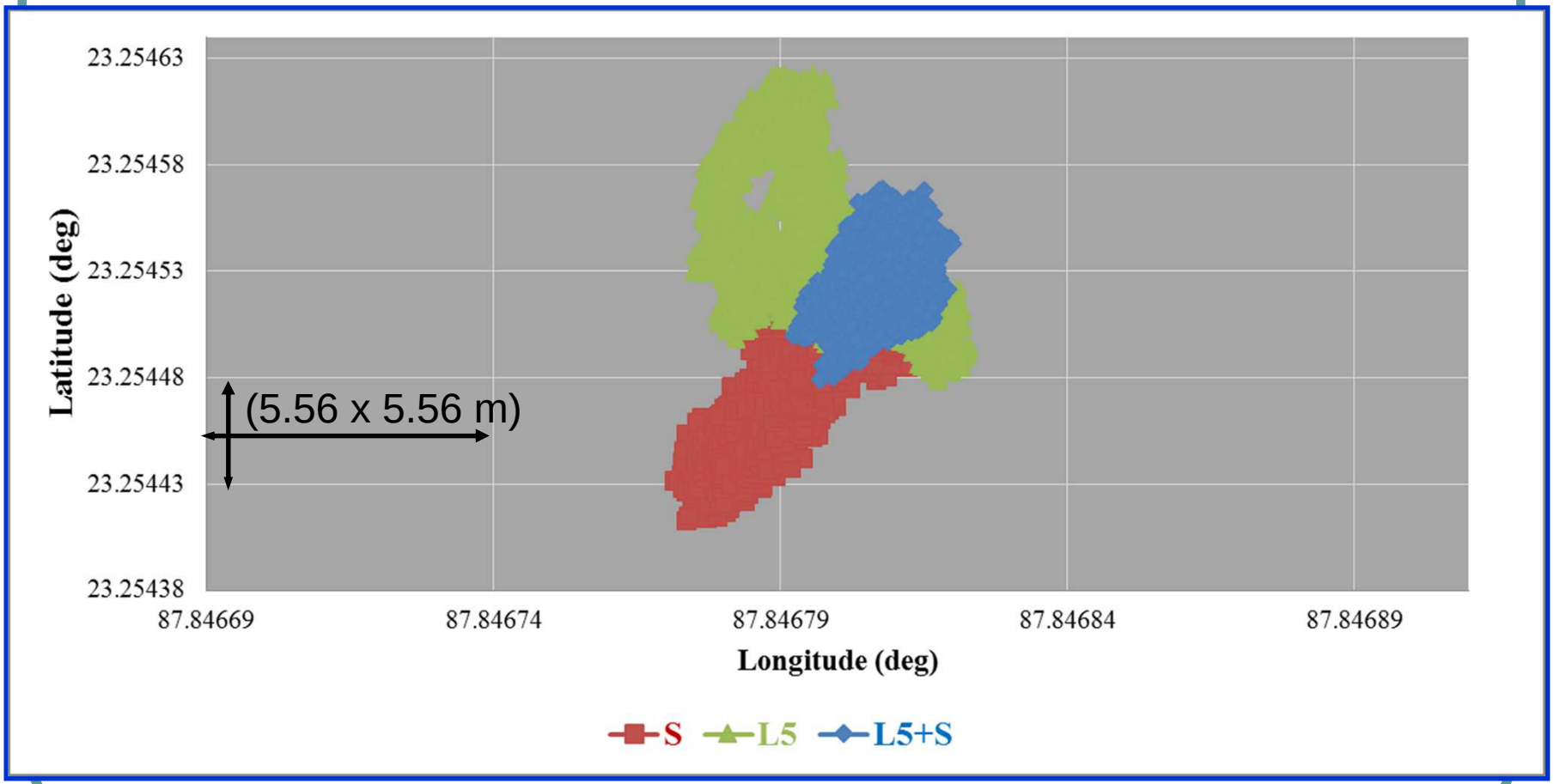


IRNSS satellite signal strength variation (GEOs)

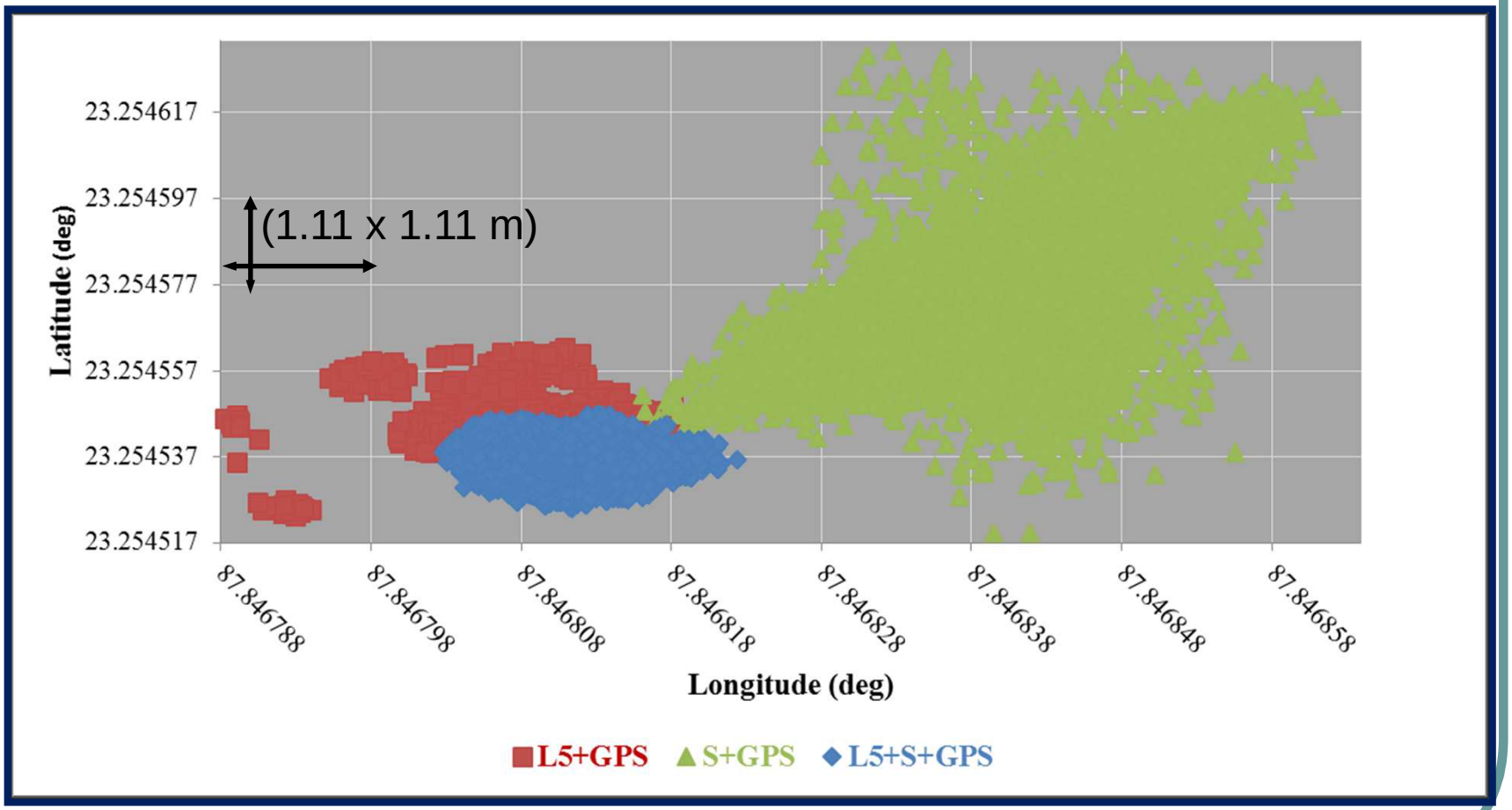




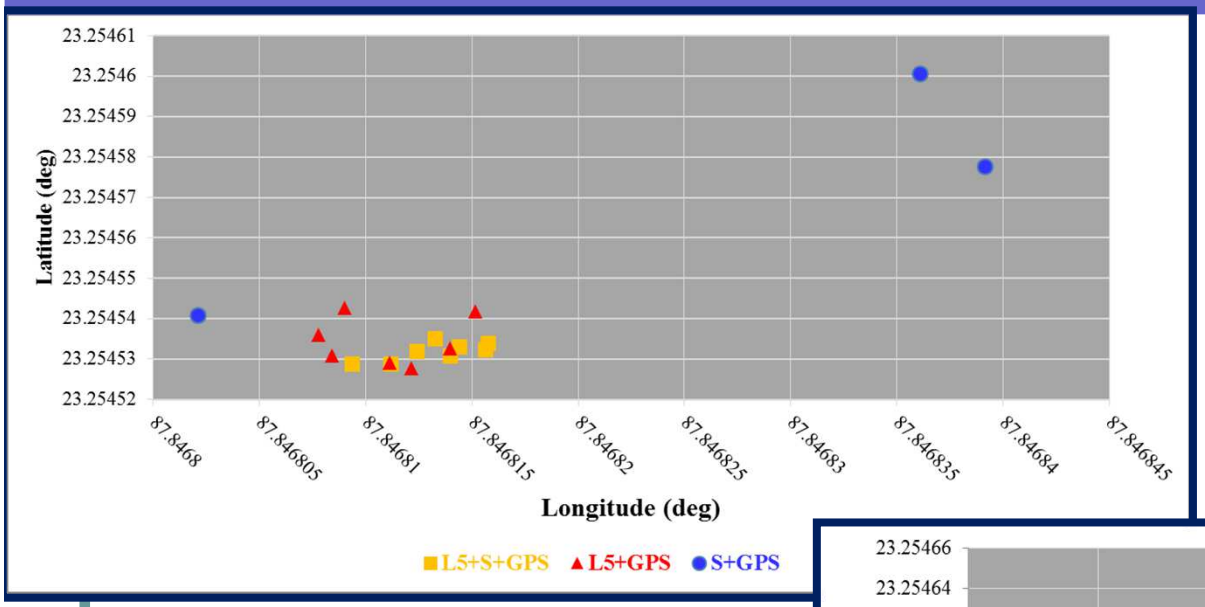
IRNSS: Position Solution Capabilities (Sept, 2016; 3hrs; 03:00-06:00 am IST), IGS Rx

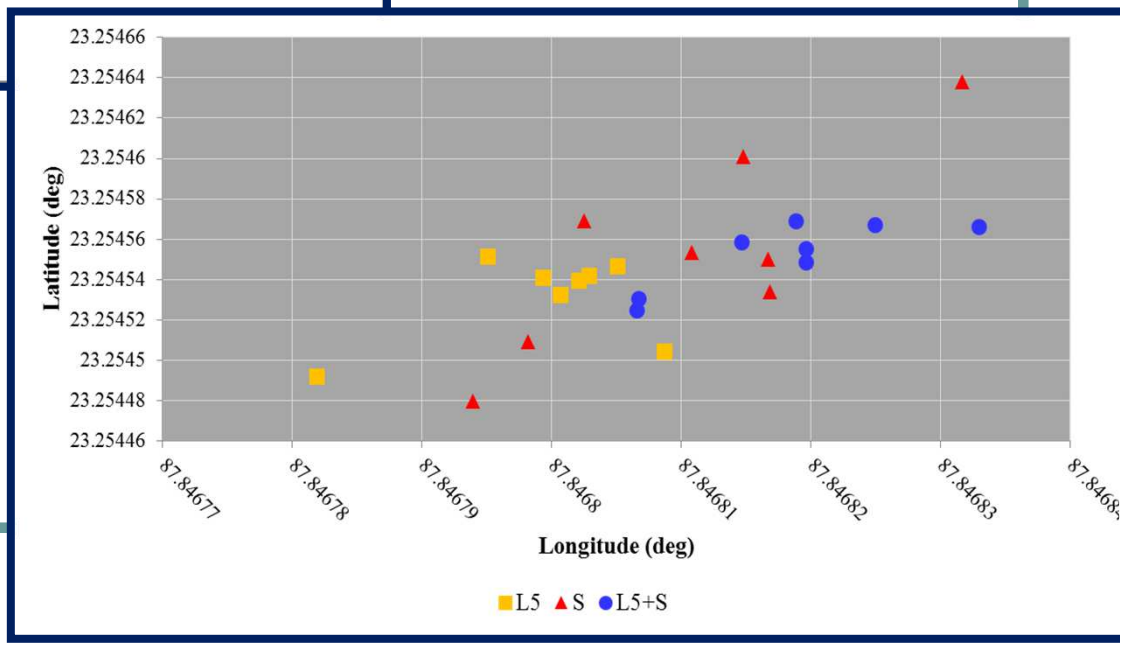


IRNSS: Solution in hybrid mode with GPS (Sept, 2016; 3hrs; 03:00-06:00 am IST), IGS Rx



Position Solutions in IRNSS and IRNSS+GPS hybrid mode (Oct, 2016; 3 hrs average values, IGS Rx





Results

Position solution results obtained using standalone IRNSS and IRNSS with SBAS

Constellation Used	No. of Samples	Latitude (m)		Longitude (m)		Altitude (m)		PDOP
		σ[1]	P-P[2]	σ	P-P	σ	P-P	
IR-S1	4604	2.5	10.5	0.55	3.49	1.9	9.88	4.3
IR-L5	7580	1.3	8.77	0.81	4.29	1.8	7.65	3.8
IR-L5+SB	4173	0.49	2.87	0.51	2.59	1.4	6.49	3.4
IR-S1+SB	5050	1.0	6.68	0.45	2.86	1.4	9.09	4.2

Position solution accuracy comparison

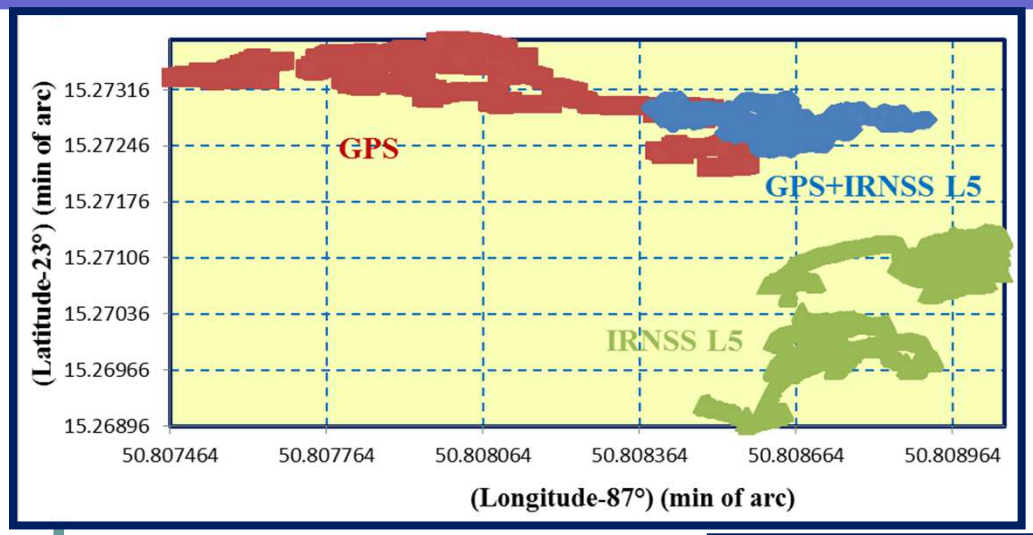
Constellation Used	No of Samples	Latitude (m)		Longitude (m)		Altitude (m)		PDOP
		σ	P-P	σ	P-P	σ	P-P	
GPL1	2887	0.52	2.3	0.49	2.4	1.55	7.7	1.9
GPL1+IRL5	7648	0.68	3.4	0.34	2.0	1.77	12.0	1.3
GPL1+IRS1	9049	0.62	6.7	0.82	3.7	1.65	13.2	1.4
GPL1+SB	6942	0.47	2.8	0.72	4.0	1.03	7.2	1.6
GPL1+IRL5+SB	6272	0.49	2.8	0.59	2.9	0.738	4.7	1.6
GPL1+IRS1+SB	6484	0.31	2.0	0.36	2.0	.577	4.8	1.2

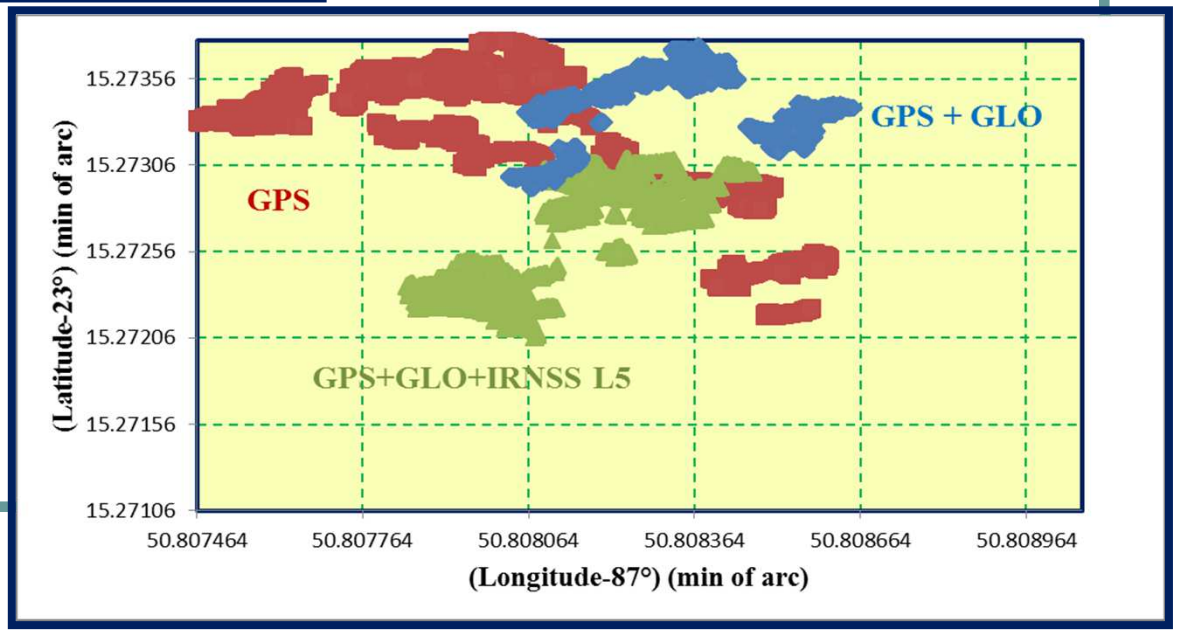
[1] σ indicates standard deviation of the observations. [2] P-P indicates the peak to peak (maximum) variation and of observations.

Results, IGS Rx

		IRNSS L5 + GPS L1					IRNSS S + GPS L1					IRNSS L5+S+ GPS L1				
	No of Samples	Latitude (m)		Longitude (m)		PDOP	Latitude (m)		Longitude (m)		PDOP	Latitude (m)		Longitude (m)		PDOP
Period		P-P	σ	P-P	σ		P-P	σ	P-P	σ		P-P	σ	P-P	σ	
0-3 am	10801	3.66	0.34	2.12	0.27	1.36	6.18	1.60	1.87	1.45	3.90	2.00	0.27	1.93	0.29	1.25
3-6 am	10801	3.76	0.38	2.84	0.29	1.29	4.71	1.17	2.63	1.02	3.25	2.46	0.36	2.00	0.29	1.43
6-9 am	10801	4.35	0.40	5.03	0.34	1.32	2.55	1.99	3.25	0.68	3.23	3.47	0.46	2.10	0.29	1.37
9-12 am	10801	3.16	0.45	1.59	0.21	1.57	7.96	1.21	3.19	0.48	3.34	2.69	0.39	1.77	0.28	1.49
12-3 pm	10801	3.08	0.43	1.74	0.21	1.39	6.51	3.43	2.72	1.11	3.94	2.32	0.35	1.72	0.22	1.38
3-6 pm	10801	2.45	0.33	1.42	0.20	1.39	7.33	1.07	2.14	0.39	3.23	3.75	0.43	2.03	0.28	1.45
6-9 pm	10801	2.27	0.32	1.64	0.22	1.33	6.51	1.47	2.22	0.71	3.19	3.59	0.48	2.03	0.34	1.30
9-12 pm	10801	2.99	0.40	2.11	0.28	1.38	4.80	1.60	4.08	0.83	3.47	2.54	0.31	1.78	0.25	1.31

Position Solutions: Observations (JAVAD DELTA Rx), 2hrs, 29/11/16





Results
(JAVAD DELTA Rx), 2 hrs in each mode

MODE	East Variation (m)		North Variation (m)	
	STDEV	P-P	STDEV	P-P
GPS	0.54	2.12	0.64	2.96
IRNSS L5	0.27	1.07	1.20	4.49
GPS+L5	0.26	0.99	0.25	1.16
GPS+GLO	0.27	1.92	0.58	1.16
GPS+GLO+L5	0.28	1.15	0.39	1.52

Conclusion and Scopes

- ✓ IRNSS would provide benefits for the GNSS users within the service area
- ✓ Potential of hybrid IRNSS-GPS operation would boost the popularity and advantages of multi-GNSS operation in the Indian region.
- ✓ IRNSS, in the current testing stage provides position solution in standalone and hybrid mode with GPS.
- ✓ A fully operational IRNSS is expected to enhance the benefits.
- ✓ Results are based on preliminary and short-term observations from a single location
- ✓ More exploration and real-time data analysis from scattered locations within the operational area over longer period of time in needed



THANK YOU



http://bugnss.webs.com/

Acknowledgement:

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