Indian RNSS: NavIC and GAGAN – Experiences and Potentials

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Web: http://bugnss.webs.com
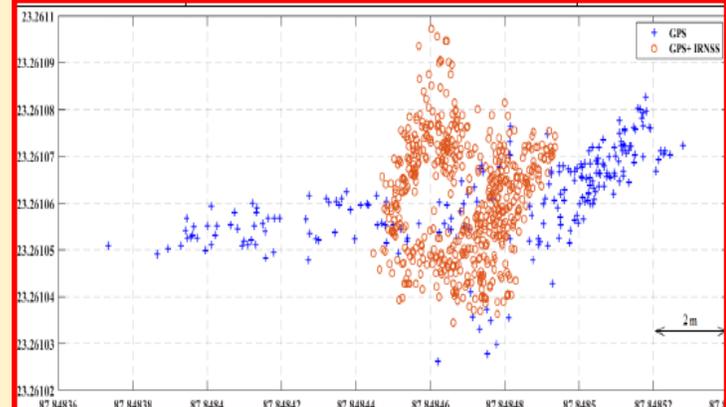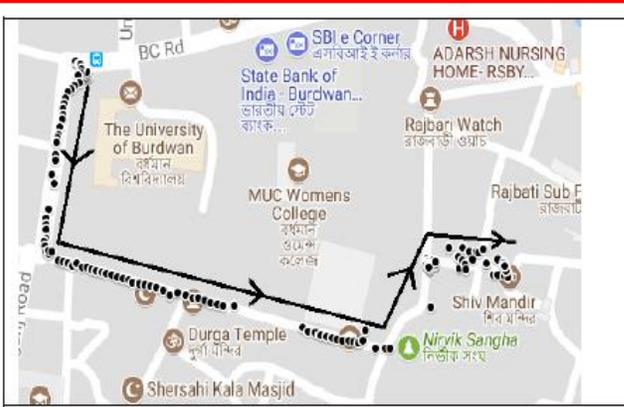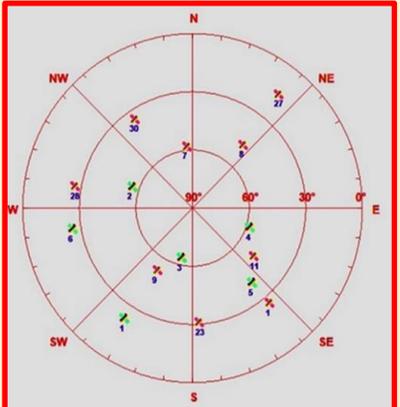
GNSS Laboratory Burdwan (GLB)
(Lat 23.2545^0 N, Lon 87.8468^0 E)

- **GNSS Laboratory in The Department of Physics, The University of Burdwan 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) Quality enhancement of GNSS solutions

3) Development of cost-effective applications and solutions

4) Capacity Building in the Field of GNSS

- GNSS data archive and data sharing

- Sponsored Projects from Govt of India Agencies, specially ISRO

- Collaboration with Industry

- Member, Multi GNSS Asia (MGA) [http://www.multignss.asia]

- Received recognition from European Space Agency (ESA)

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

http://bugnss.webs.com
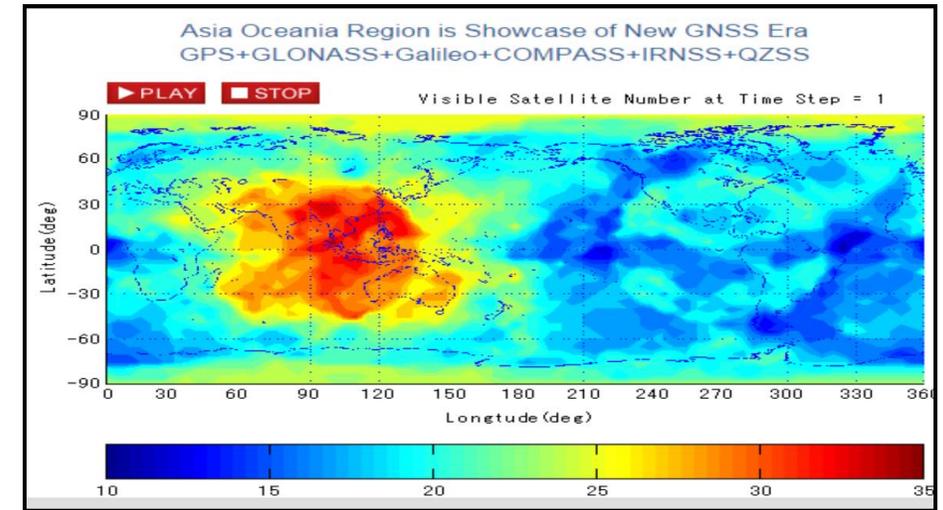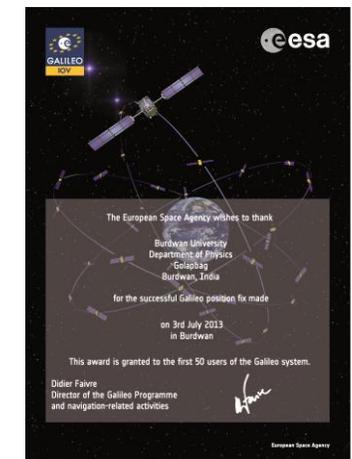
Our Infrastructure

IRNSS-GPS-SBAS (IGS) Receivers

Multi-GNSS Receivers (Javad DELTA G3T, Triumph LS)

Labsat 3: Record and Replay System

Leica GR50

U blox Low-cost Multi GNSS boards

GoeS-1M OEM Boards (GPS, GLONASS)

RTKLIB: An Open Source Package for GNSS

Systems Tool Kit
Courtesy: AGI

http://bugnss.webs.com

Agenda

- **IRNSS/ NavIC- brief Introduction**
- **Hardware Availability**
- **Solution and Navigation parameters – brief discussion**
- **Visibility and satellite geometry**
- **Experience in Metropolis Environment of India**
- **Advantages in augmenting Multi-GNSS in constrained situations**
- **Potential for atmospheric studies**
- **Experience with GAGAN**
- **Future research**

IRNSS/ NavIC- Indian Effort towards a regional independent satnav

An independent regional navigation satellite system being developed by Indian Space Research Organization (ISRO).

Designed to provide accurate position information service to users in India as well as the region extending up to 1500 km from its boundary (primary service area).


More details at: http://www.isro.gov.in/irnss-programme
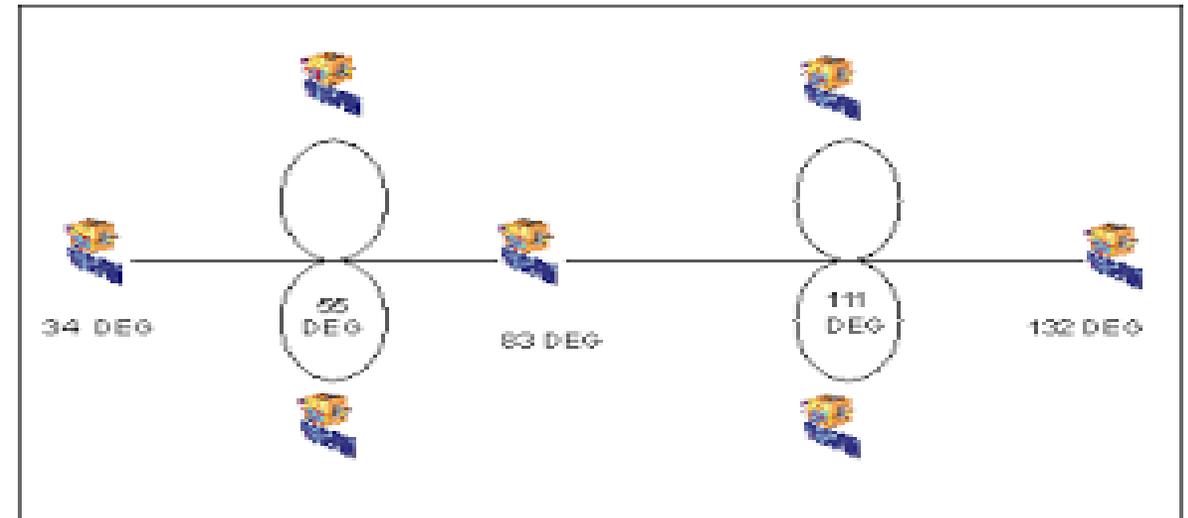
NavIC: Satellites, Launches, Frequencies

SI No	Satellite	Launch Date	Launch Vehicle	Orbit Type
1	IRNSS 1A	Jul 01, 2013	PSLV- C22	GSO
2	IRNSS 1B	Apr 04, 2014	PSLV- C24	GSO
3	IRNSS 1C	Oct 16, 2014	PSLV- C26	GEO
4	IRNSS 1D	Mar 28, 2015	PSLV-C27	GSO
5	IRNSS 1E	Jan 20, 2016	PSLV-C31	GSO
6	IRNSS 1F	Mar 10, 2016	PSLV-C32	GEO
7	IRNSS 1G	Apr 28, 2016	PSLV-C33	GEO
8	IRNSS 1H	Aug 31, 2017	PSLV-C39	-
9	IRNSS 1I	Apr 12, 2018	PSLV-C41	GSO

L5: 1.1764 GHz, 24 MHz bandwidth

S: 2.4292 GHz, 16 MHz

NavIC: Hardware

**IRNSS-GPS-SBAS (IGS) Receiver, (ISRO-Accord) L and S Bands**

Not Commercially Available

Javad Multi-GNSS receivers Future upgradable for NavIC L5 only

**Leica GR50 L5 only**

Trimble Alloy L5, S

Racelogic Wideband III Record and Replay System L5 only

SkytraQ NavIC-GAGAN-GPS Evaluation Board L5 only
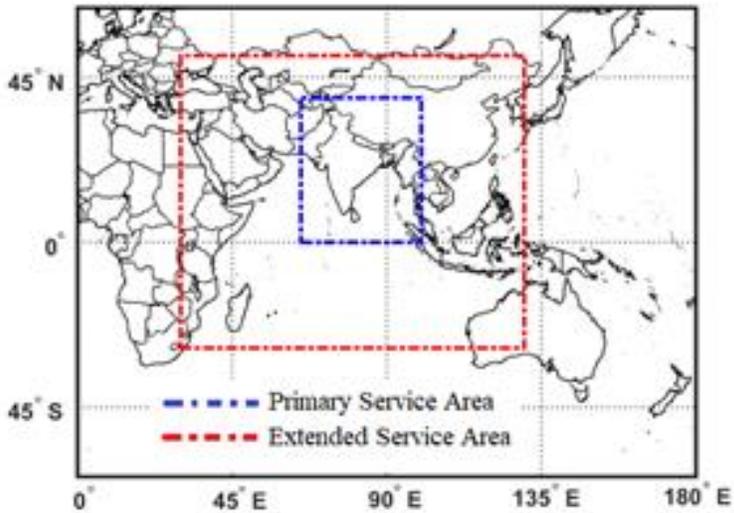
Colour Code	Maximum No. of Satellite	Minimum No. of Satellite
(teal)	7	6
(blue)	7	5
(olive)	7	4
(light green)	6	5
(green)	6	4
(pink)	5	4
(red)	5	3
(grey)	Always 7	
(light blue)	Always 6	
(orange)	Always 4	

NavIC: Visibility
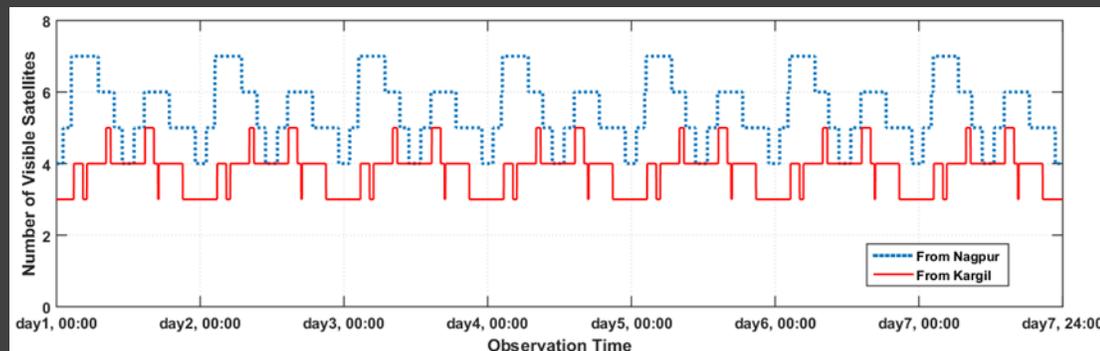
Typical visibility at Central and Northern India, 30 deg elevation mask
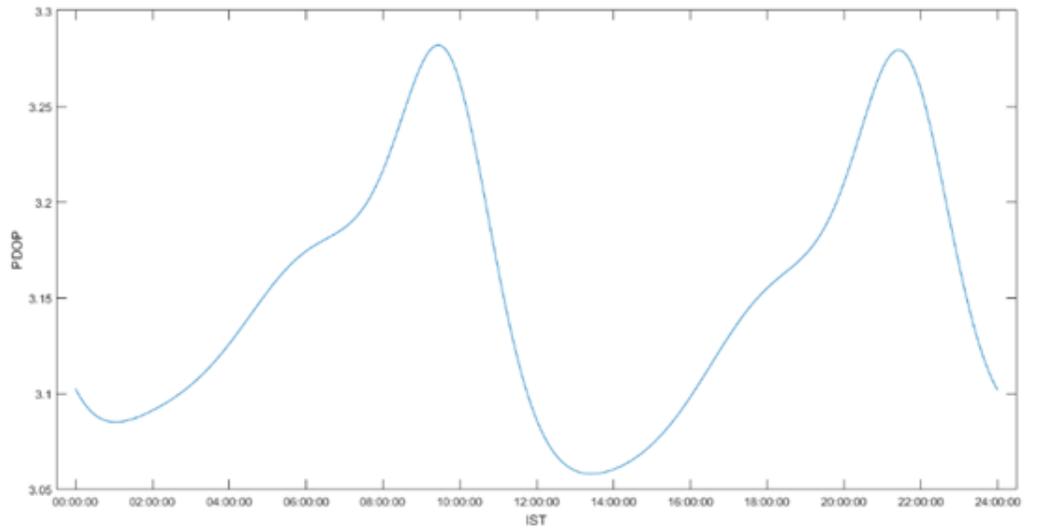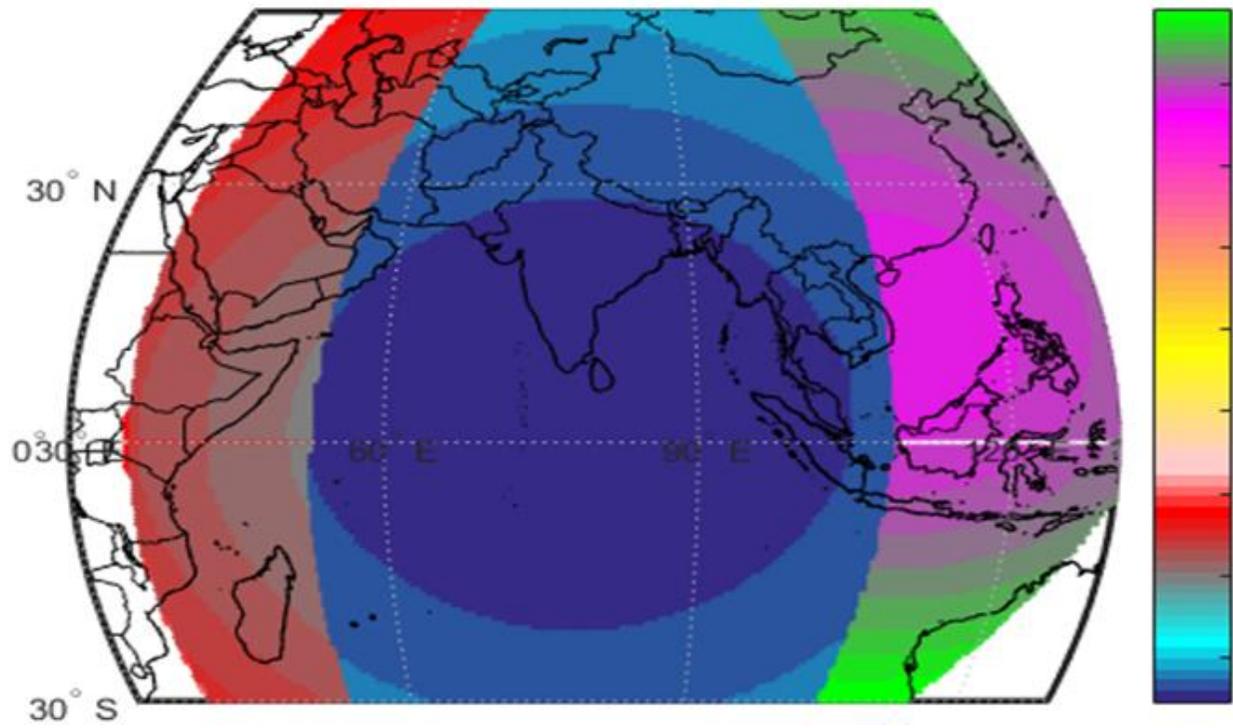
Typical PDOP variation from Central India

NavIC: Satellite Geometry
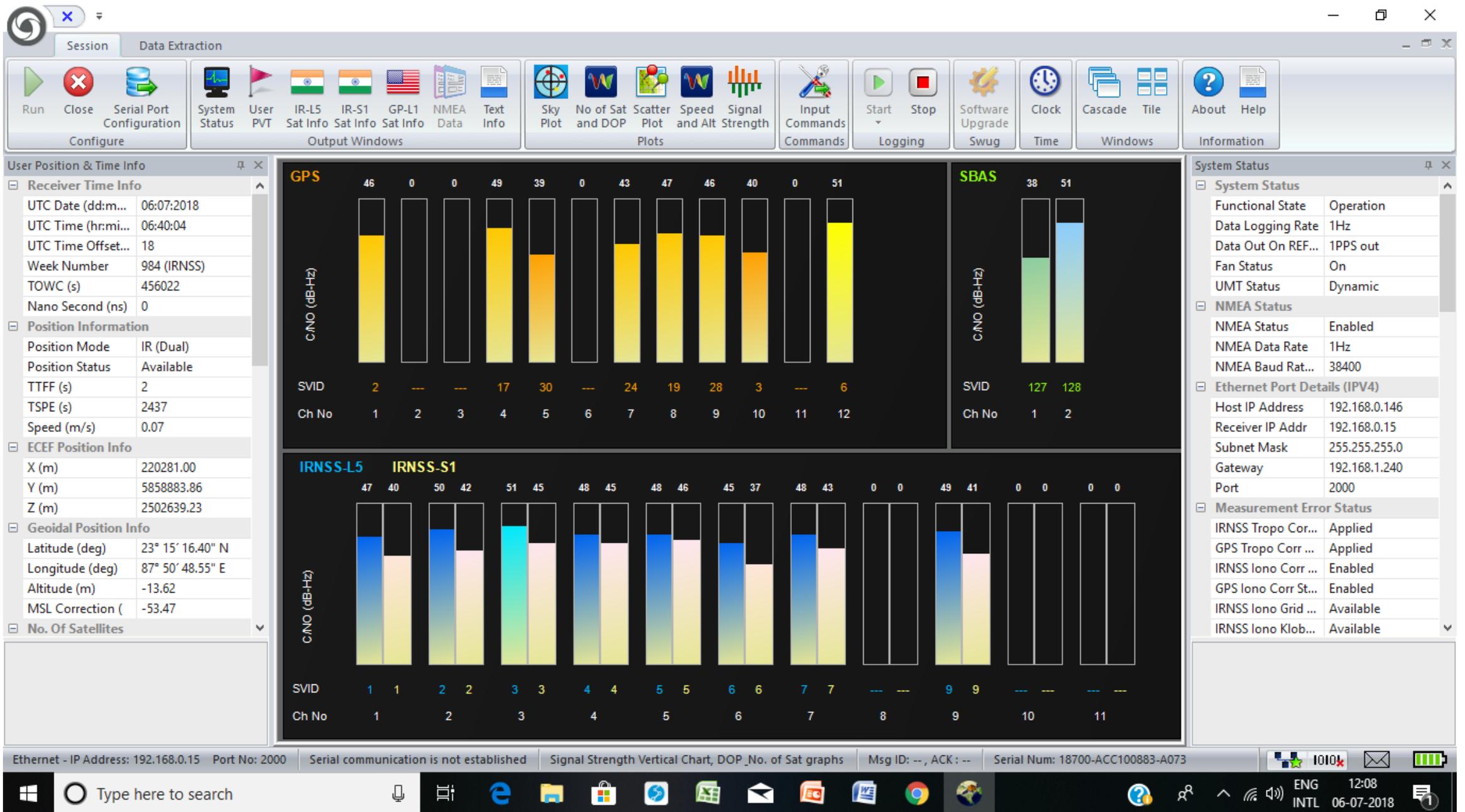
NavIC observations using IGS receiver; Burdwan, INDIA, 06 July 2018

NavIC observations using Javad GNSS receivers; Burdwan, INDIA, 05 July 2018

|	
Latitude	23°15'16.228098"N
Longitude	87°50'48.520762"E
Ellipsoidal height	-12.0146741 m
Position SEP	2.7450530 m
Velocity 2D	0.0166341 m/s
Position RMS	2.7450528 m
Velocity RMS	0.0191553 m/s

Stand Alone

PDOP	3.6826080
HDOP	2.5082760
VDOP	2.6963220
Receiver Date	2018:7:5 (GPS)
Receiver Time	15:46:36
Clock Offset	0.000189
Osc. Offset	0.000102
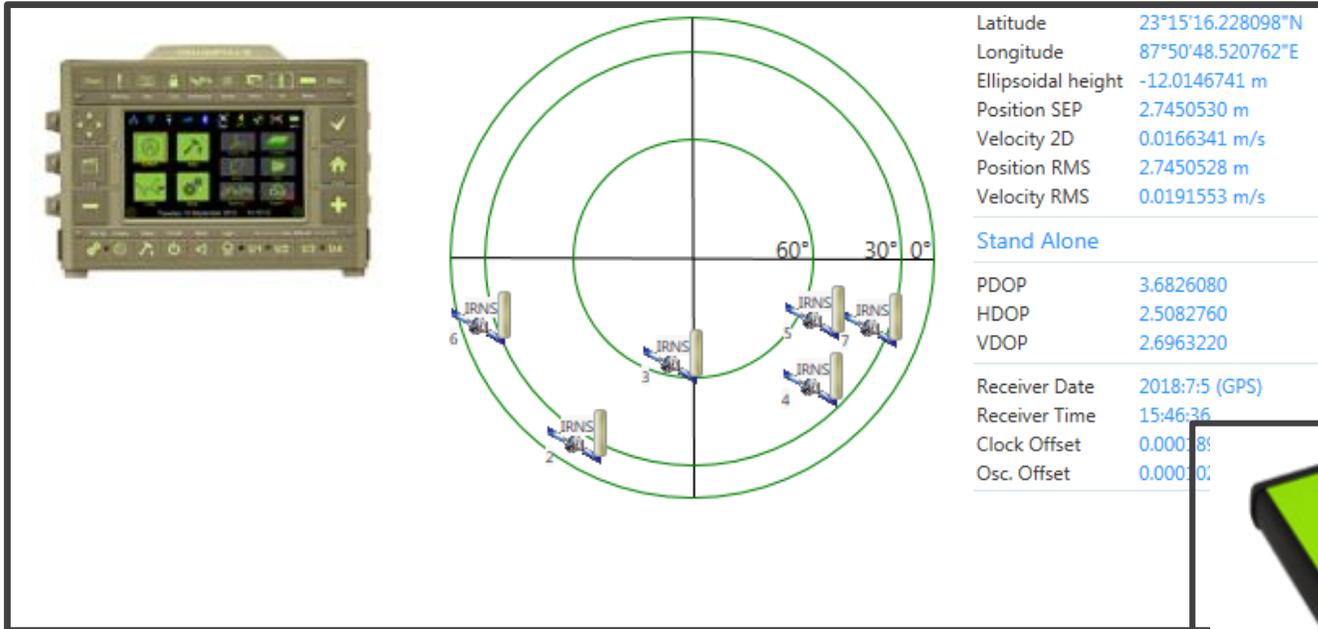
Javad Triumph LS, L5 only

Javad DELTA G3T, L5 only

Latitude	23°15'16.218217"N
Longitude	87°50'48.532218"E
Ellipsoidal height	-15.0013182 m
Position SEP	2.9577640 m
Velocity 2D	0.0086939 m/s
Position RMS	2.9577634 m
Velocity RMS	0.0152548 m/s

Stand Alone

PDOP	3.8738194
HDOP	2.7119380
VDOP	2.7662010
Receiver Date	2018:7:5 (GPS)
Receiver Time	16:20:40
Clock Offset	-0.0000676 s
Osc. Offset	-0.0001765 ms/s
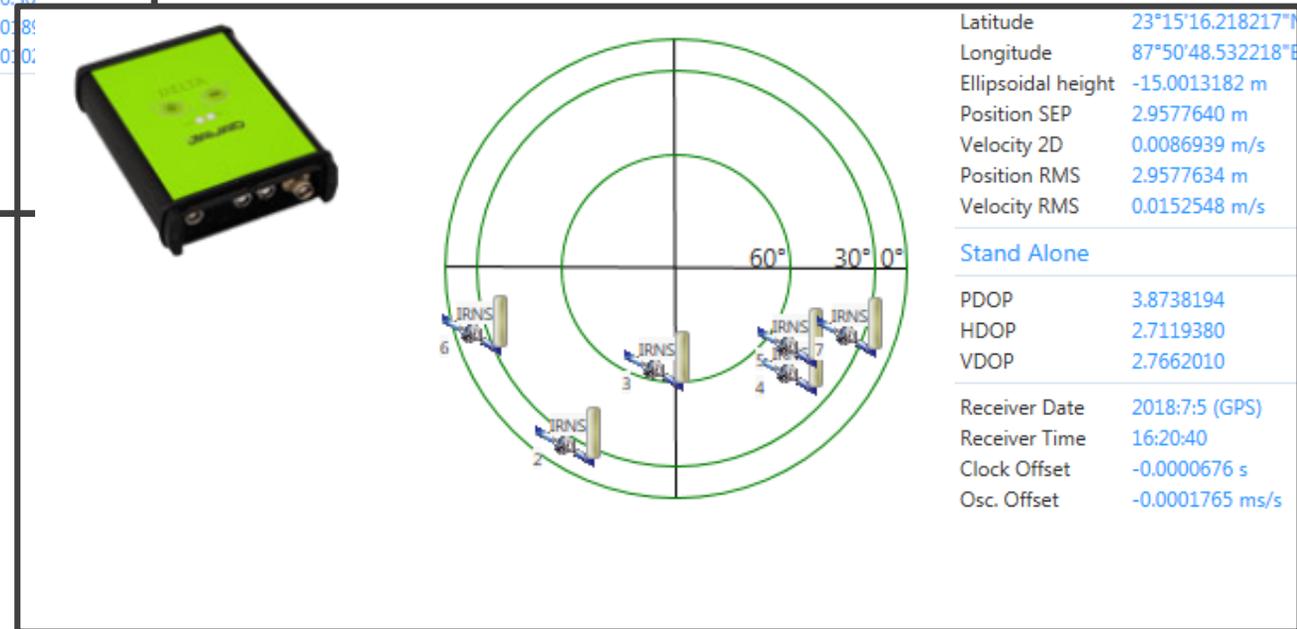
# Typical NavIC satellite signal strength variation (GSOs)
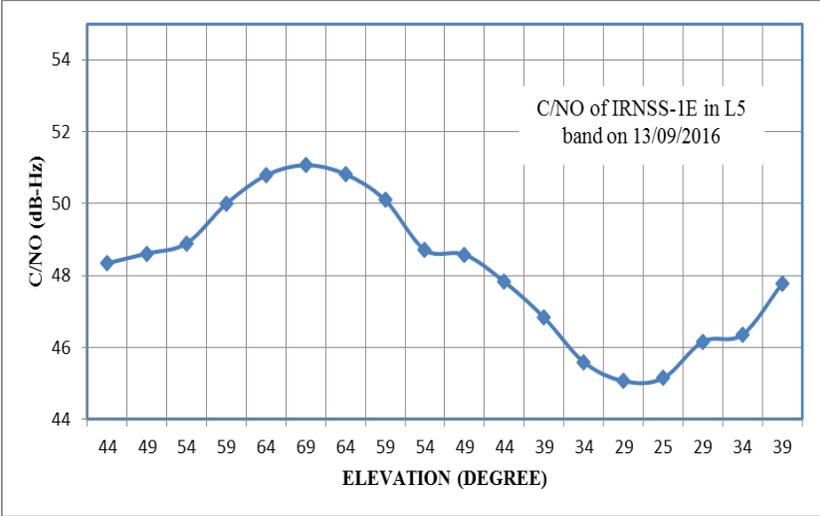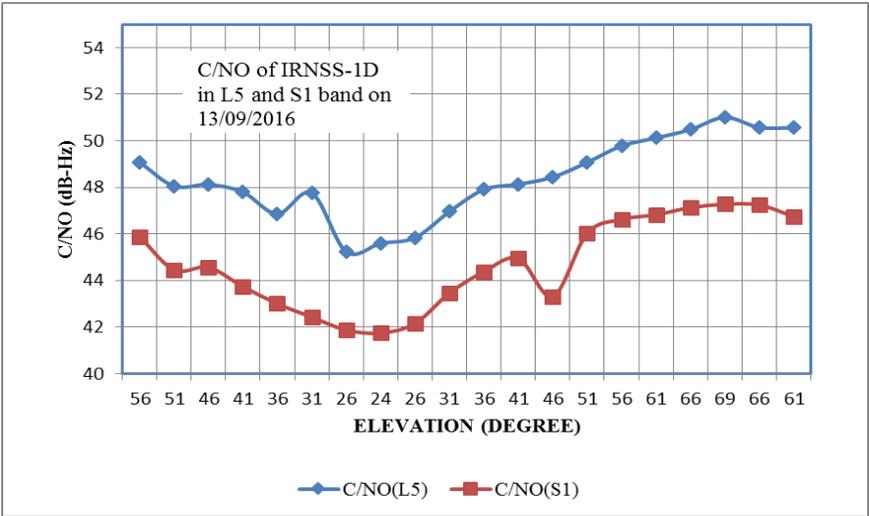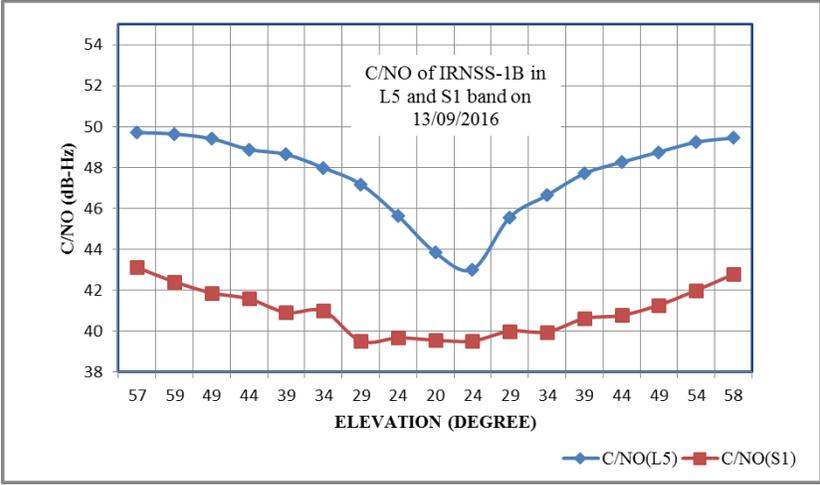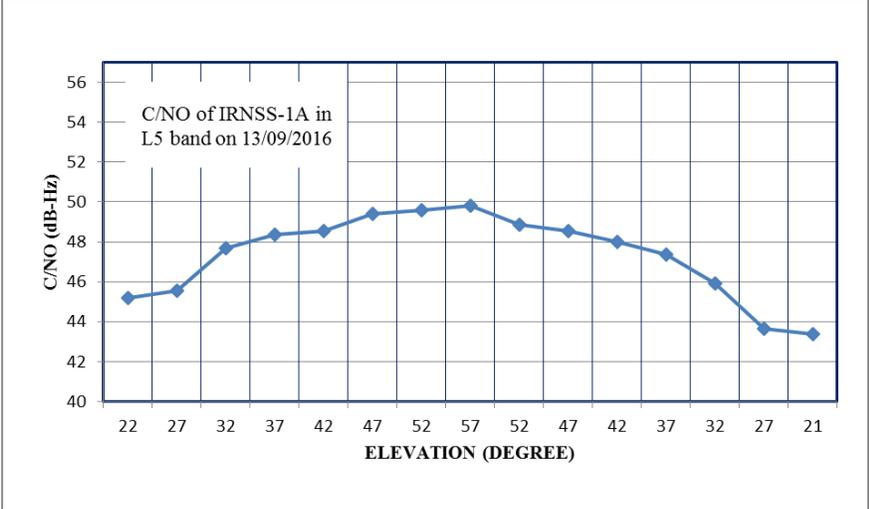
# NavIC satellite signal strength variation (GEOs)
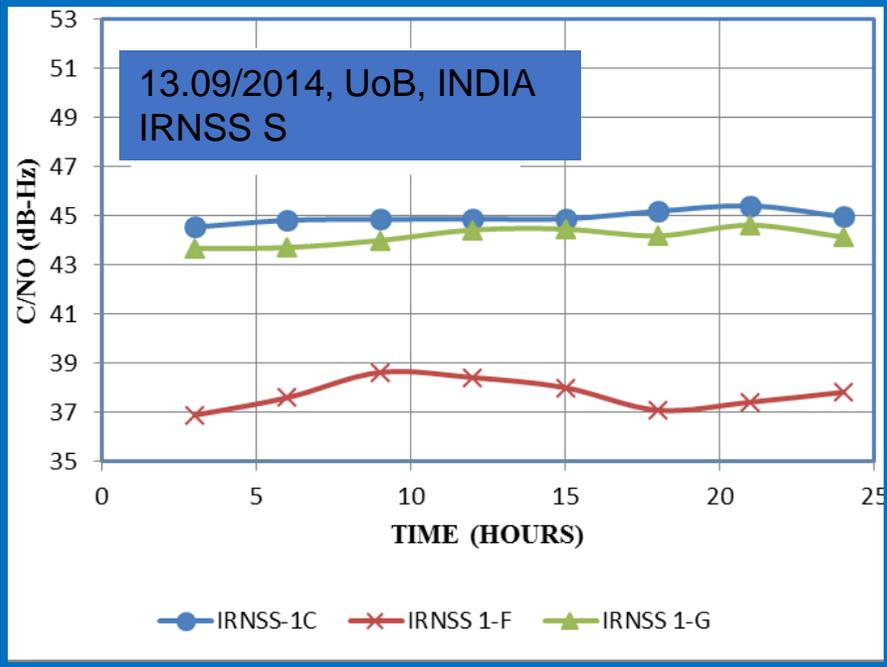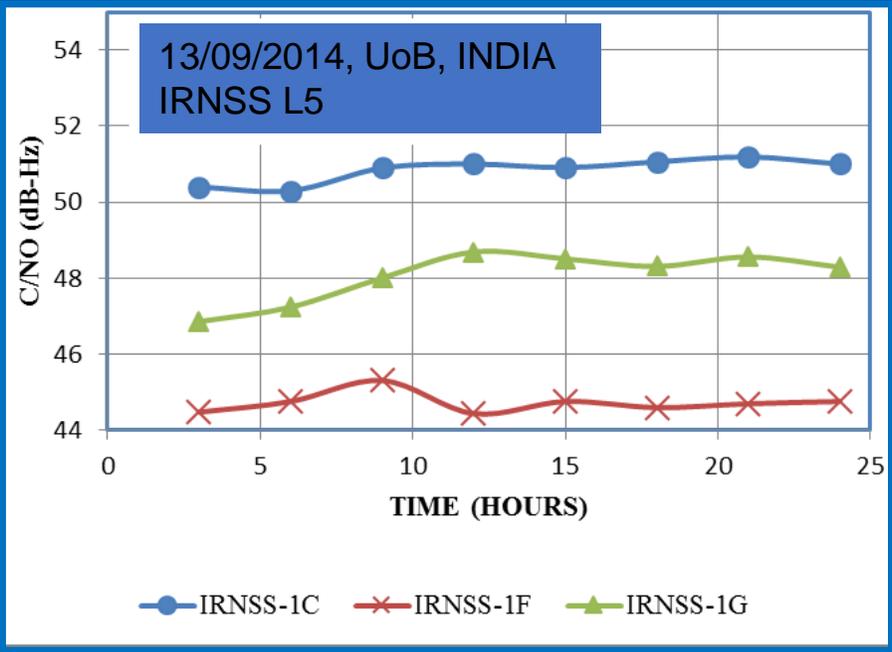
IRNSS: Position Solution Capabilities
(Sept, 2016; 3hrs; 03:00-06:00 am IST), IGS Rx
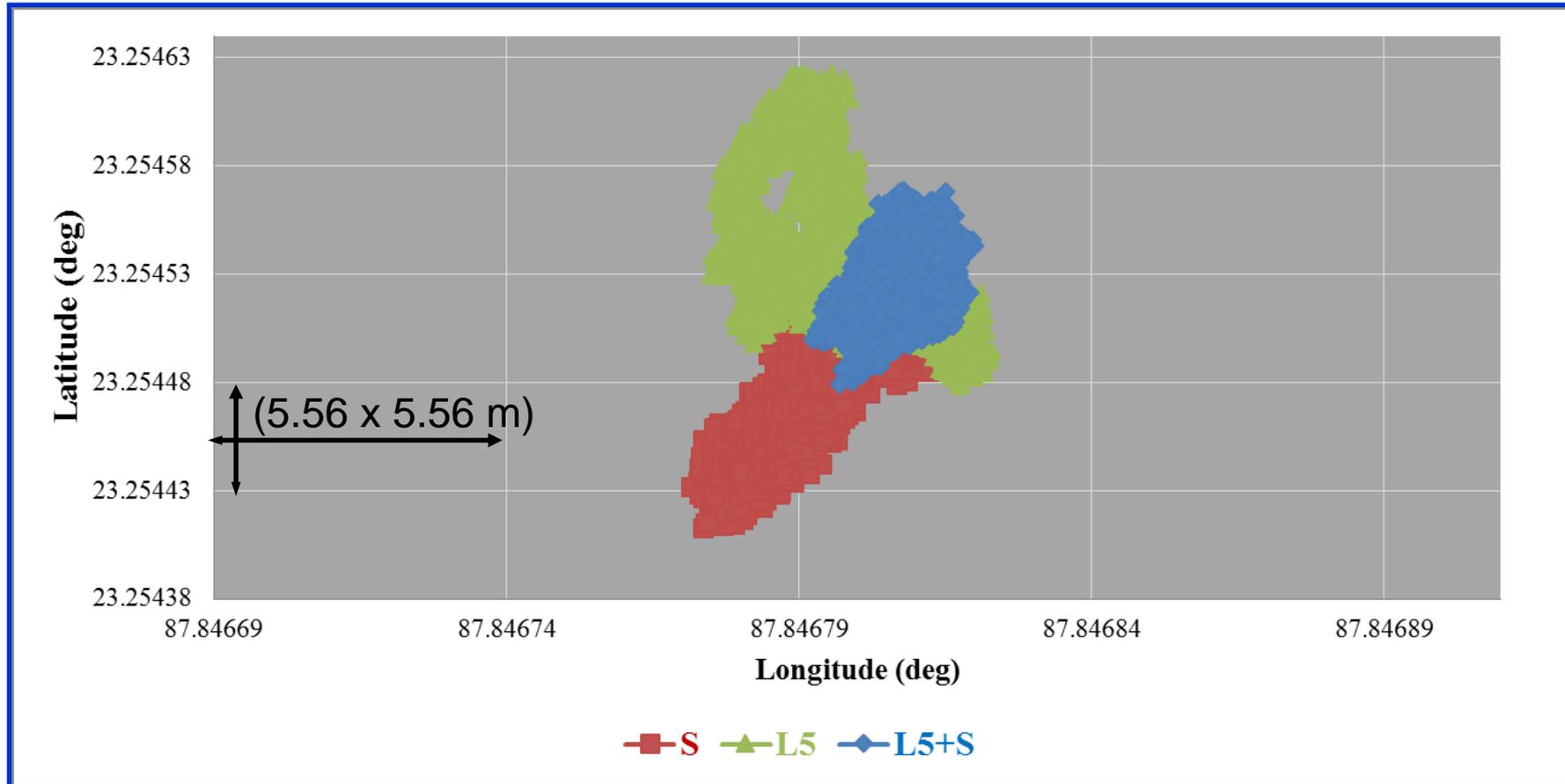
IRNSS: Solution in hybrid mode with GPS
(Sept, 2016; 3hrs; 03:00-06:00 am IST), IGS Rx
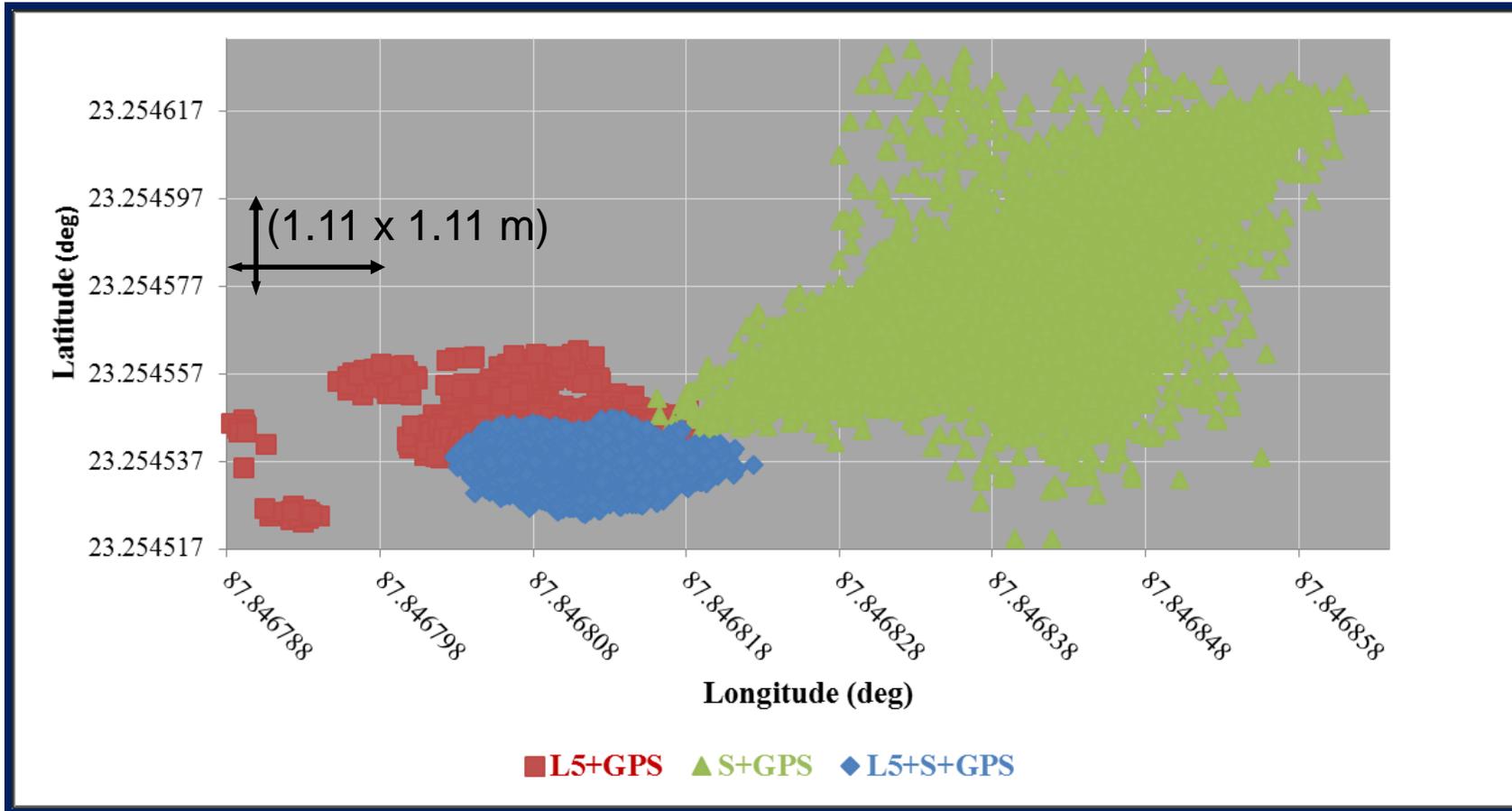
Position Solutions: Observations, (JAVAD DELTA Rx), 2hrs, 29/11/16
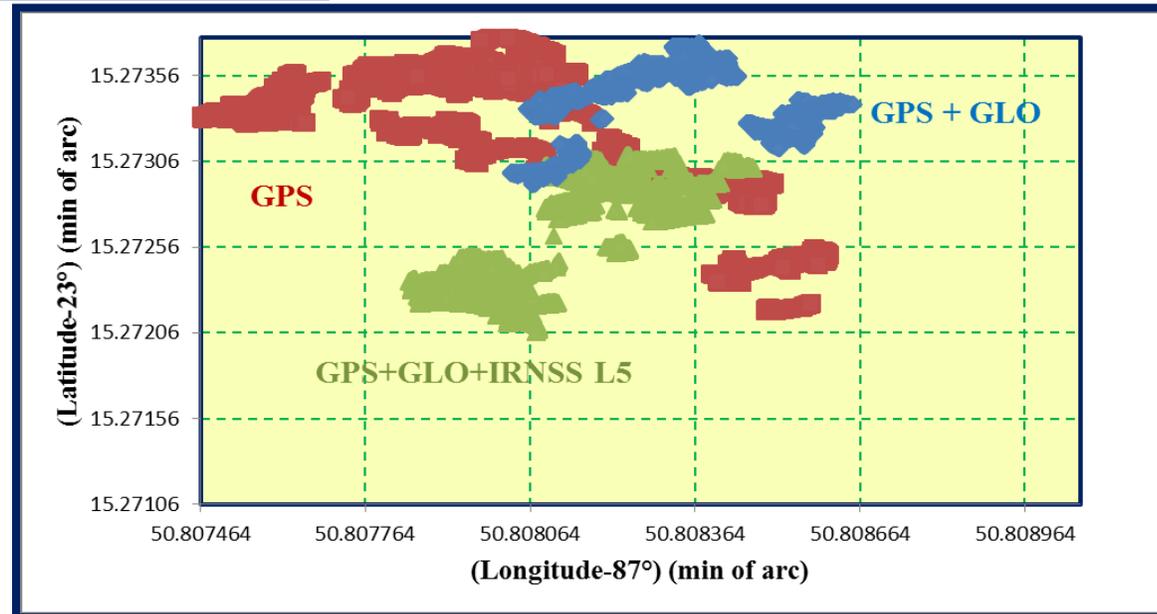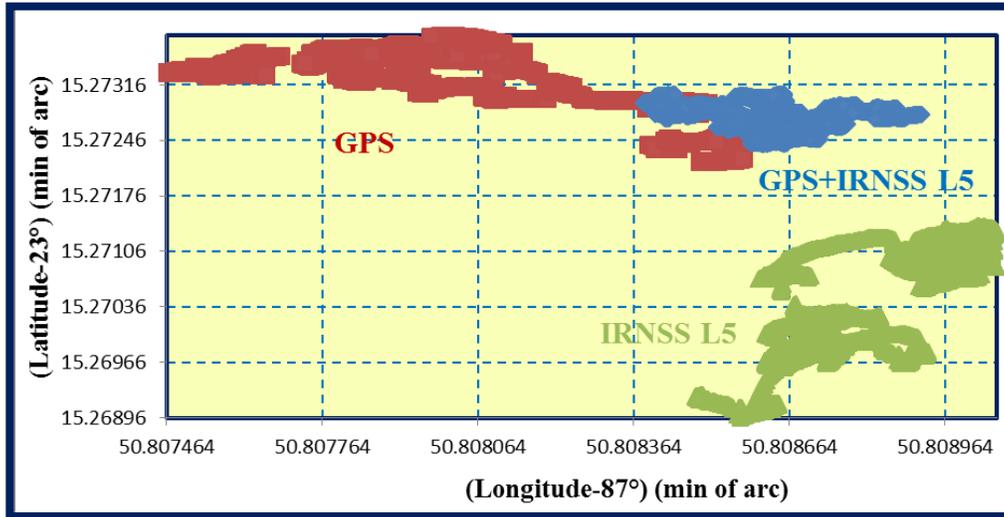
NavIC: Experience in Metropolis Environment of India

Pick up vehicle with external GNSS antenna

➢ The vehicle is taken through various road conditions at an average speed of 15-20 km/ hr.

  ▪ Case- I : In wide highway below or parallel to the flyover.

  ▪ Case- II : The narrow road in densely populated area.

Case I: (Below Flyover)
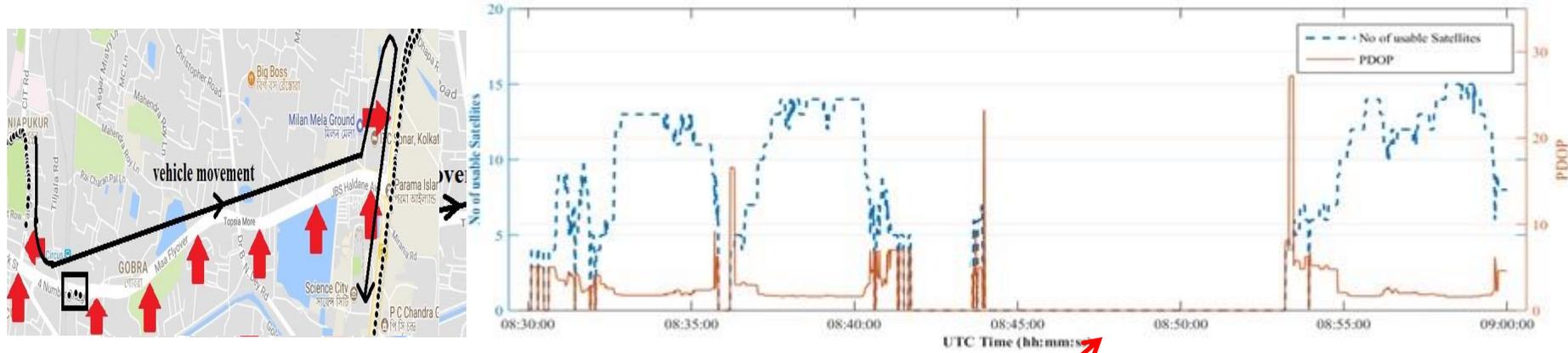
Map of study area : EM bypass, Kolkata
(Direction of vehicle movement is shown in dark line)
Image courtesy : Google map

Variation of total number of usable satellites (GPS+IRNSS) and PDOP, 25th October 2017

Picture taken from the back of the vehicle, below flyover

Variation of number of tracked GNSS satellites, 25th October, 2017
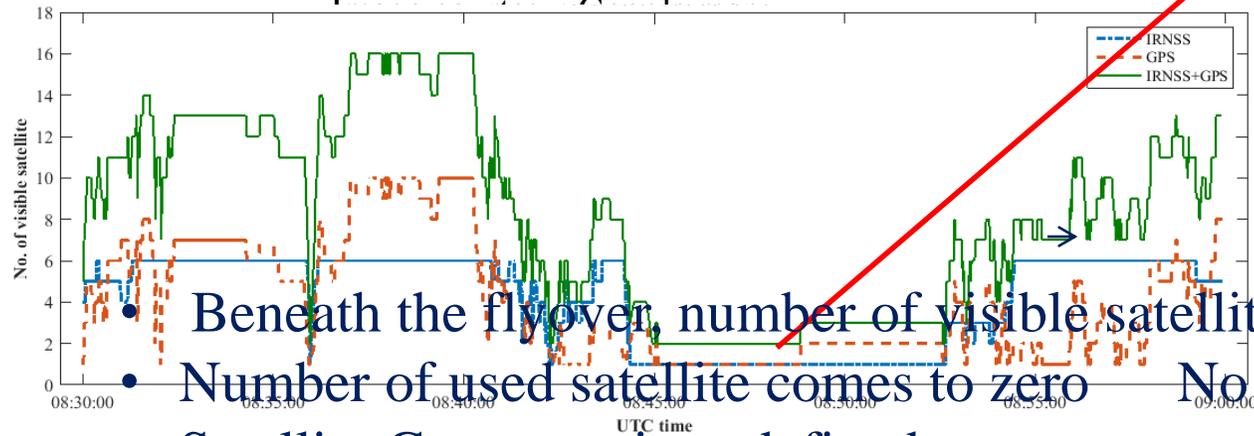
- Beneath the flyover, number of visible satellite is less then 4.
- Number of used satellite comes to zero   No Position Solution.
- Satellite Geometry is undefined.

18

Case I: (Beside the Flyover)

- Beside the flyover number of visible satellite is 8 or 9.
- Number of used satellite is 5 or 6.
- Satellite Geometry is poor
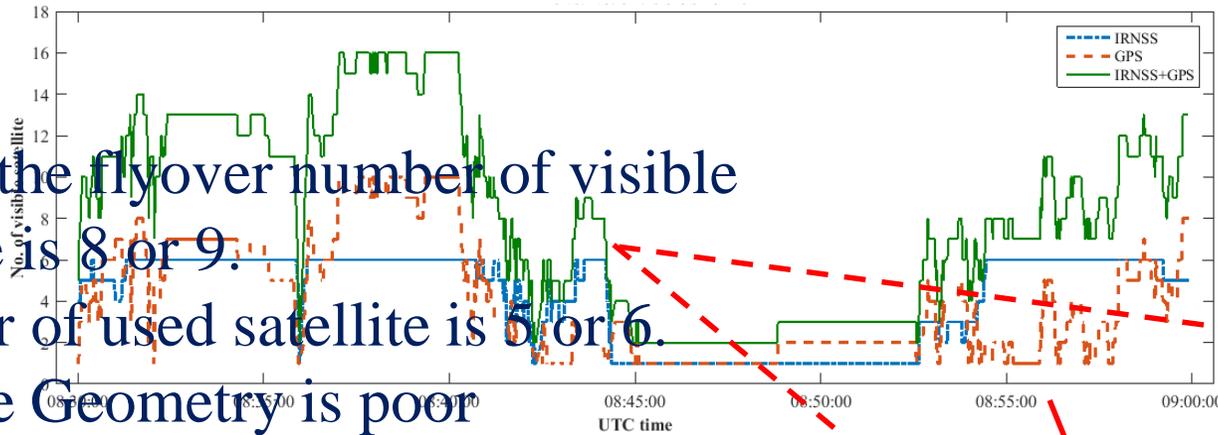
Picture taken from the back of the vehicle beside the flyover

Variation of number of visible GNSS satellites
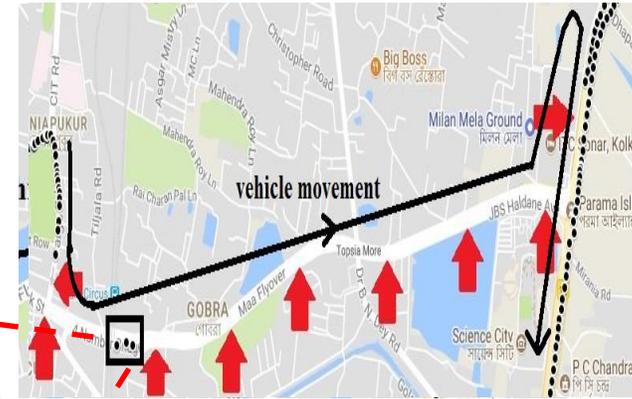
Map of study area
(Direction of vehicle movement is shown in dark line)
Image courtesy: Google map
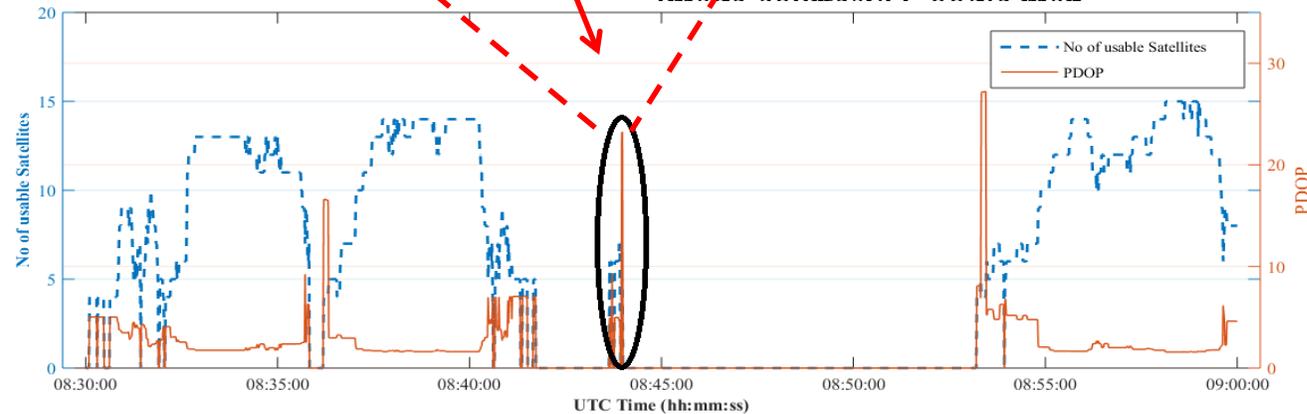
Variation of total number of usable satellites (GPS+IRNSS) and PDOP, 25th October 2017

19

Case II: Densely populated dwelling areas with narrow roads

Discussion
- Number of total tracked satellite is 4 to 8 in A, B, C and D regions.
- Number of used satellites sometimes comesdown to Zero in the aforesaid regions..

Variation of total number of usable GNSS satellites observed from Jadavpur area, Kolkata, India on 25th October 2017

n from the back of the vehicle, narrow roads with buildings alongside
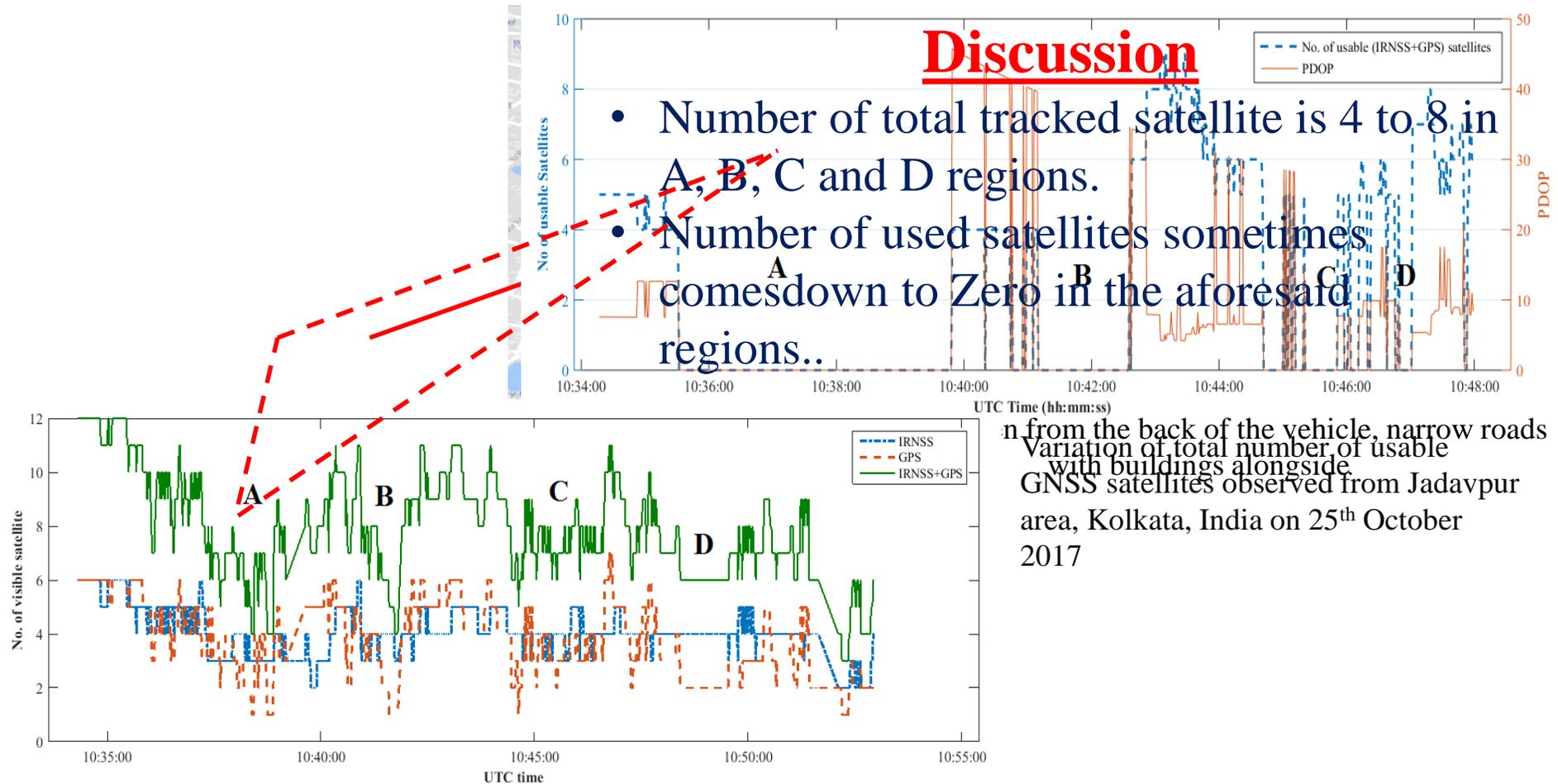

Variation of number of tracked GNSS satellites in GPS+ IRNSS operation, Kolkata, India on 25th October 2017

NavIC: Advantages in augmenting Multi-GNSS

(a) (b)

(c) (d)
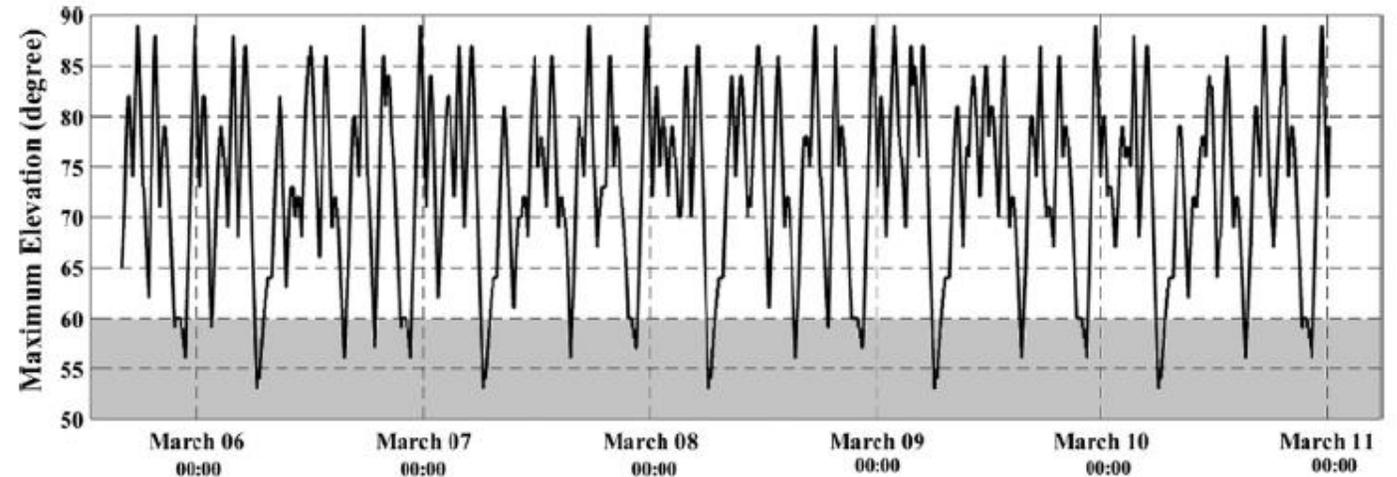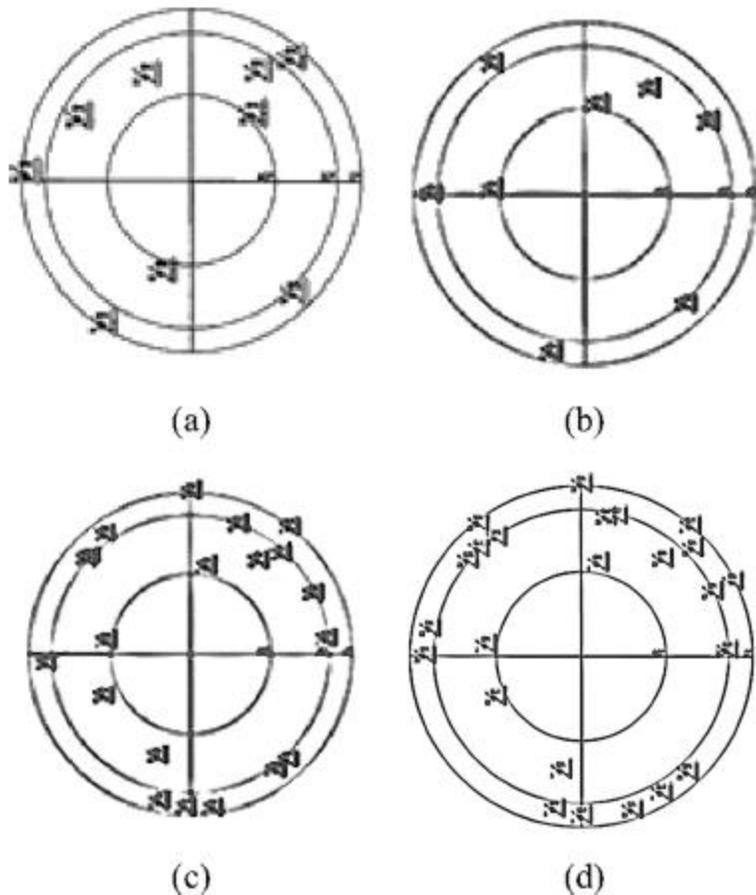
March, 2018, Burdwan, INDIA

"No GNSS above 60 degree elevation for part of the day
(a), (b) GPS only (2015, 2016);
(c), (d) GPS+GLONASS+GALILEO (2016, 2017)
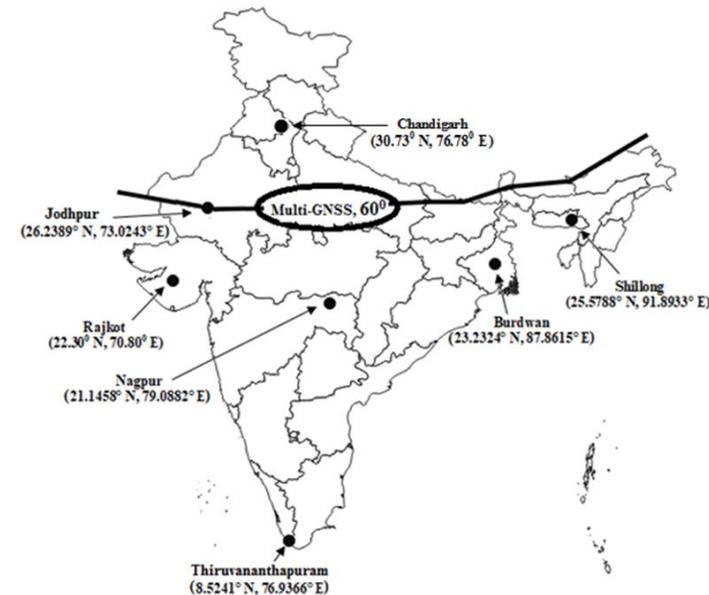
Problem contour over India
Below the dark line problem exists
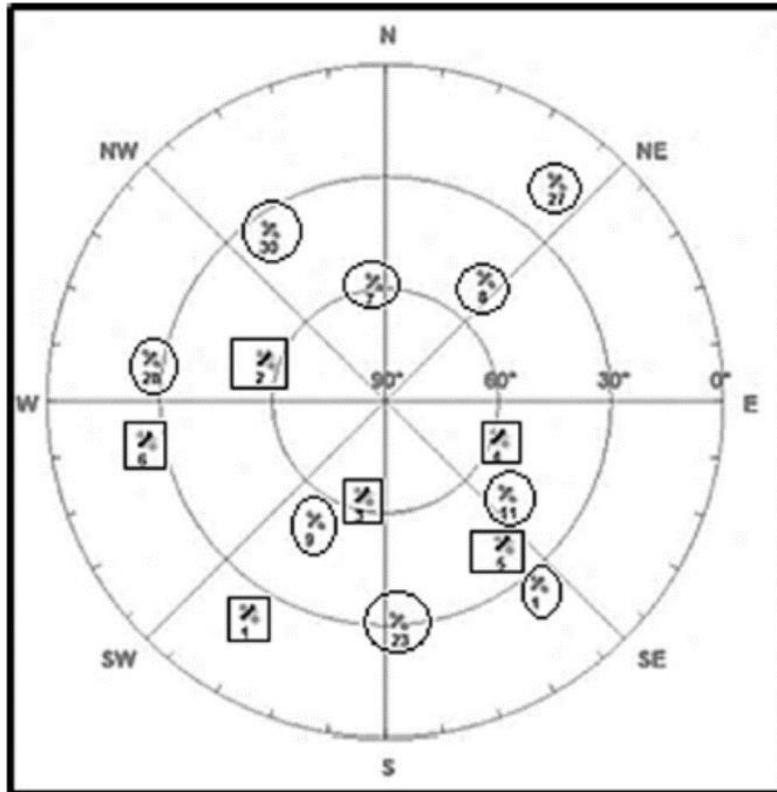
GPS+IRNSS; 28 April, 2016
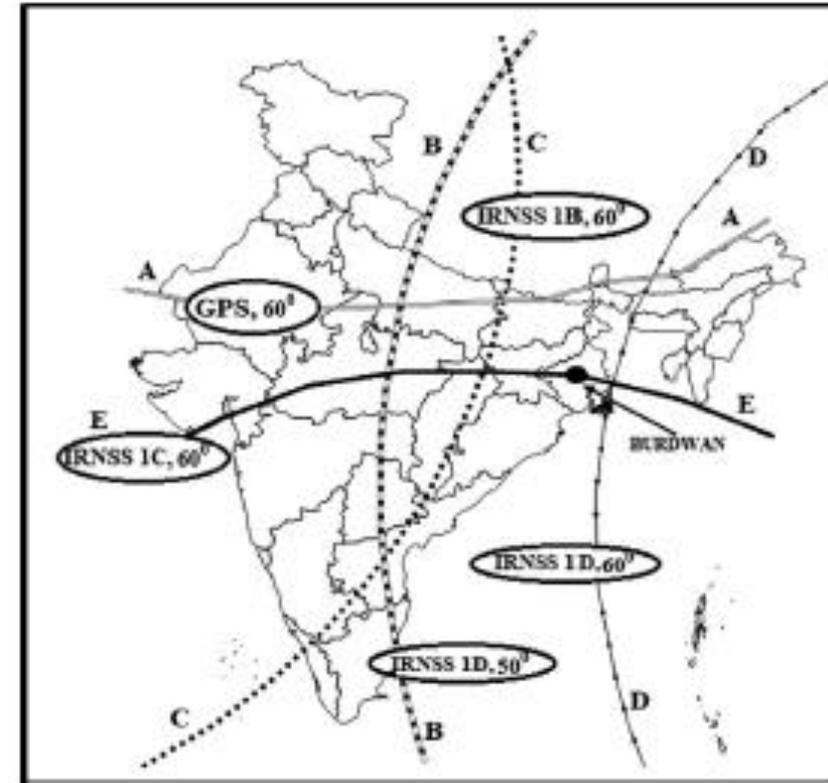
Typical NavIC coverage over the Indian region

WE tried to see how NavIC can handle the situation and
what are the real-time effects ?

**NavIC: Advantages in augmenting Multi-GNSS**
Dynamic Survey in city environment

Kolkata, INDIA, October 2017

**Burdwan, INDIA, March 2018**

Affected Time

During the affected Time
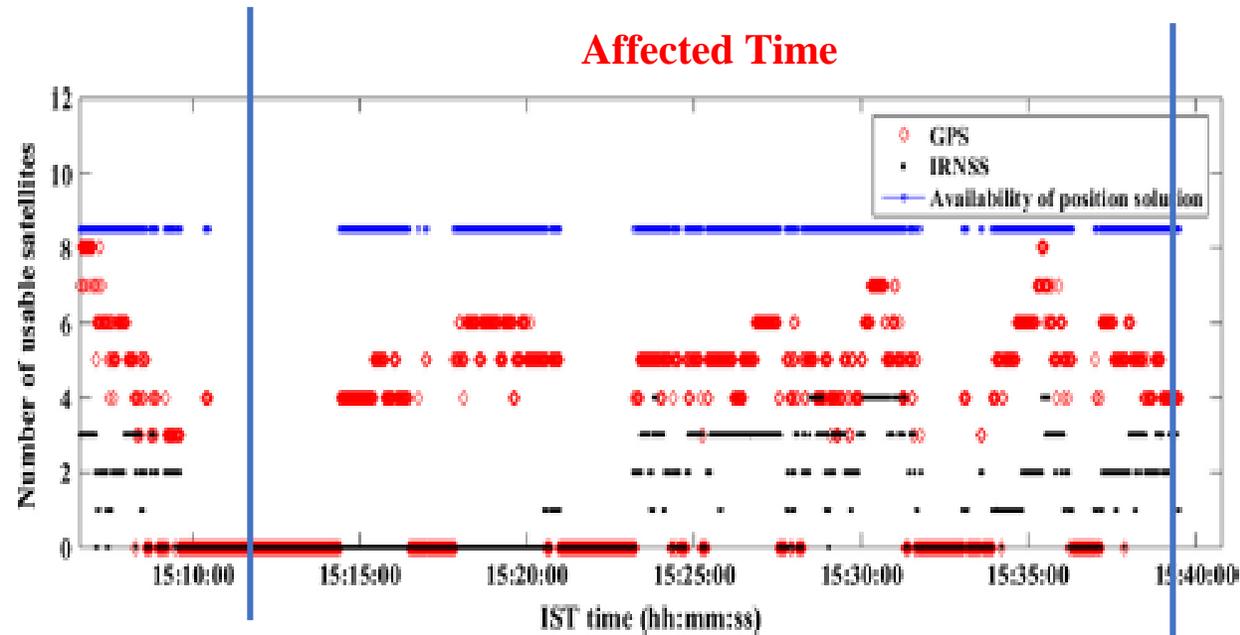
For many epochs solution is possible using NavIC
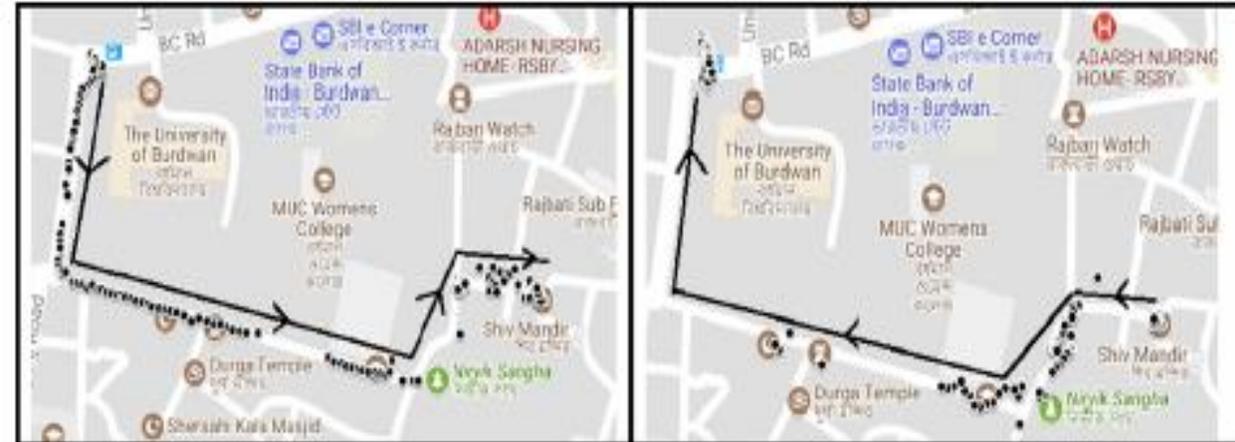
More solution is obtained in GPS+NavIC operation (left) than GPS only operation (right) during the affected time
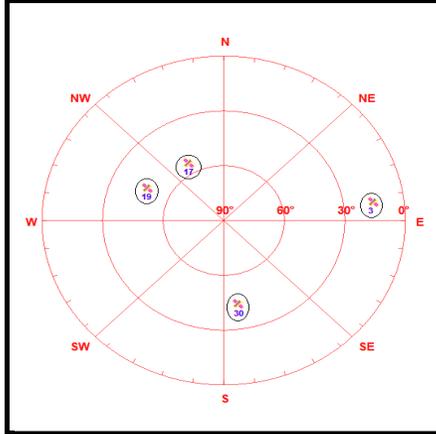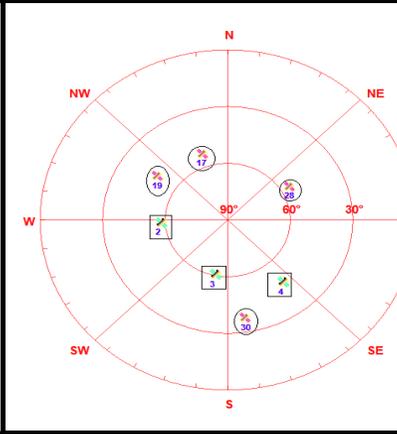
(a)   (b)   (c)
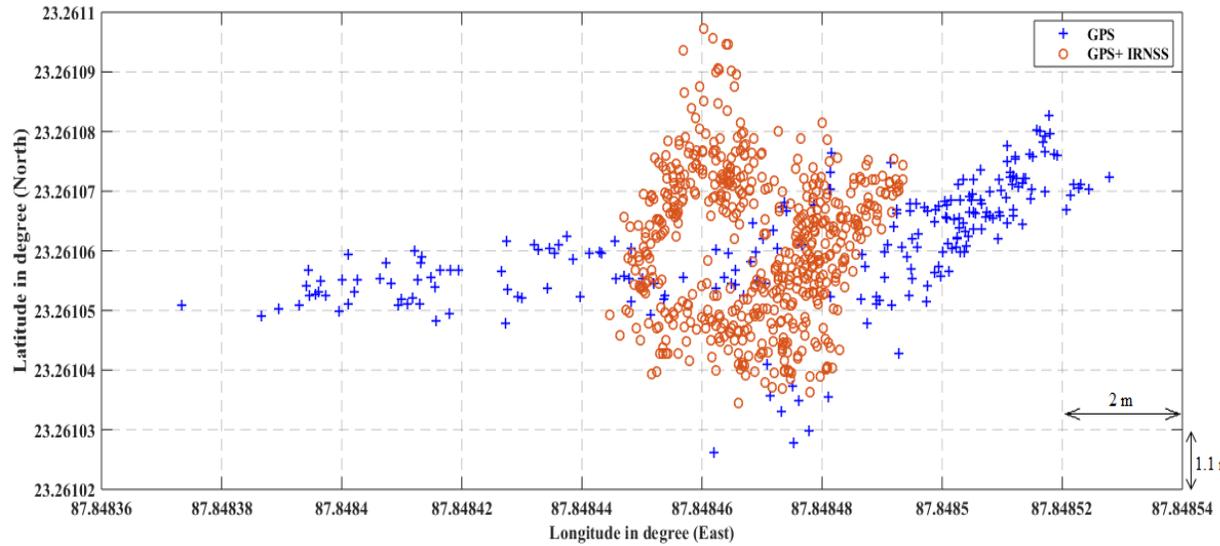
(d)

NavIC: Advantages in augmenting Multi-GNSS

Static Survey in city environment

Mode (Time, IST)	Total Number of Epoch (Average PDOP)	Total Solution Obtained (Solution Success)	Maximum Variation (m)			2DRMS (m)	CEP (m)	SEP (m)	MRSE (m)
			Lat	Lon	Alt				
GPS (18:52 - 19:00)	468 (5.08)	224 (46.09%)	6.28	15.76	50.06	8.28	2.91	8.80	12.85
GPS+ IRNSS (19:02 - 19:11)	557 (4.30)	557 (100%)	6.98	4.98	34.81	3.51	1.50	3.83	5.30

Comparison of static GPS and GPS-IRNSS hybrid solutions in constrained city environment of Burdwan during the affected time of GPS visibility

Static survey of GPS and GPS-IRNSS hybrid operation within constrained city environment during 'no GPS above 60 deg' condition at Burdwan (10 March 2018, (a) survey location, (b) and (c) representative skyplots (d) solution scatter plot

NavIC: Advantages in augmenting Multi-GNSS
Dynamic Survey in mixed environment; Burdwan University Campus, May-June 2018, IGS Receiver (NavIC 1I used for solution)

GPS only operation
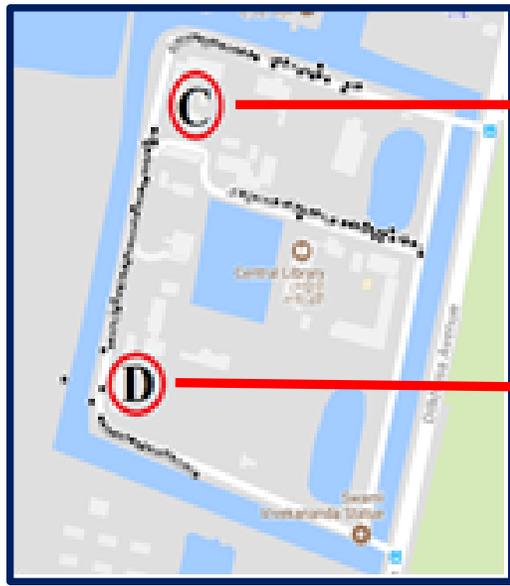
GPS+NavIC operation
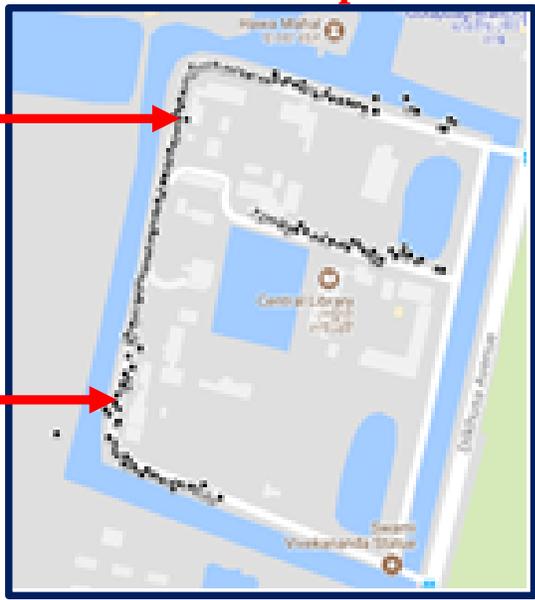
Solution capabilities of GNSS combinations in semi-urban mixed environment							
Date (Rx used)	Duration of data collection (IST)	Total Epochs	GNSS constellation(s) used	Solution Success Rate	Tracked Satellite range	Used Satellite range	PDOP range
1 June 2018	18:43:02 − 18:52:47	587	GPS	45.99%	$1-7	$4-7	2.64-16.3
	18:54:33 − 19:04:02	570	GPS+NavIC	58.07%	$2-15	$5-12	2.64-12.2
$NavIC 1I is included in the tracked and used satellites.							

NavIC: for Atmospheric Studies
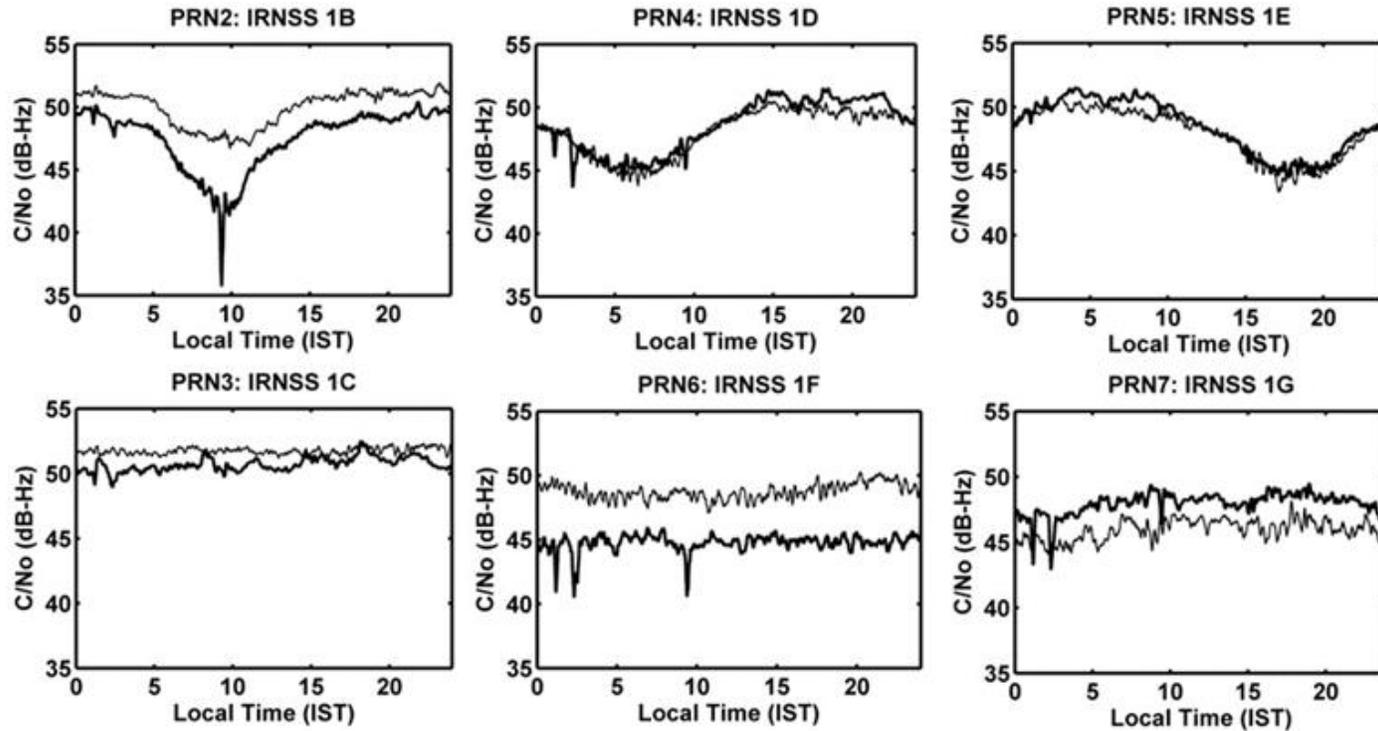
Variation of C/N0 values of IRNSS/ NavIC satellites (L Band) for 30 September, 2016 through simultaneous observation from Panhala, Westren India (16.48⁰ N, 74.6⁰ E) and Burdwan, Eastern India (23.15⁰ N, 87.5⁰ E).. **The darker thick line is for Burdwan** and the thin line is for Panhala

- **Fixed or low variation of IPP for RF Signal to study the local effects in comparison to other GNSS**
- **Signal from GEO/ GSO**
- **Extra S-Band for study**

Experiences with GAGAN

Position solution results obtained using standalone IRNSS and IRNSS with GAGAN enabled								
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 analysis using IRNSS, GPS with GAGAN enabled								
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.**

Research Roadmap

- Studies using different NavIC-enabled GNSS receivers
- Exploring potentials of S-Band Signal
- Studies in forest environments
- Studies of capabilities of low-cost NavIC receivers
- Integration with RTKLib for post processing
- Timing capabilities of NavIC

- Collaboration, Idea exchange

International Groups working with NavIC

- Curtin University, Australia
- FGI, Finland
- University of Calgary, Canada

THANK YOU

Somnath **Pratibha** **Atanu** **Sukbya** **Debipriya** **Raisa**