NavIC Availability, Performance and Advantages

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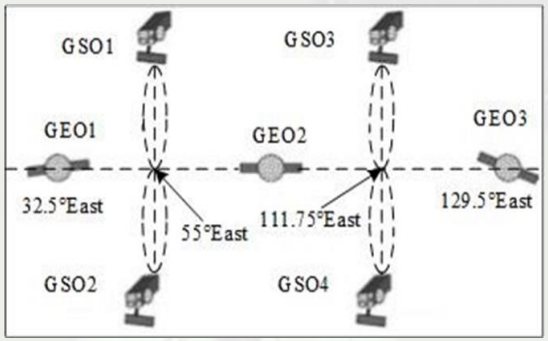
ICG-14, Bengaluru

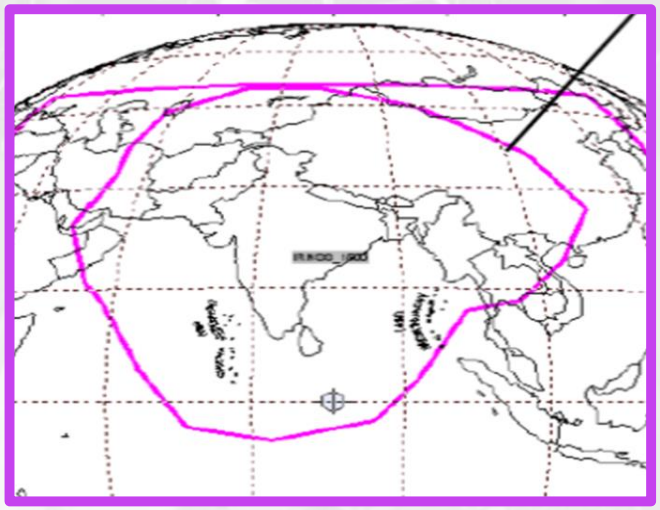
AGENDA

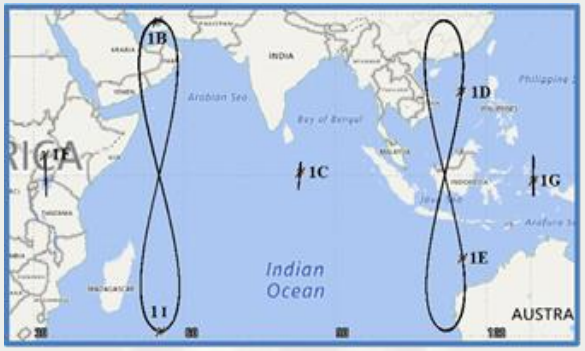
- NavIC: Constellation
- Visibility
- Offshore NavIC reception report
- Accuracy
- GNSS Visibility Issue and NavIC Support
- NavIC hardware modules
- Concluding Remarks

NavIC Constellation



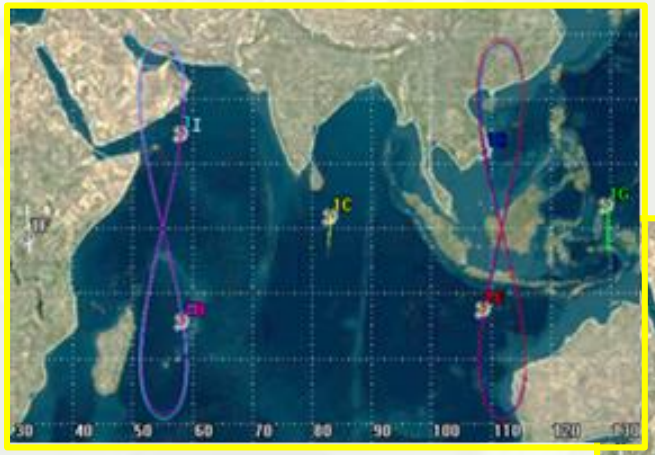
NavIC Constellation



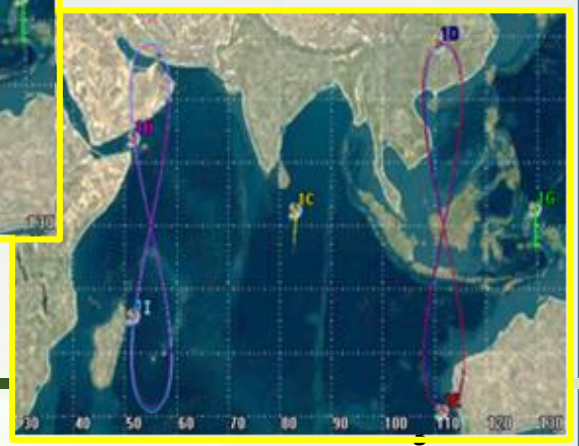


NavIC Typical Footprint

- Complimentary Coverage
- GEO/ GSO satellites (fixed/ low-varying IPP)
- S Band operation with L5 supports Enhanced Interference/ Jamming resistance

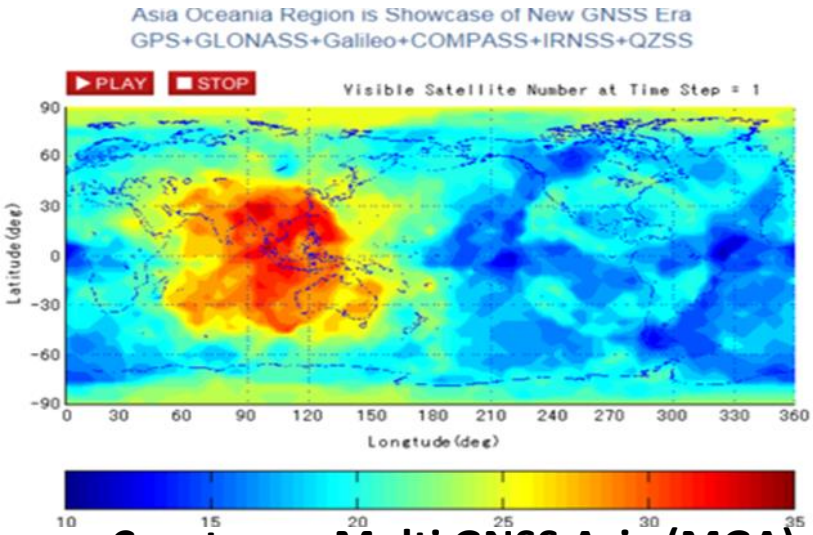


Best geometry

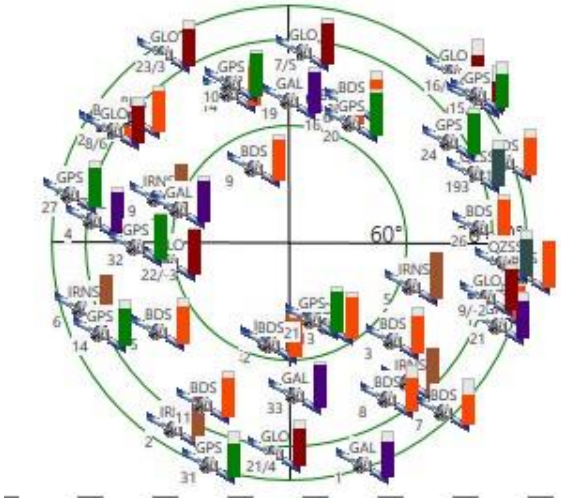


Worst geometry

Multi-GNSS: Advantage Asia
(Skyplot from Javad Triumph LS Multi GNSS receiver)

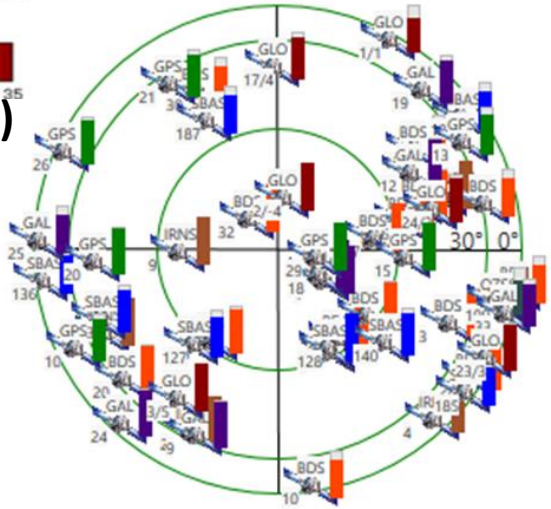


Courtesy: Multi GNSS Asia (MGA)



Typical skyplot for Eastern India
(04 December, 2019: 10:15 hrs IST)
48 satellites in view, 46 used

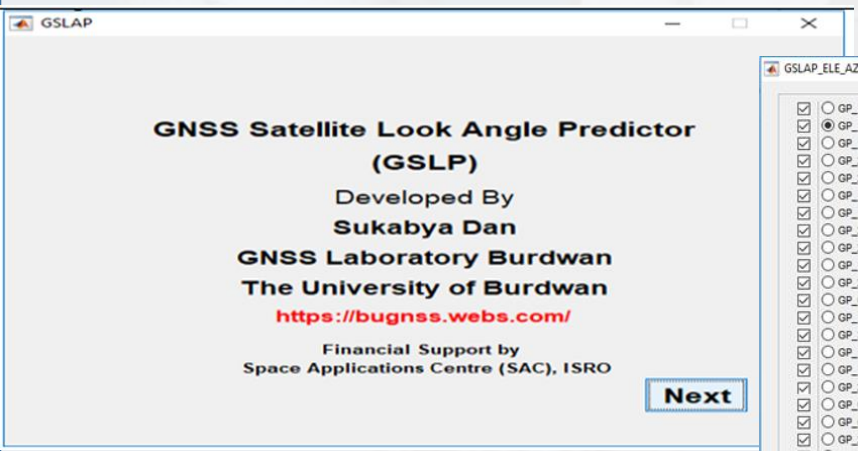
GPS+GLONASS+Galileo+Beidou
+NavIC+QZSS

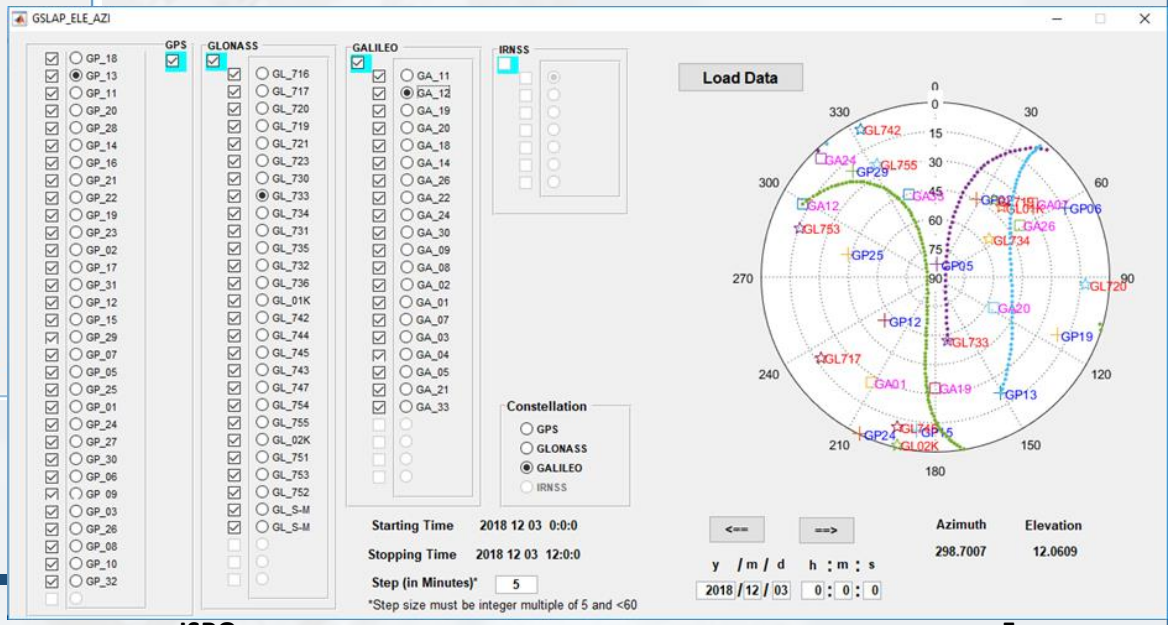


Typical skyplot for Western India
(23 June, 2019: 18:11 hrs IST)
54 satellites in view, 45 used

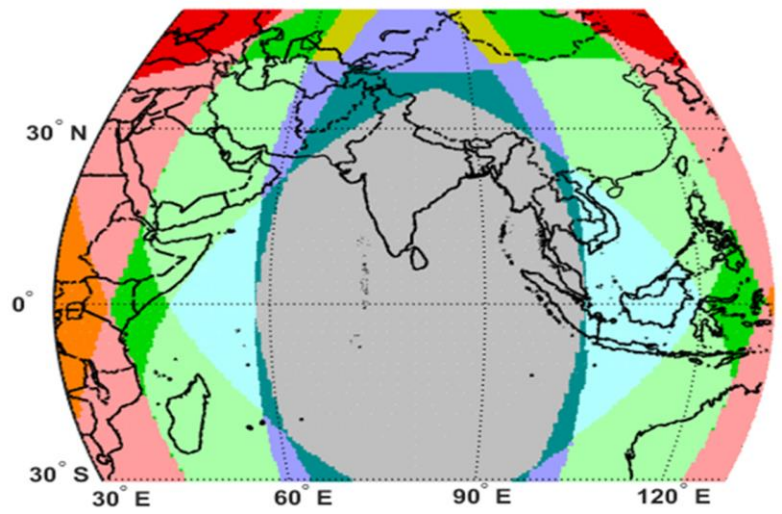
Simulation Tool integrating STK, Matlab

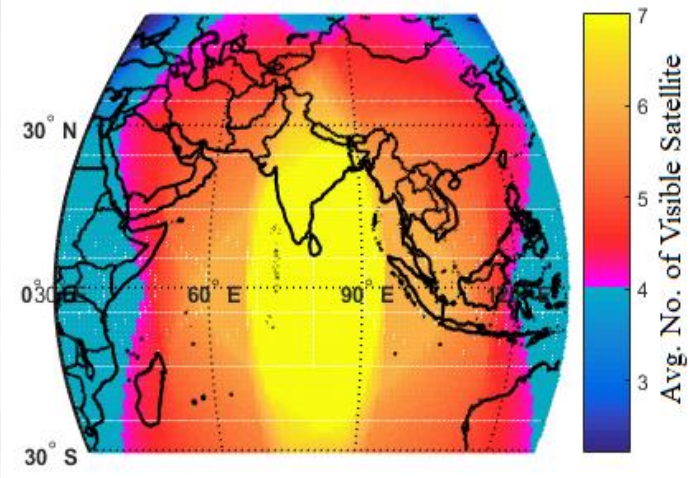
- A simulation tool was developed integrating System Tool Kit (STK) and MatLab, generates Look Angles (Elevation and Azimuth) for the GNSS satellites
- GNSS satellite visibility scenario are created for any observation point
- The Tool is used to generate global GNSS satellite visibility scenarios at grid points separated by 5º in latitude and longitude (5º x 5º)
- Simulated results are validated; GSLP is used for NavIC visibility prediction





NavIC visibility



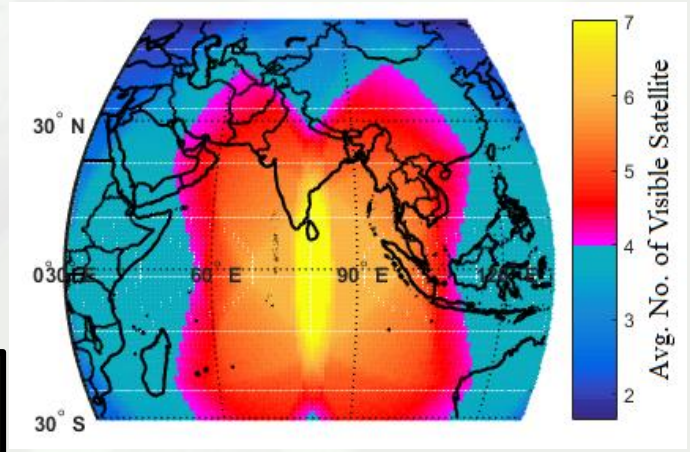


20° elevation mask angle

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

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

10° elevation mask angle

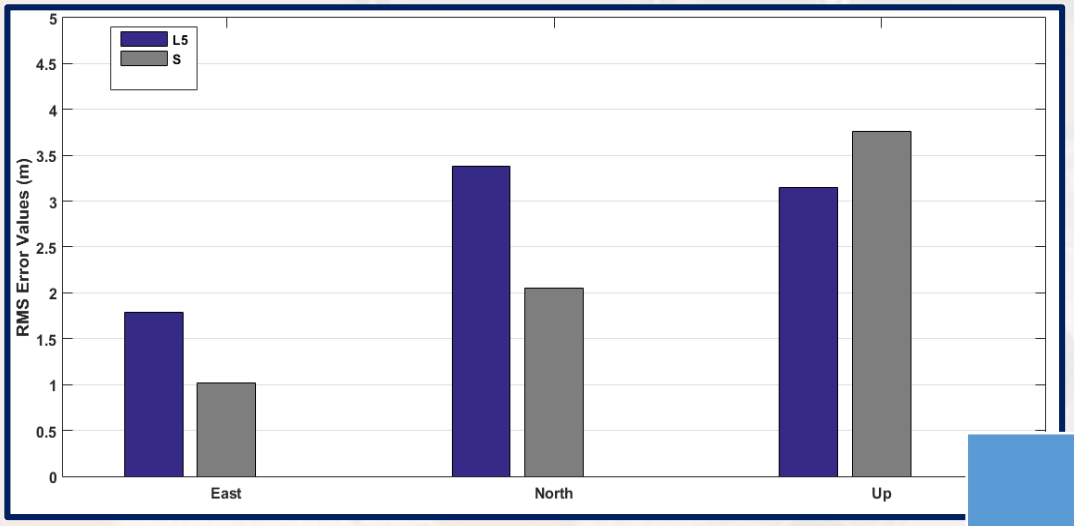


30° elevation mask angle

Even with 20 or 30° elevation mask, over a large area of the globe sufficient NavIC satellites are available

Users in and around India may obtain the benefit of NavIC

NavIC Solution Accuracy (Receiver: IRNSS-GPS-SBAS [IGS])

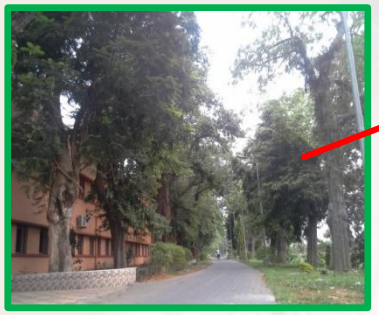


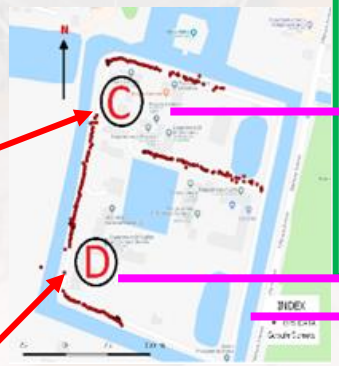
Single Point Position solution components, GLB, Burdwan, India, February, 2019

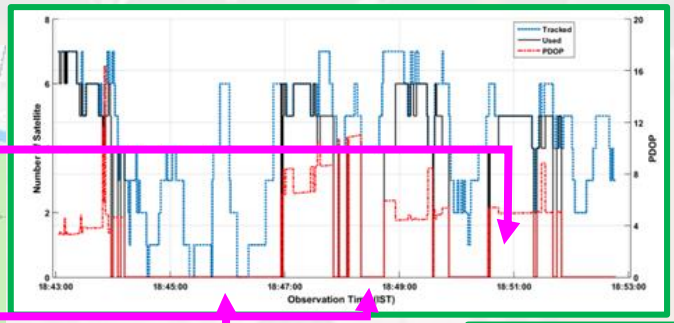
Precision and Accuracy

Operation Mode	Precision				2d Offset (m)	3d Offset (m)
	2DRMS (m)	CEP (m)	SEP (m)	MRSE (m)		
L5	6.97	2.68	3.83	4.65	1.57	1.71
S	4.51	1.80	3.30	4.13	0.39	1.53

NavIC supporting navigation in real-life environment (University of Burdwan Campus)

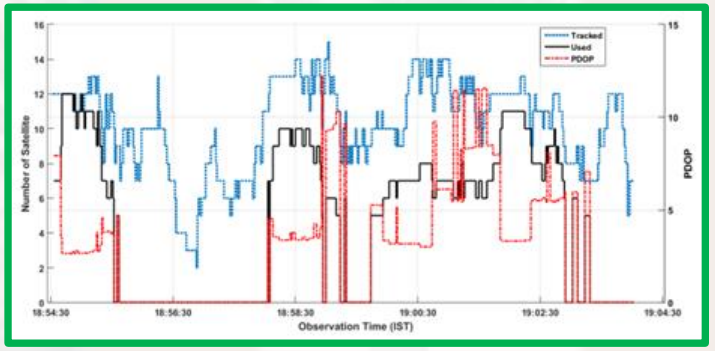






(a) GPS

(b) GPS+ NavIC

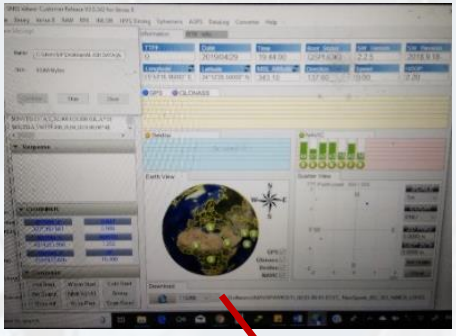


Number of tracked and used satellites and satellite geometry using IGS receiver on 1 June 2018

"A Study using Multi-GNSS Services in Indian Semi-Urban Environment", Atanu Santra, Somnath Mahato, Prasenjit Ghosh, Sukabya Dan and Anindya Bose, Proc. MDCCT 2018, The University of Burdwan, India, 2018, pp. 77-80

Total Epochs	GNSS constellation(s) used	Solution Success Rate
587	GPS	45.99%
570	GPS+NavIC	58.07%

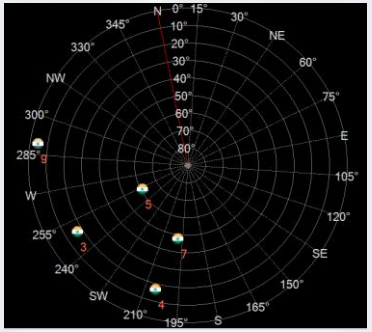
NavIC International Data Collection Efforts



TUMSAT, Tokyo, Japan

From field surrounded by buildings

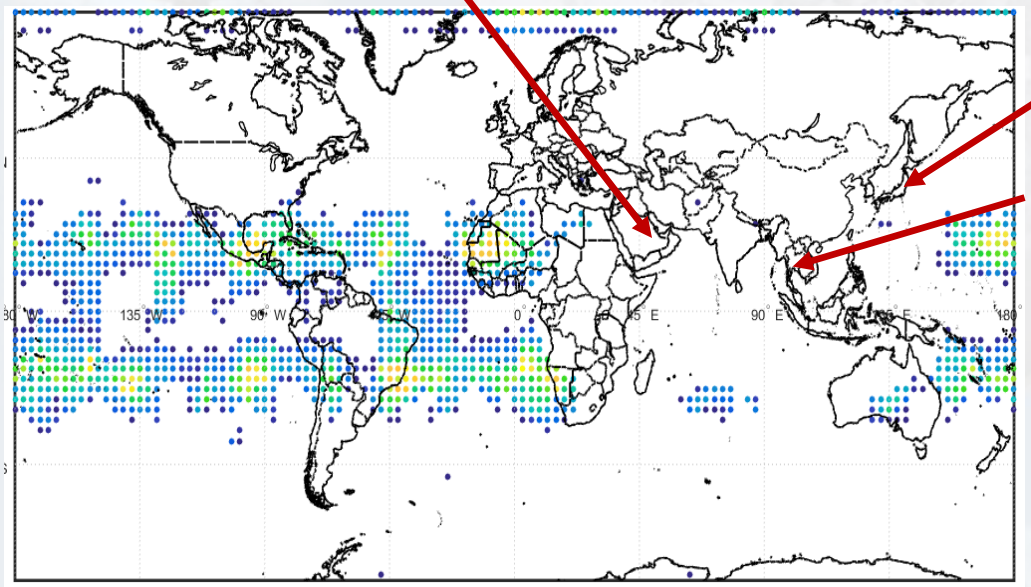
Receiver used: Allystar (L5)



Al-AIN, UAE

Data for small time, not all-in-view visibility

Receiver used: Skytraq (L5)

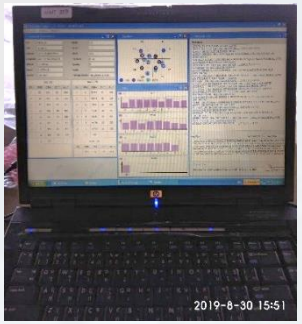


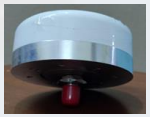
NIMT, Bangkok, Thailand

Clear view of the sky, 7-day data

L5, S, NavIC+GAGAN

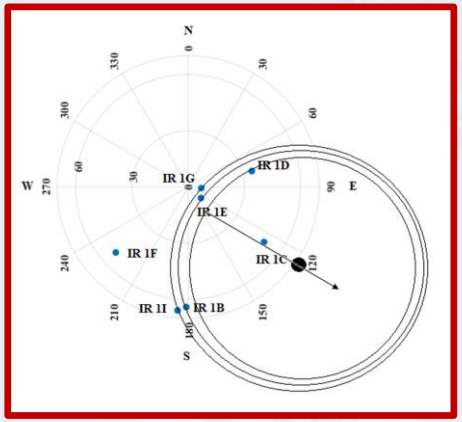
Receivers used: Allystar (L5); Elena (L5 +S)

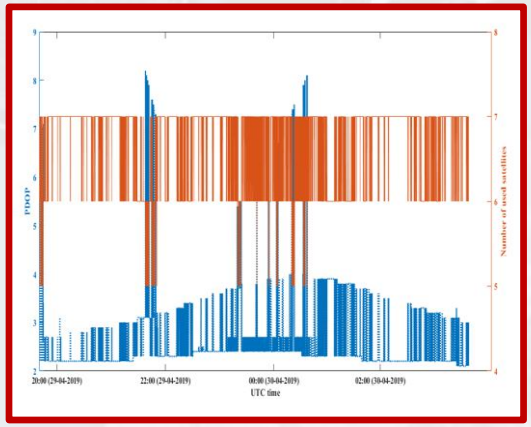




S-Band capable Antenna used

Results

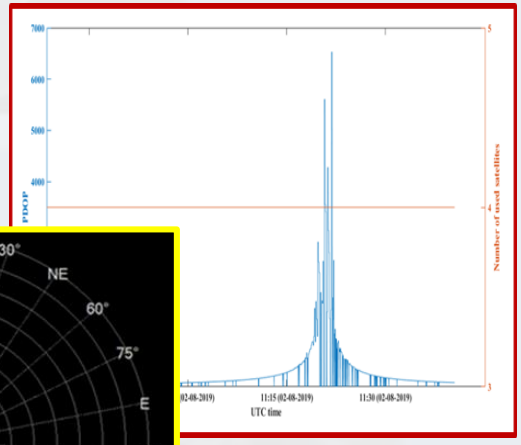


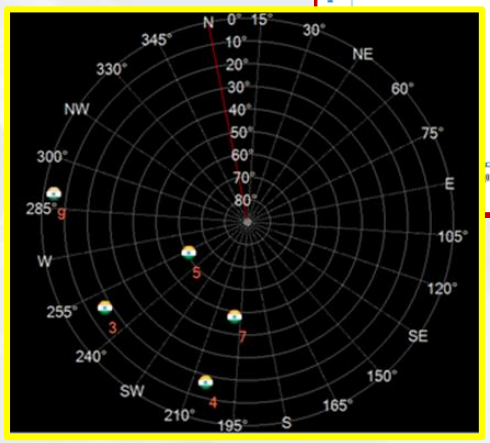


Skyplot :01:16:19 UTC 30-04-2019

Satellite visibility and geometry

AL AIN, UAE



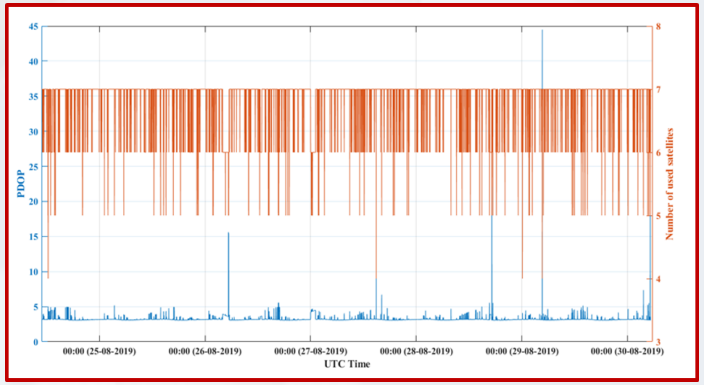


TOKYO, JAPAN

The **black dot** denotes the symmetry axis of the cone formed by satellites IR 1D, 1B, 1E and 1I i.e., the direction in which the receiver position estimate is poorest [1].

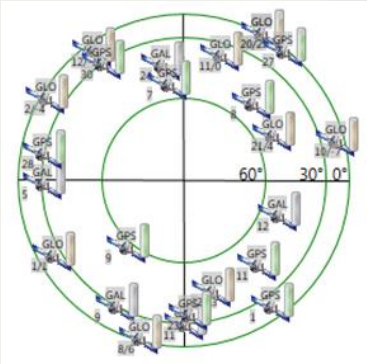
[1] "IRNSS stand-alone positioning: first results in Australia, Journal of Spatial Science", S. Zaminpardaz, P. J. Teunissen and N. Nadarajah, 2016, 61(1), pp.5-27

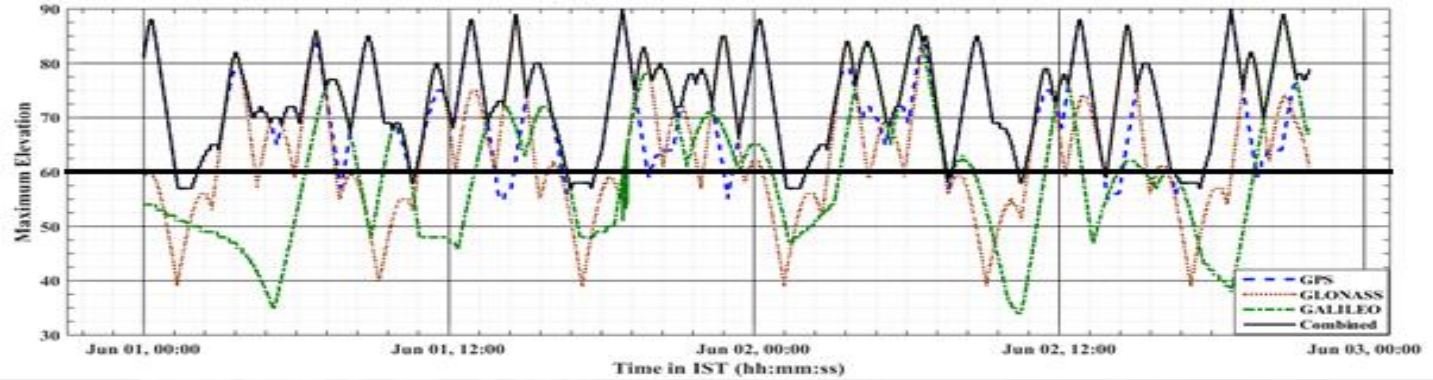
Pathum Thani, Thailand



GNSS Visibility Issue (from GLB, Burdwan, INDIA)

During some parts of the day, all GPS+GLONASS+Galileo satellites lie below 60º elevation angle



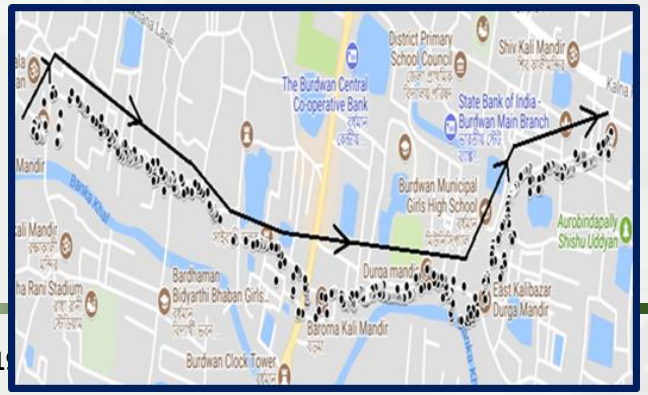


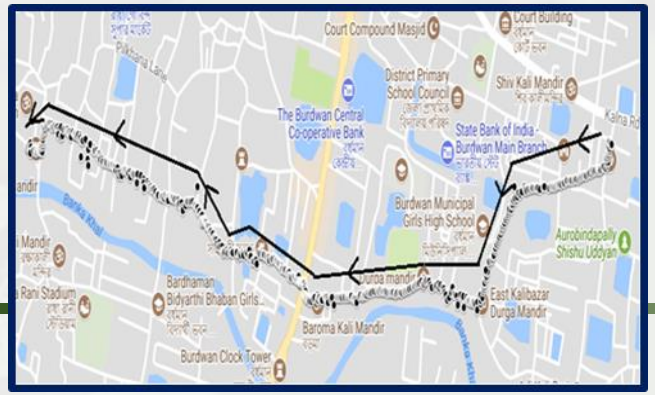
Typical '*skyplot*' for **all tracked satellites below 60º elevation angle** for GPS+GLONASS+Galileo satellites. (20 GNSS satellites above 10º)

Maximum elevation of tracked satellites in standalone and hybrid GNSS operation (June 2017 from GLB, India)

During the affected period of "No GNSS above 60º", from a restricted satellite visibility region with obstruction from lower elevation angles, solution performance and quality degrades.

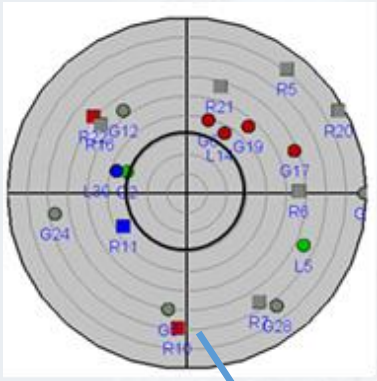
Affected period

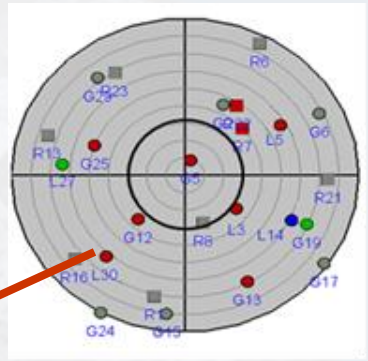




Normal period

Consequences of the situation (Static Case, GNSS, Burdwan, INDIA)





A Multi-GNSS receiver in GPS+GLONASS+Galileo mode is used within a constrained city environment

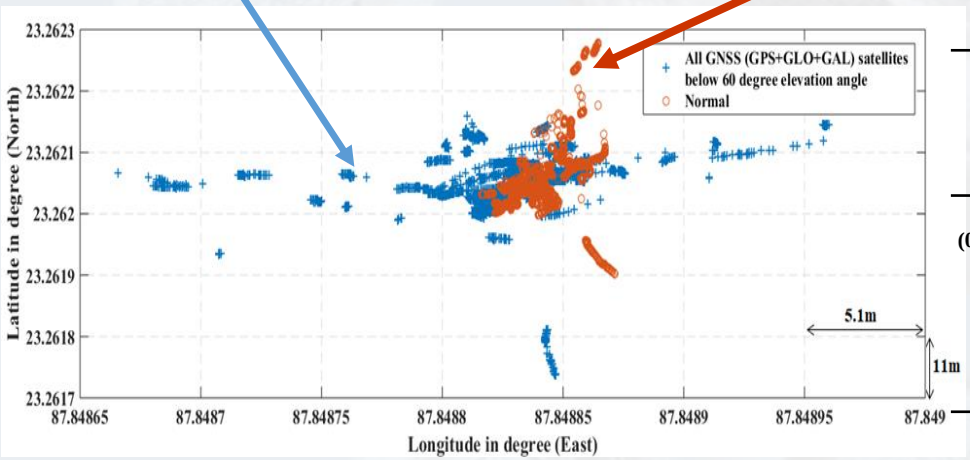
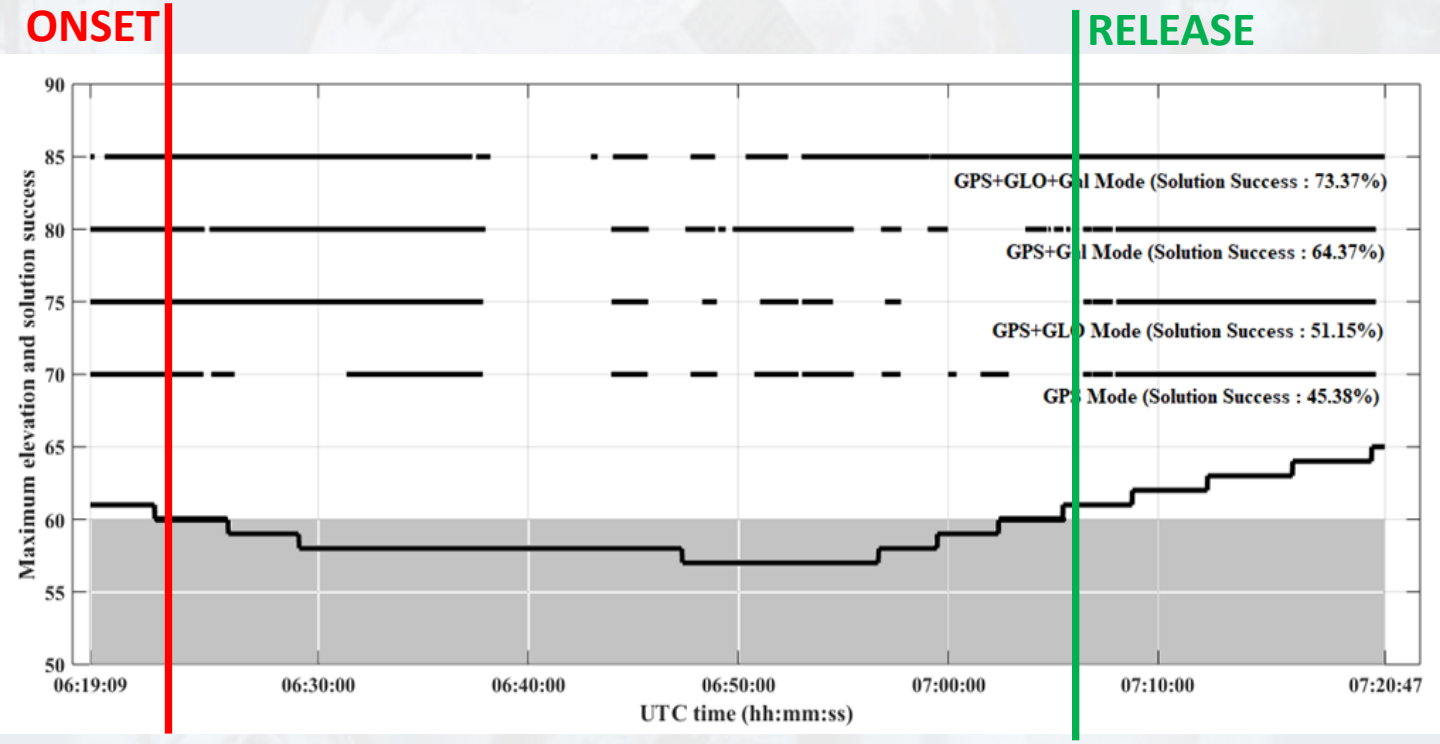


Table:. Comparison of position solution in normal and affected periods for static hybrid (GPS+GLO+GAL) operation in constrained city environment of Burdwan, India, 14 July 2018

Condition (Time, IST)	Total Epochs (Average PDOP)	Total Solution Obtained (Solution Success)	Maximum Variation (m)			2DRMS (m)	CEP (m)	SEP (m)	MRSE (m)
			Lat	Lon	Alt				
Normal (06:53 – 07:10 and 08:24 – 09:14)	4012 (3.05)	4012 (100%)	41.8	5.64	26.08	11.74	4.22	5.45	6.97
Affected period (07:10 -08:24)	4441 (6.23)	4146 (93.35%)	46.94	30.05	126.05	11.8	4.87	11.30	15.17

Consequences of the situation (Static, GNSS, Burdwan, INDIA)

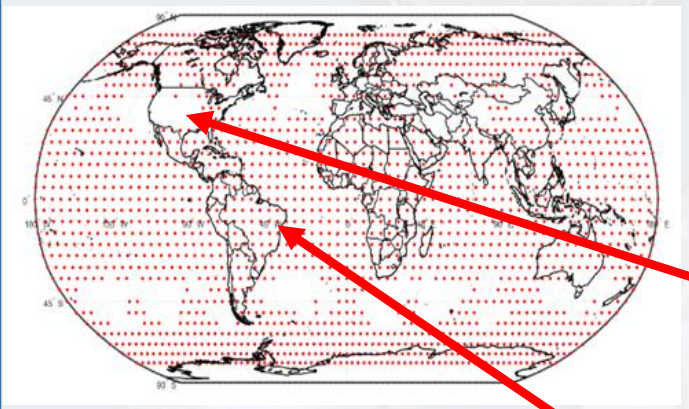
- Data collected within an urban canyon using a “Record and Replay” system
- GPS+ GLONASS+ Galileo data was recorded before, during and after the affected period
- Recorded data was played back through a multi-GNSS receiver.
- Position solution success rates for GPS and Multi-GNSS combinations were calculated



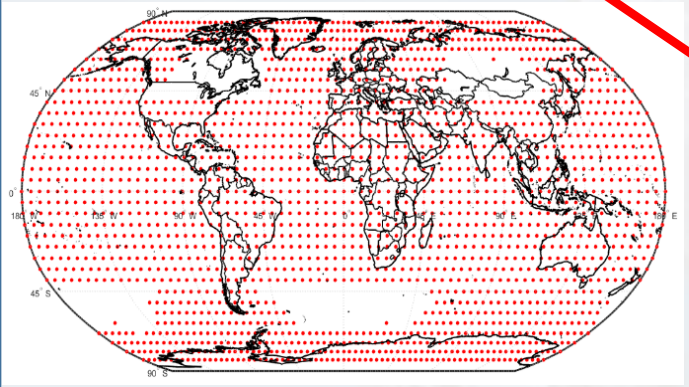
Global Scenario and Validation using IGS data

The red dots show the locations where all satellites lie below 60 deg elevation angle for more than 20 minutes over a day.

(24 April 2018)

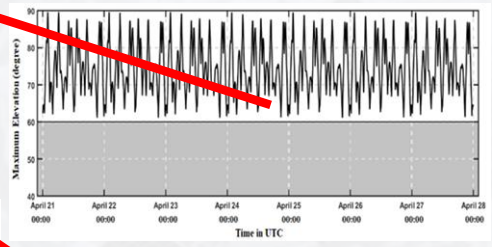


GPS

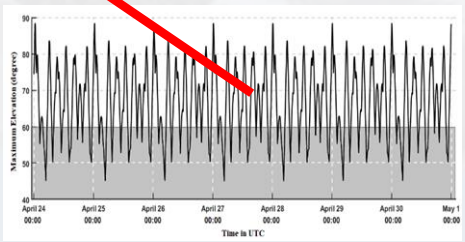


GALILEO (22 satellites)

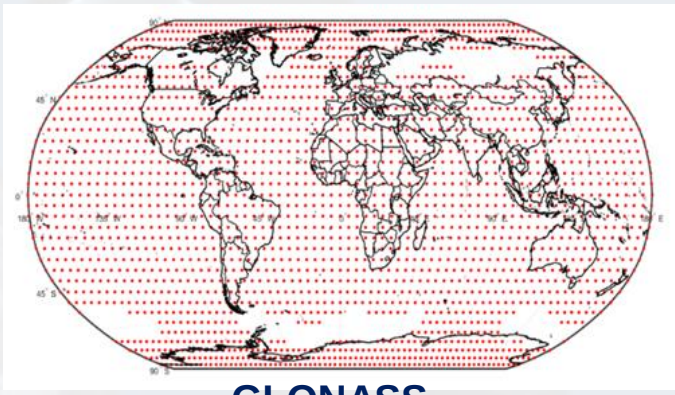
06 April 2019



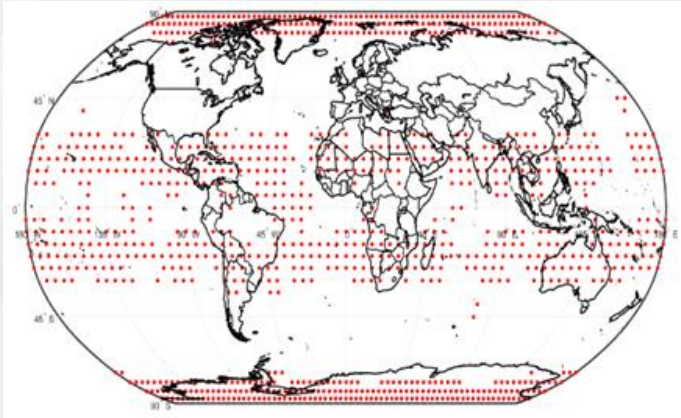
Quincy (42.2529° N, 71.0023° W), United States (QUIN)



Addis Ababa (8.9806° N, 38.7578° E), Ethiopia (ADIS)

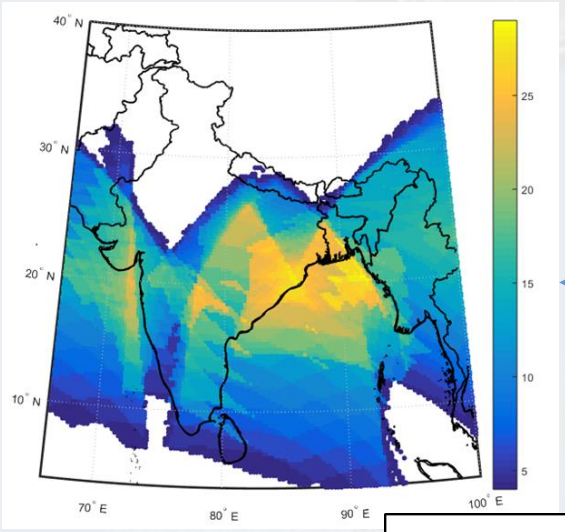


GLONASS

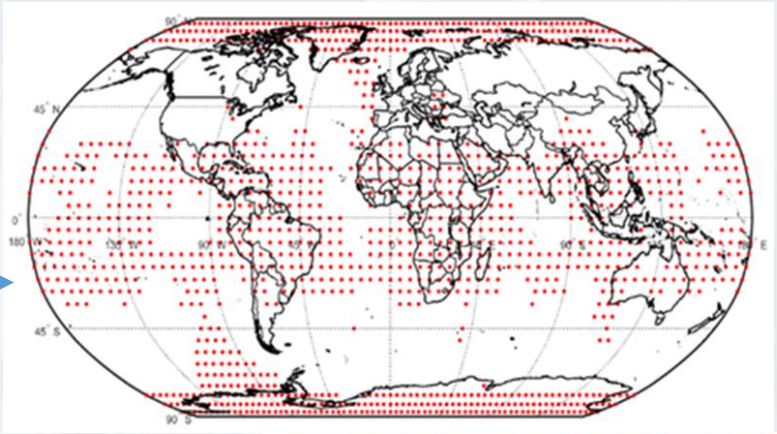


GPS+GLO+GAL

NavIC supporting navigation in such situation

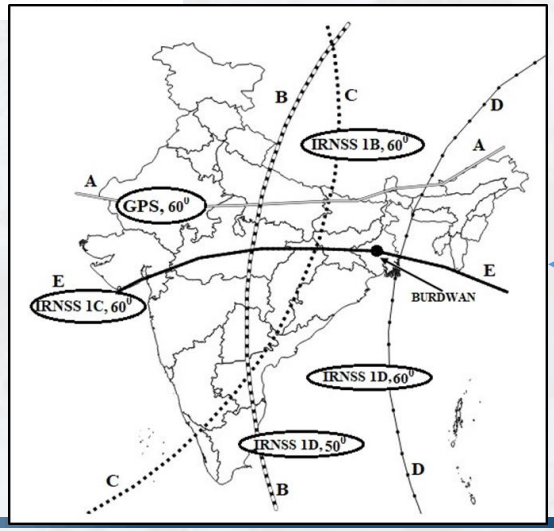


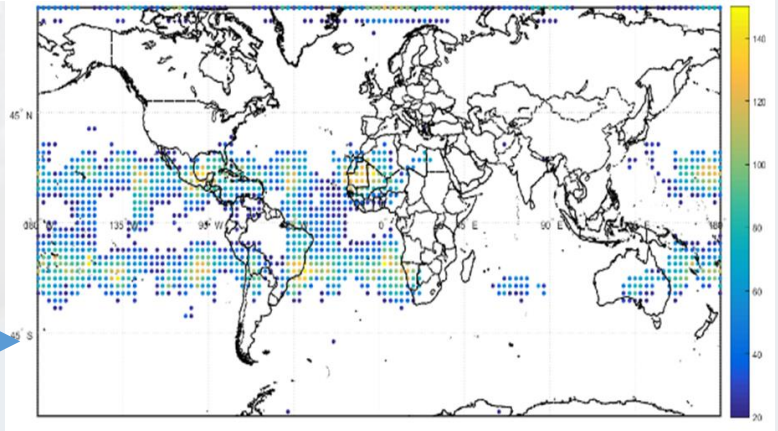
GPS+
GLONASS+
GALILEO



GLOBALLY

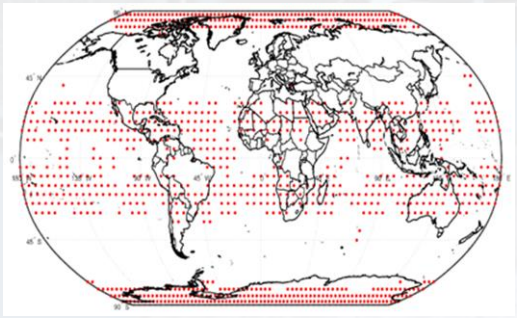
FOR INDIA



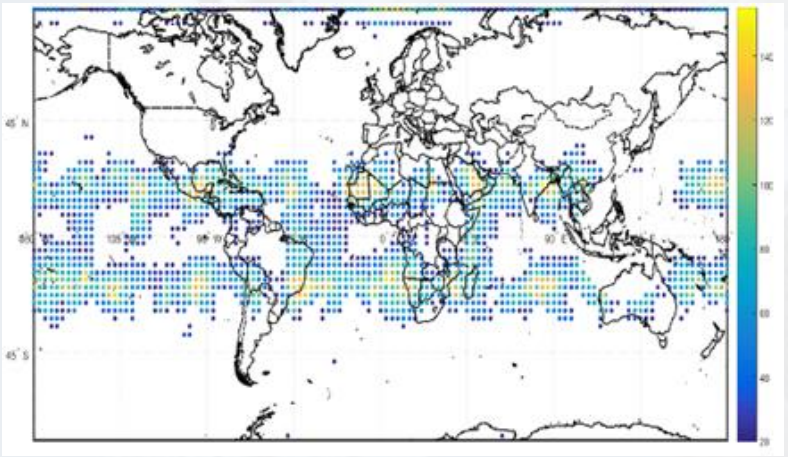


GPS+GLONASS+
GALILEO+NavIC

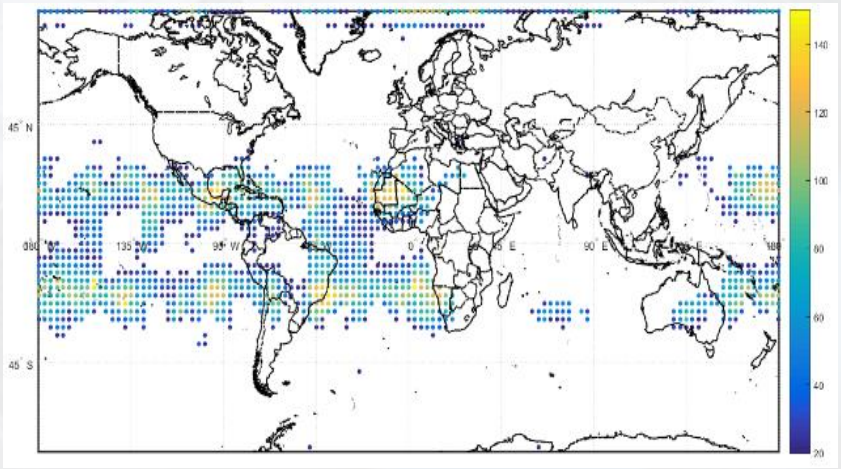
GNSS + QZSS or NavIC



GPS+GLONASS+ Galileo



GPS+GLONASS+Galileo+QZSS



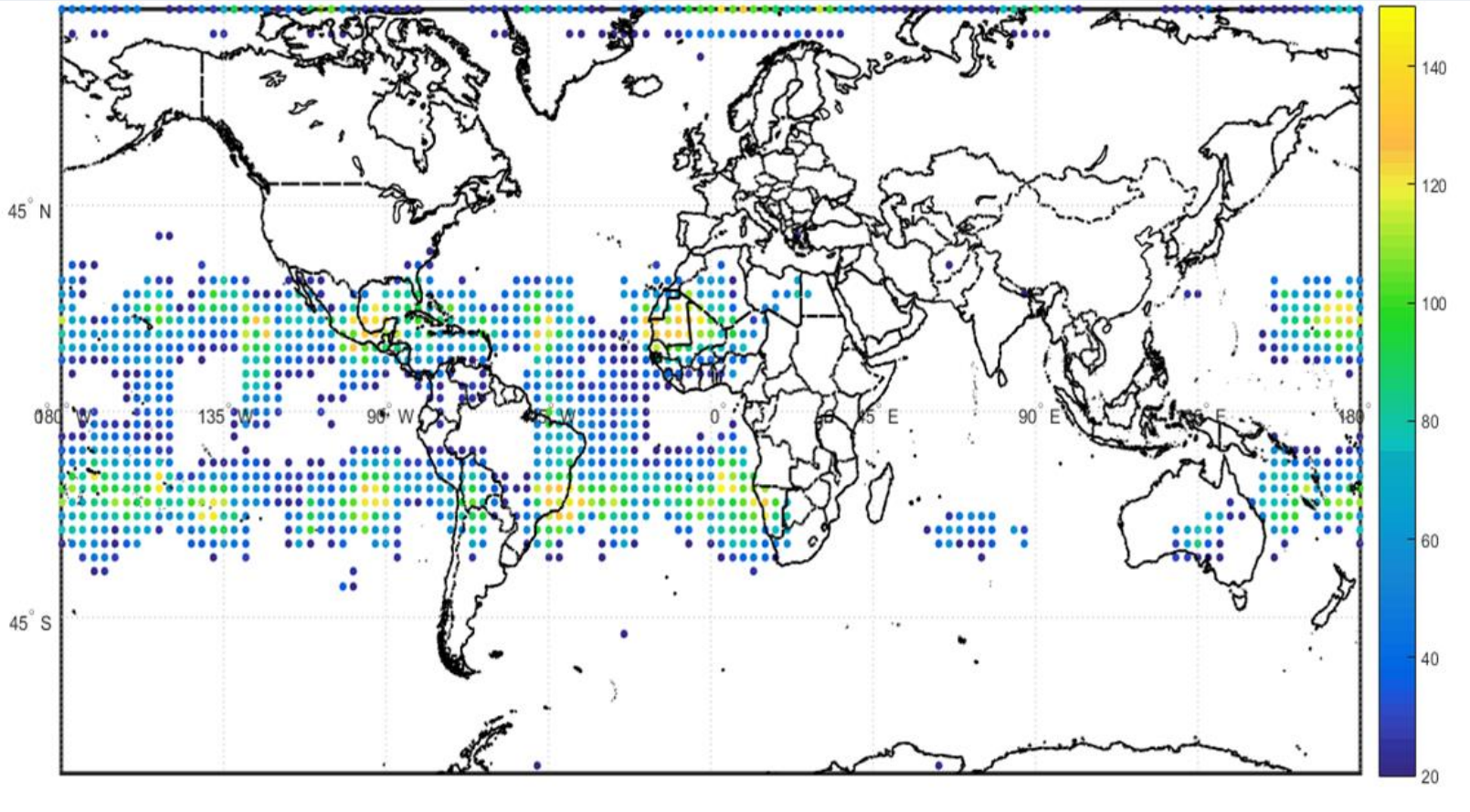
GPS+GLONASS+Galileo+NavIC

Cumulative time span of the problem for more than 20 minutes over a day (03 December 2018)

NavIC shows the capability of mitigating the problem of limited GNSS visibility over a larger part of the globe

"Augmentation of GNSS Utility by IRNSS/ NavIC Constellation Over the Indian Region", Atanu Santra, Somnath Mahato, S Mandal, Sukabya Dan, Pratibha Verma, P Banerjee and Anindya Bose, *Advances in Space Research*, 63(9), pp 2995-3008, (2019) DOI: https://doi.org/10.1016/j.asr.2018.04.020

GPS+GLONASS+Galileo + QZSS +NavIC



Using NavIC and QZSS with the global systems, over a large part of the globe, the problem of time-dependent limited visibility disappears

Available NavIC Hardware at GLB (Survey Grade and Compact)

IRNSS-GPS-SBAS (IGS) Receiver L5+S

JAVAD Triumph LS and DELTA Leica
Commercial Survey-grade Receivers L5

RACELOGIC
Record and Replay System L5

NavSpark GPS+GLONASS+ NavIC

Quicktel GPS+NavIC

Telit GPS+NavIC

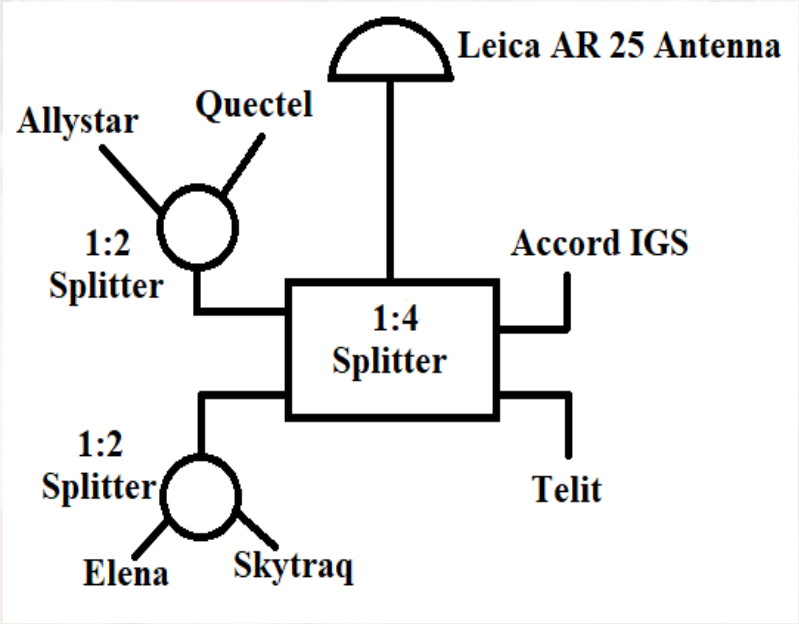
Allystar GPS+NavIC

GLB NavIC module Version 1.0 (NavSpark Chip)

L5

ELENA GPS+NavIC
L5+S

Performance comparison of compact NavIC modules



- The antenna is in a precise location calculated through PPP using AUSPOS service (True Value) [It is also being used for NTRIP service].
- Data has been collected for NavIC only (7 days) and GPS+NavIC (7 days)
- Parameters of interest are: Data quality, Position solution accuracy, signal strength,
- Future studies would be made on: cold start TTFF, interference tolerance, multipath handling capability

Result: Solution Performance comparison of compact NavIC modules (NavIC L5 only)

Make # (data duration)	Max Latitude variation (m)	Max ongitude variation (m)	Max Altitude variation (m)	2DRMS (m)	CEP (m)	SEP (m)	MRSE (m)	RMS Offset* (m)		
								East	North	UP
#1 (7 days)	59.968	41.300	102.400	6.553	2.637	4.641	5.735	1.521	2.934	4.917
#2 (5 days)	56.301	38.918	139.570	13.274	5.519	11.395	14.648	4.552	5.386	20.256
#3 (7 days)	98.526	81.511	42.100	10.446	4.363	4.788	5.596	3.729	4.081	10.071
#4 (7 days)	25.002	18.889	46.150	5.819	2.357	4.618	5.891	1.617	2.575	5.553
ISRO-IGS (7 days)	15.946	7.988	21.389	5.133	2.083	3.560	4.343	1.379	2.273	5.335

*Precision of Satellite Based Navigation Position Solution: a Review using NavIC Data, Atanu Santra, Somnath Mahato, Sukabya Dan and Anindya Bose, Proc. ICRTECS 2019, National Institute of Technology, Silchar, India, March, 2019

* RTKLib, *http://www.rtklib.com/*

Result: Performance comparison of compact NavIC-enabled modules (NavIC L5 + GPS L1)

Make # (data duration)	Max Latitude variation (m)	Max longitude variation (m)	Max Altitude variation (m)	2DRMS (m)	CEP (m)	SEP (m)	MRSE (m)	RMS Offset (m)		
								East	North	UP
#1 (7 days)	10.278	7.368	20.400	2.662	1.106	1.978	2.418	0.859	1.091	2.031
#2 (5 days)	23.576	14.770	31.350	8.795	3.523	5.773	7.006	3.430	3.968	5.986
#3 (7 days)	2.778	2.552	8.500	1.932	0.750	1.215	1.456	0.878	0.852	2.253
#4 (7 days)	14.446	28.929	33.460	2.983	1.240	2.591	3.343	1.114	1.256	3.664
#5 (7 days)	13.333	11.915	48.030	2.467	1.011	1.791	2.199	0.754	1.066	1.868
ISRO-IGS (7 days)	5.277	4.078	9.416	2.095	0.572	1.463	1.750	0.687	0.870	2.374

FINAL REMARKS

- NavIC would be beneficial for regions surrounding INDIA
- Can enhance Multi-GNSS potential for System Independence, Redundancy and Confidence for the users
- NavIC enabled hardware is being increasingly available (Compact, Low-Cost, Power-efficient)
- NavIC Single Point Positioning Accuracy in Single Frequency mode is <5m
- In really challenged environment, NavIC inclusion with GPS inproves position availability from 46% to 58%