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21-25 June 2021 in Virtually in the Netherlands

SMART SURVEYORS FOR LAND AND WATER MANAGEMENT
CHALLENGES IN A NEW REALITY

FIG NL THE NETHERLANDS

e WORKING WEEK 2021
20-25 JUNE

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Paper ID-10986

The Contribution of BeiDou-3 Binary Offset Carrier Signals to Single Point Positioning

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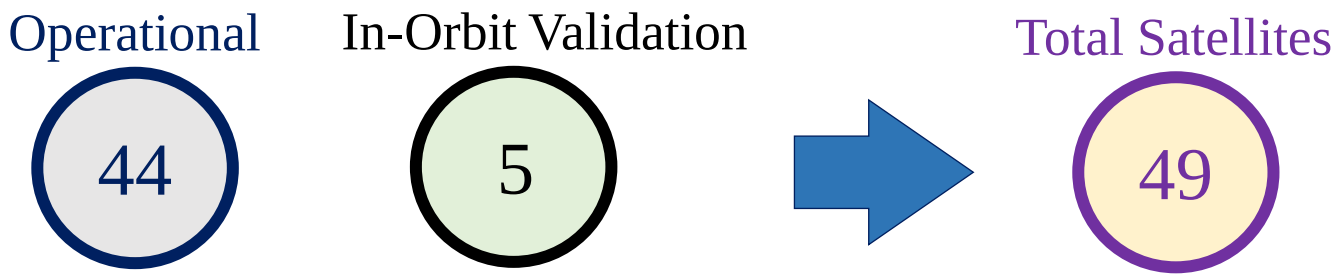
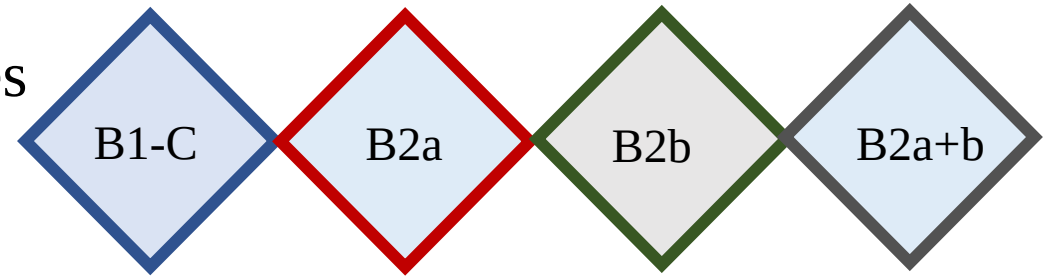
20-25 June, 14:00 Hrs

- As of December 2020



- BDS quad new frequencies



- BDS legacy freq. signals

1. Multipath
2. Signal-to-noise ratio (SNR)
3. Visible number of satellites (NSAT)
4. Dilution of precision (DOP)
5. Single point positioning (SPP)

Experimental Description

- 30 days datasets: DOY 153 -182, 2020
- Number of stations: 19 (Figure 1)

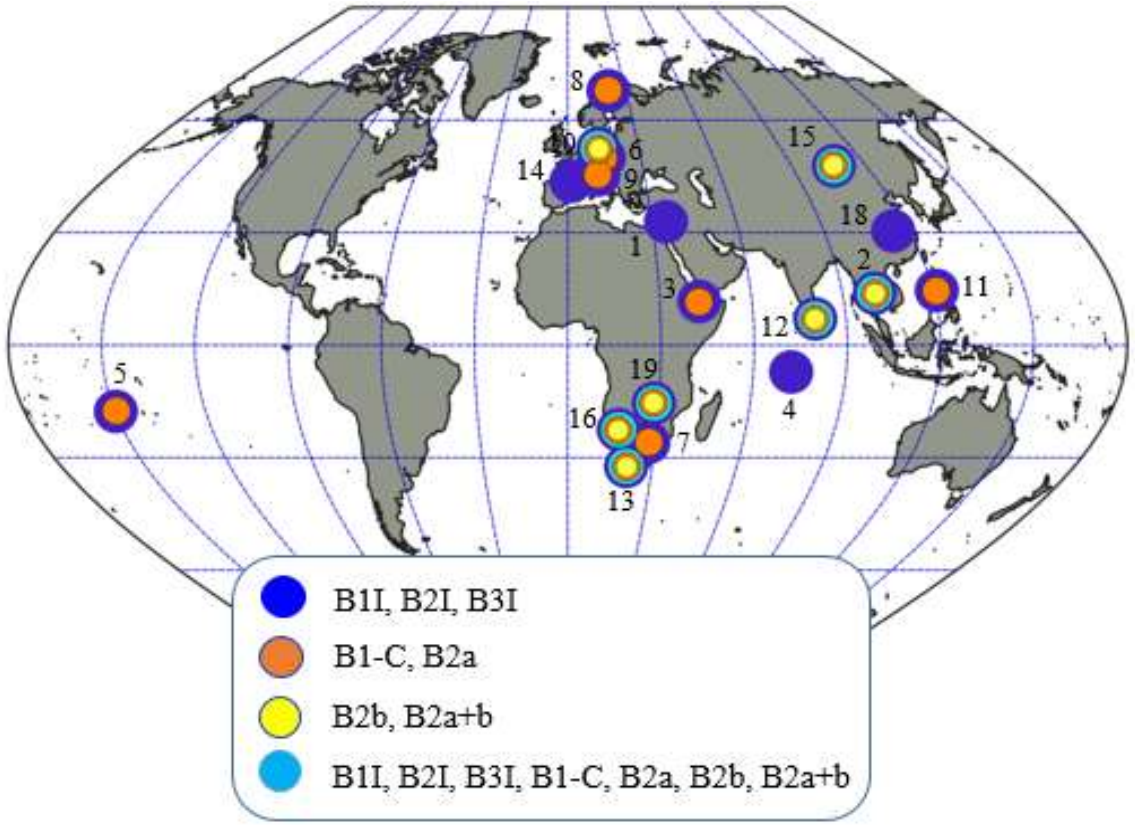


Figure 1: Geographical Distribution of the selected stations (https://www.igs.org/network/#station-map-list)

Table 1: Geospatial locations

SN	ID	Latitude	Longitude
1	bshm	32° 46' 44.4"	35° 01' 12.0"
2	cusv	13° 44' 09.3"	100° 32' 02.1"
3	dgar	-08° 43' 49.1"	72° 22' 12.9"
4	djig	11° 31' 34.6"	42° 50' 49.4"
5	faa1	-18° 26' 40.9"	-150° 23' 08.5"
6	gop6	49° 54' 49.2"	14° 47' 08.2"
7	harb	-26° 06' 46.9"	27° 42' 26.1"
8	kiru	67° 51' 26.5"	20° 58' 06.4"
9	pado	45° 24' 40.1"	11° 53' 45.8"
10	pots	52° 22' 45.5"	13° 03' 57.9"
11	ptgg	14° 32' 07.5"	121° 02' 28.6"
12	sgoc	06° 53' 31.5"	79° 52' 27.1"
13	sutm	-33° 37' 06.8"	20° 48' 39.3"
14	tlse	43° 33' 38.5"	01° 28' 51.2"
15	ulab	47° 51' 54.2"	107° 03' 08.4"
16	wind	-23° 25' 30.3"	17° 05' 22.0"
17	wtzz	49° 08' 39.2"	12° 52' 44.0"
18	wuhn	30° 31' 54.0"	114° 21' 26.1"
19	zamb	-16° 34' 28.1"	28° 18' 39.6"

Results and Discussions

C7D has the least code multipath

Visible NSAT: BDS-2(~8), ~ BDS-3(~7),& ~ BDS-2+3(~7)

Improvement in DOP: GDOP, PDOP & HDOP(~ 52%)
VDOP(~ 49%)

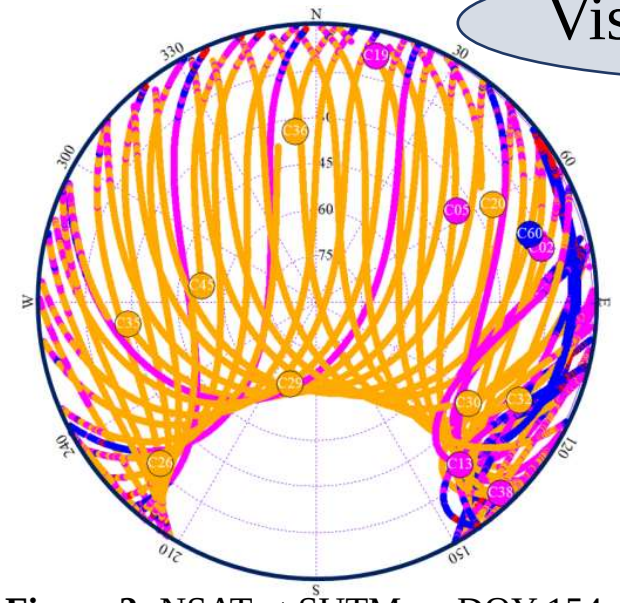


Figure 2: NSAT at SUTM on DOY 154

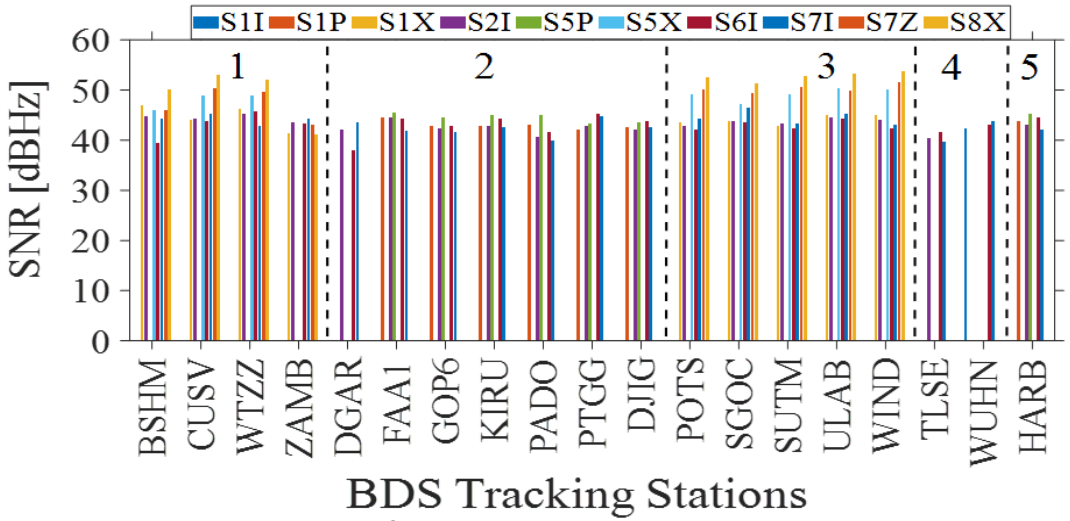


Figure 3: SNR for the selected stations

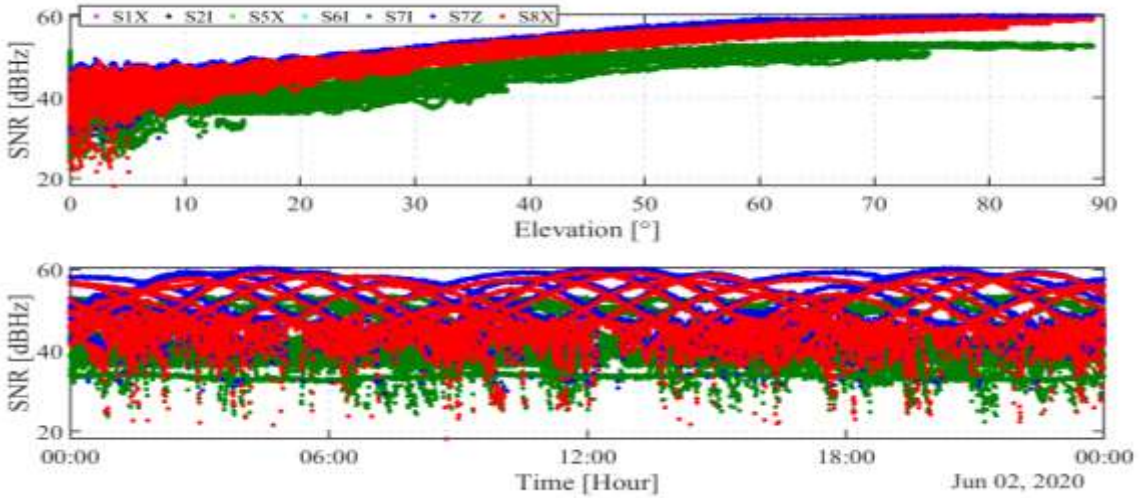


Figure 4: SNR with respect to elevation/time at SUTM station on DOY 154 (2020)

1 JAVAD TRE_3 DELTA
2 SEPT POLARX5
3 JAVAD TRE_3
4 TRIMBLE NETR9
5 SEPT POLARX5TR

SNR: ~ 92% > 40 dBHz

SPP Performance

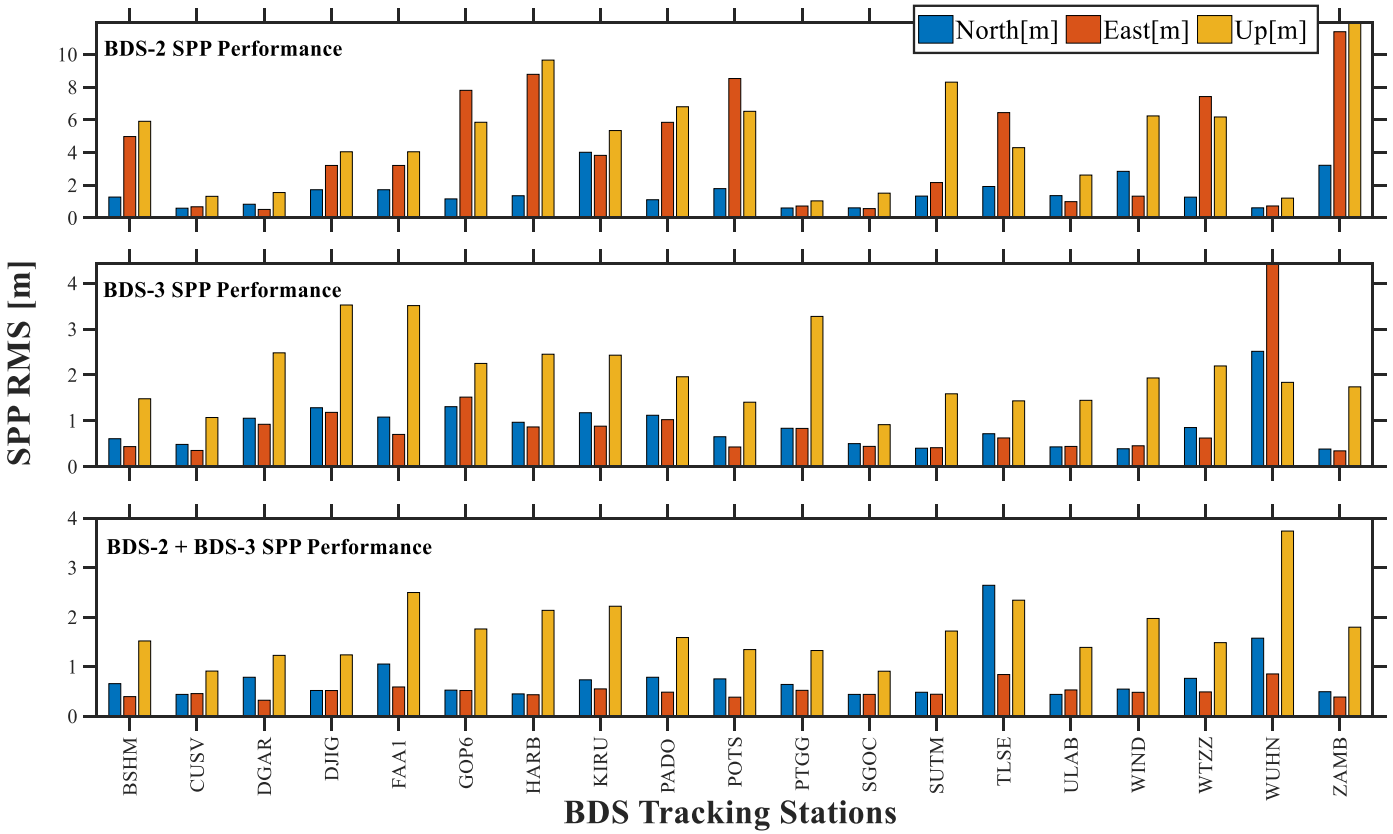


Figure 5: SPP performance

SPP performance: N(53%), E(73%), Up(61%)

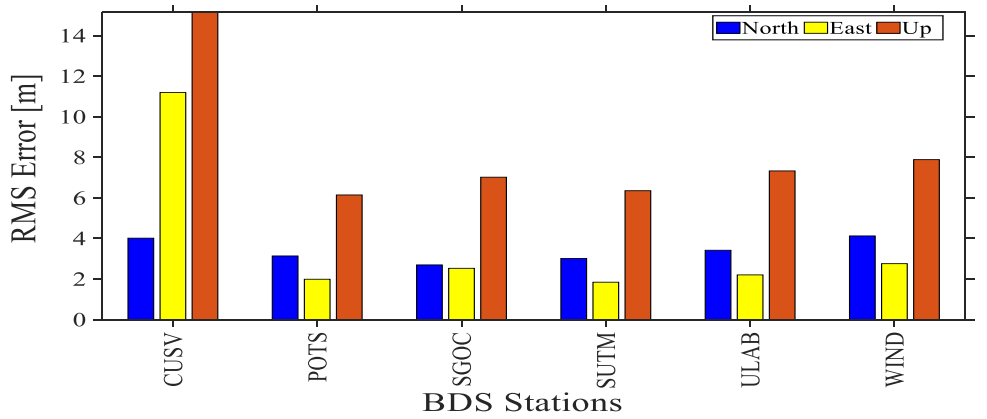


Figure 6: SPP performance for B1C and B2a+b

- 83% of the stations have SPP performance less than 5 m in both N and E dimensions
- 83% of the stations have an SPP performance of at less than 10 m in height
- Averaged RMS errors are all above 3 m

*** *Reduced Number of satellites with BOC signal tracking capability*

Table 2: SPP performance statistics (BOC)

Station	North [m]	East [m]	Up [m]
Min	2.69	1.84	6.14
Max	4.12	11.19	15.15
Average	3.4	3.75	8.31

Conclusions

- For the Selected stations + days, C7D has the least code multipath
- Visible NSAT
  - BDS-2 ~ 8
  - BDS-3 ~ 7
  - BDS-2 + BDS-3 ~ 7
- Improvement in DOP
  - GDOP, PDOP & HDOP ~ 52%
  - VDOP ~ 49%
- SNR: about 92% is above 40 dBHz

- With respect to BDS-2, improvement in SPP performance:
  **N(53%), E(73%) & Up(61%)
- Averaged SPP for stations with BOC signal tracking capability:>3m
- Overall SPP accuracy – will likely improve upon the inclusion of the in-orbit validation BDS satellites in the operational orbital constellation

Thanks

Backup slides

Results and Discussions

Multipath Analysis

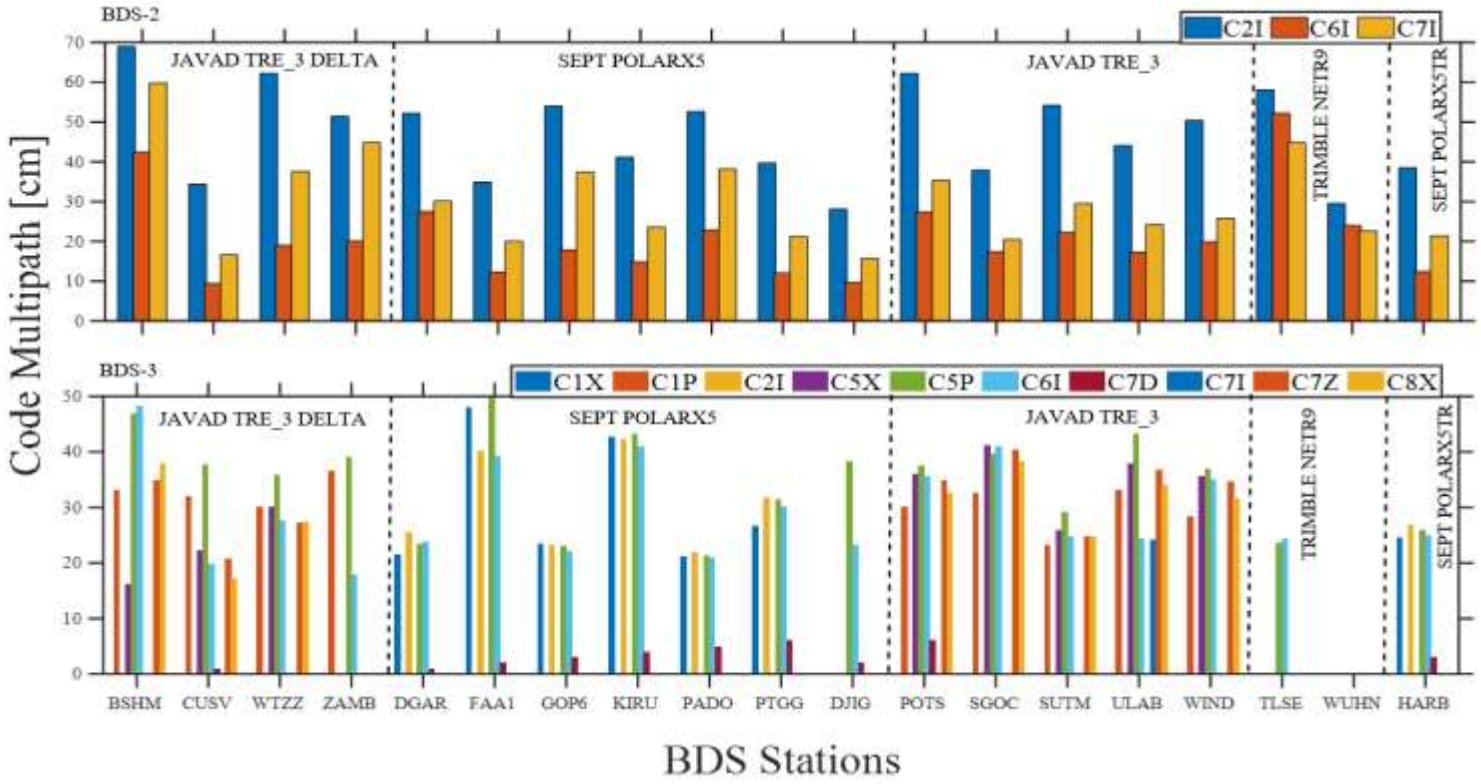


Figure 7: Code multipath comparison

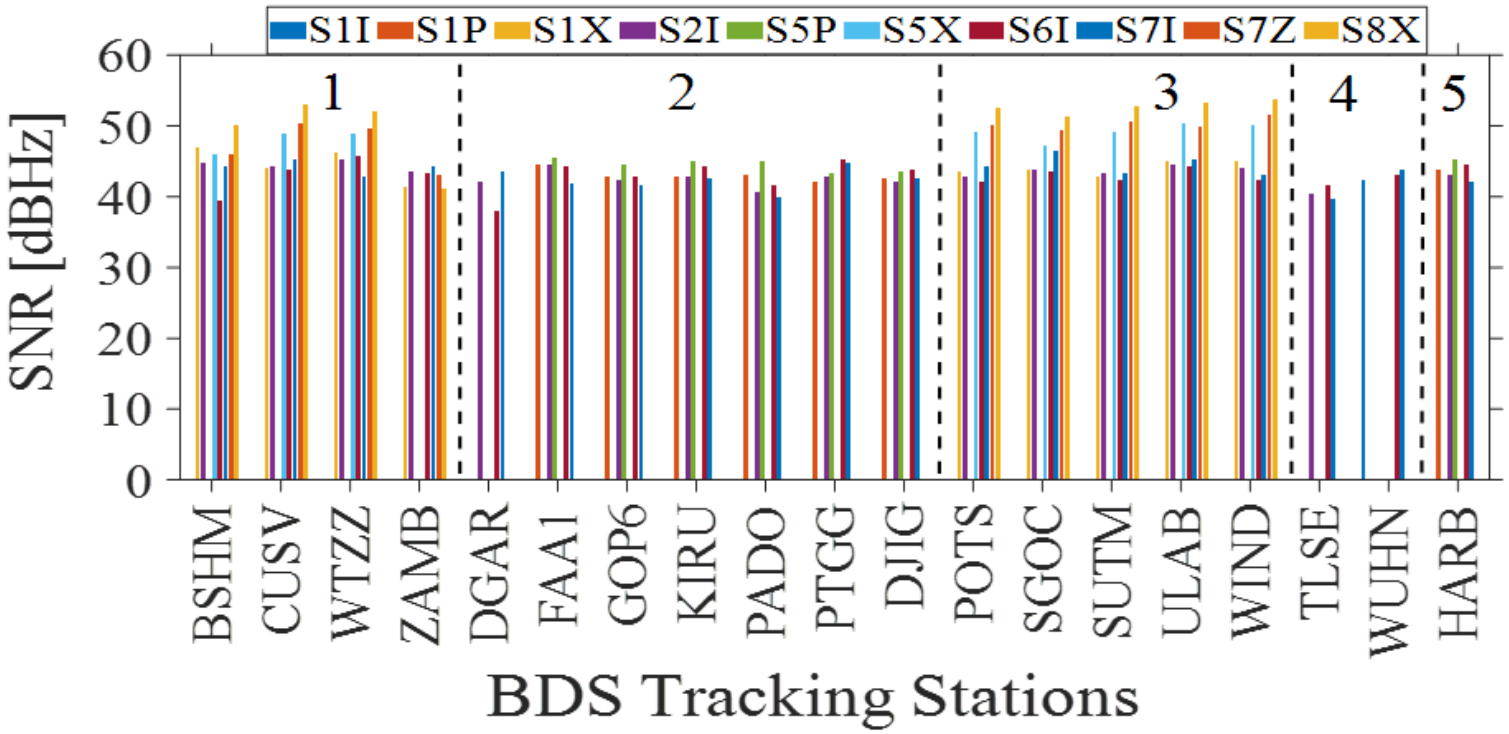
Table 3: BDS-2 multipath statistics

	C2I	C6I	C7I
Minimum [cm]	28.10	9.40	15.70
Maximum [cm]	69.00	52.20	59.80
Average [cm]	47.08	21.10	29.96

Table 4: BDS-3 multipath statistics

	C1X	C1P	C2I	C5X	C5P	C6I	C7D	C7Z	C8X
Min [cm]	21.20	23.20	21.90	16.10	21.40	17.90	1.00	20.70	17.20
Max [cm]	48.10	36.50	42.40	41.20	49.80	48.20	6.00	40.50	38.40
Average [cm]	29.71	31.04	30.29	30.66	34.81	29.10	3.30	31.79	30.51

SNR



1. JAVAD TRE_3 DELTA
2. SEPT POLARX5
3. JAVAD TRE_3
4. TRIMBLE NETR9
5. SEPT POLARX5TR

Figure 8: SNR for the selected stations

92.16% of the estimated SNR are above 42 dBHz

NSAT, SNR vs Elevation Angle, and SNR Time Series

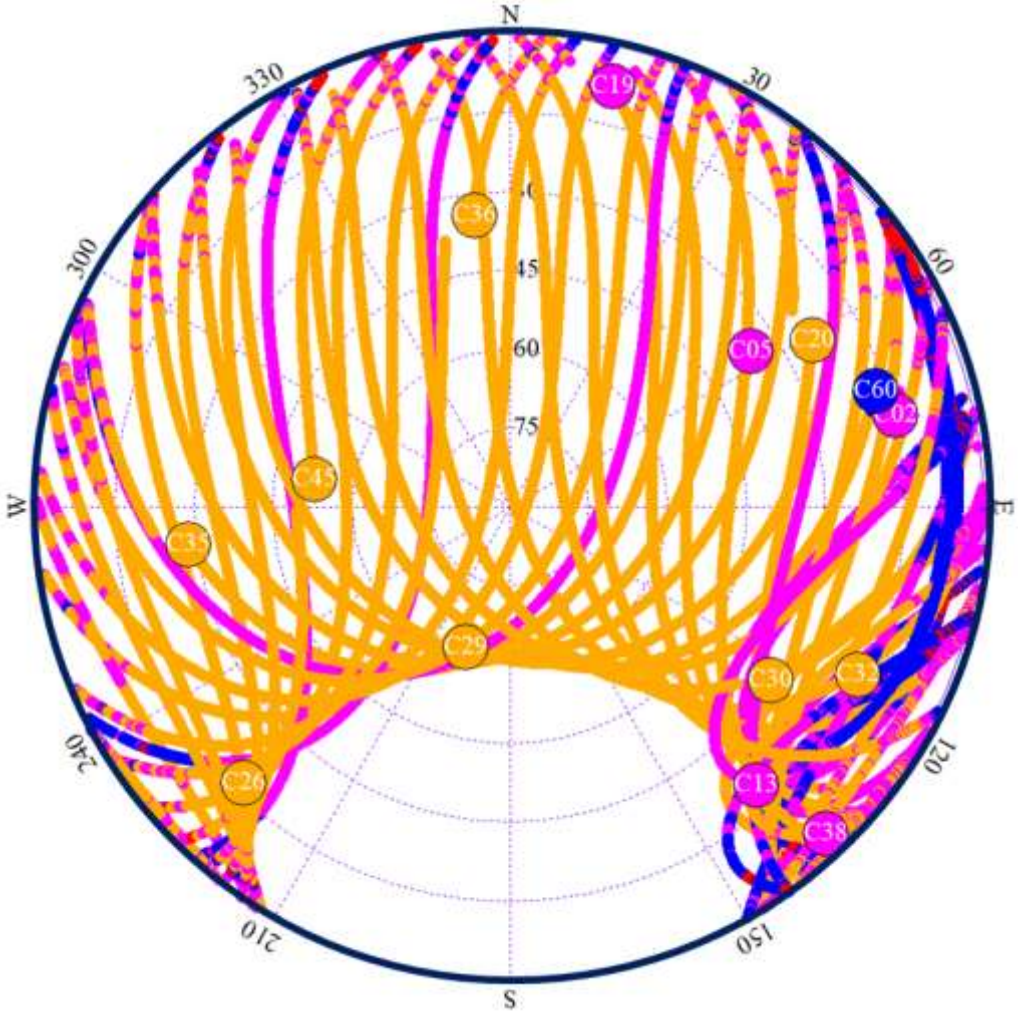


Figure 9: NSAT at SUTM on DOY 154

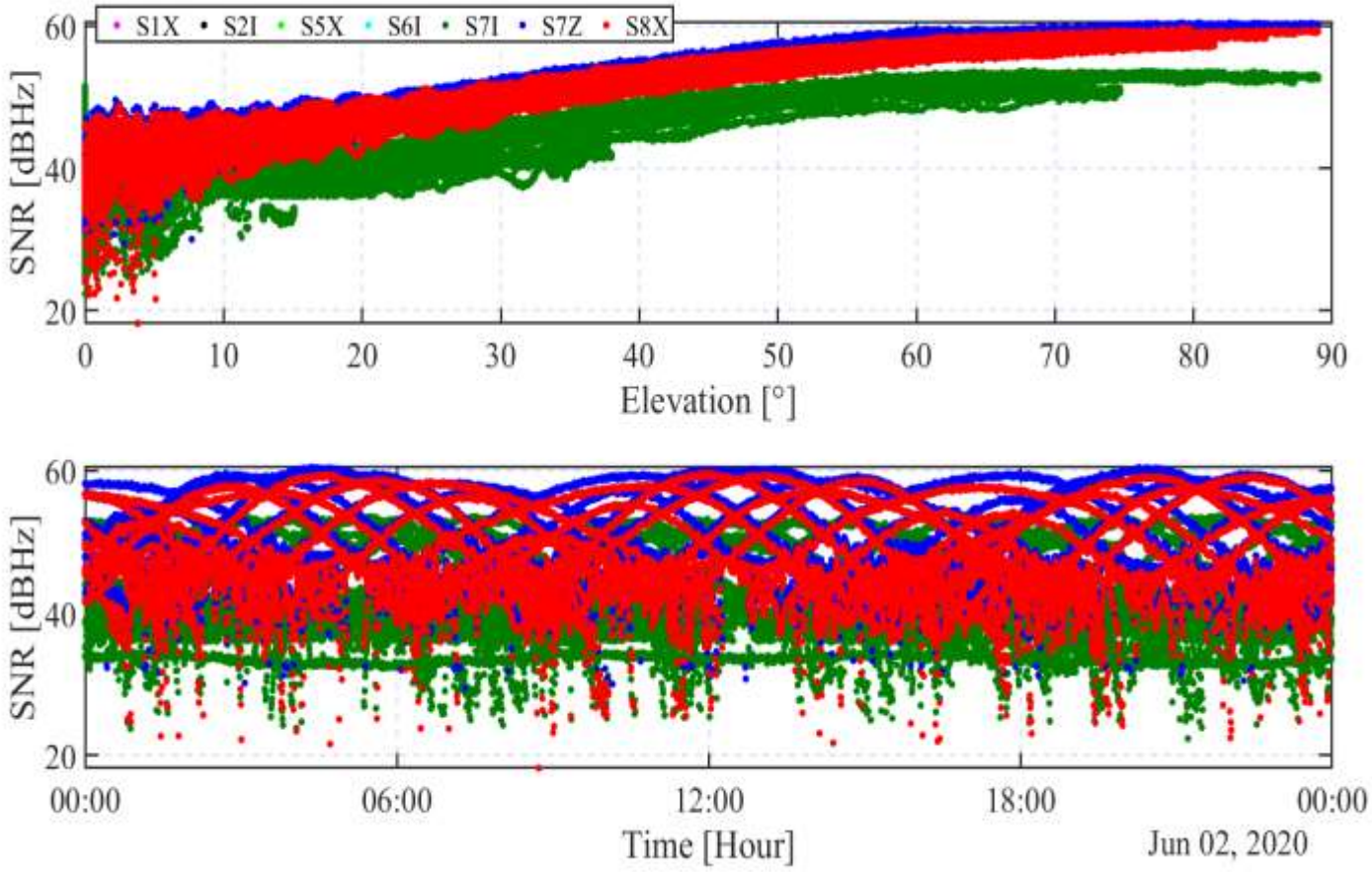


Figure 10: SNR with respect to elevation/time at SUTM station on DOY 154 (2020)

Visible Number of Satellites

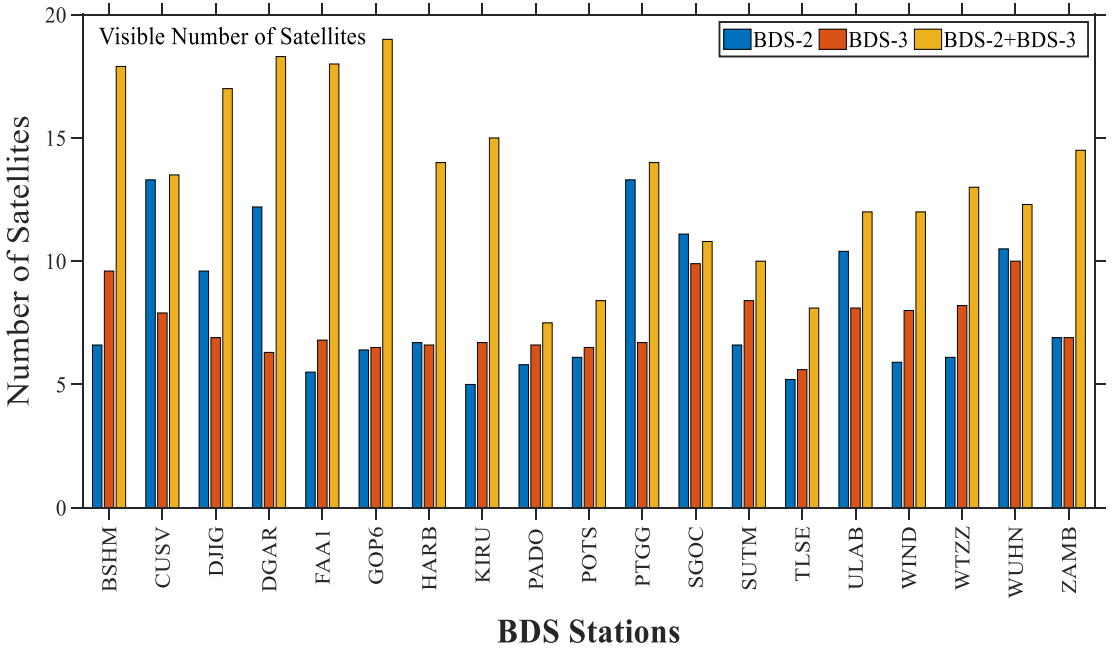


Figure 11a: Visible NSAT

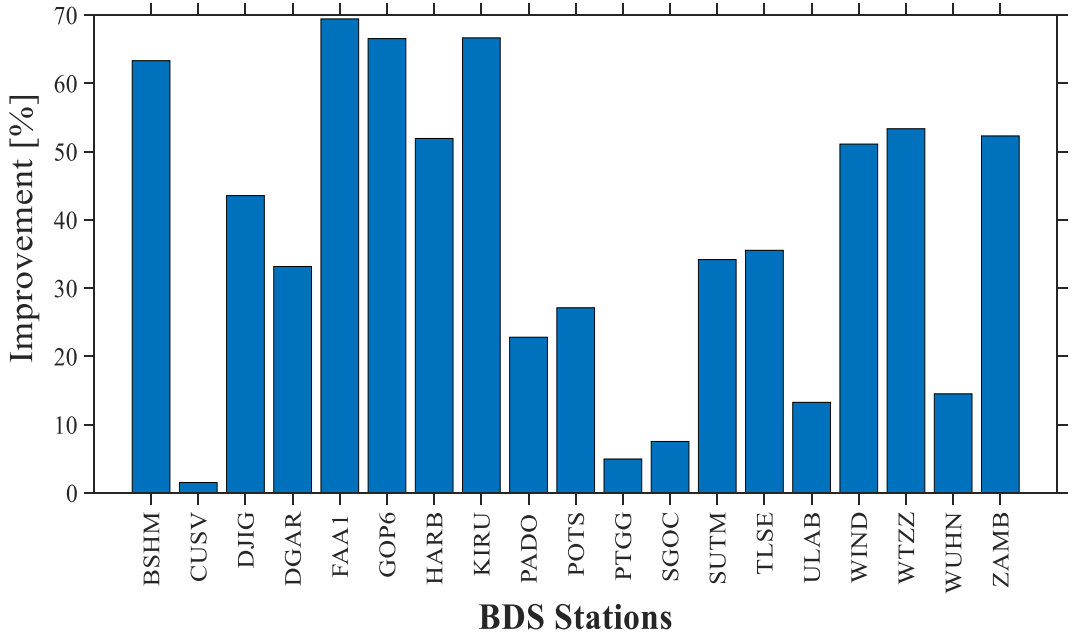


Figure 11b: Improvement in the visible NSAT

Table 5: NSAT statistics

	BDS-2	BDS-3	BDS-2+BDS-3	Improvement [%]
Min	5	6	7	2
Max	13	10	19	69
Average	8	7	14	38

Dilution of Precision (DOP)

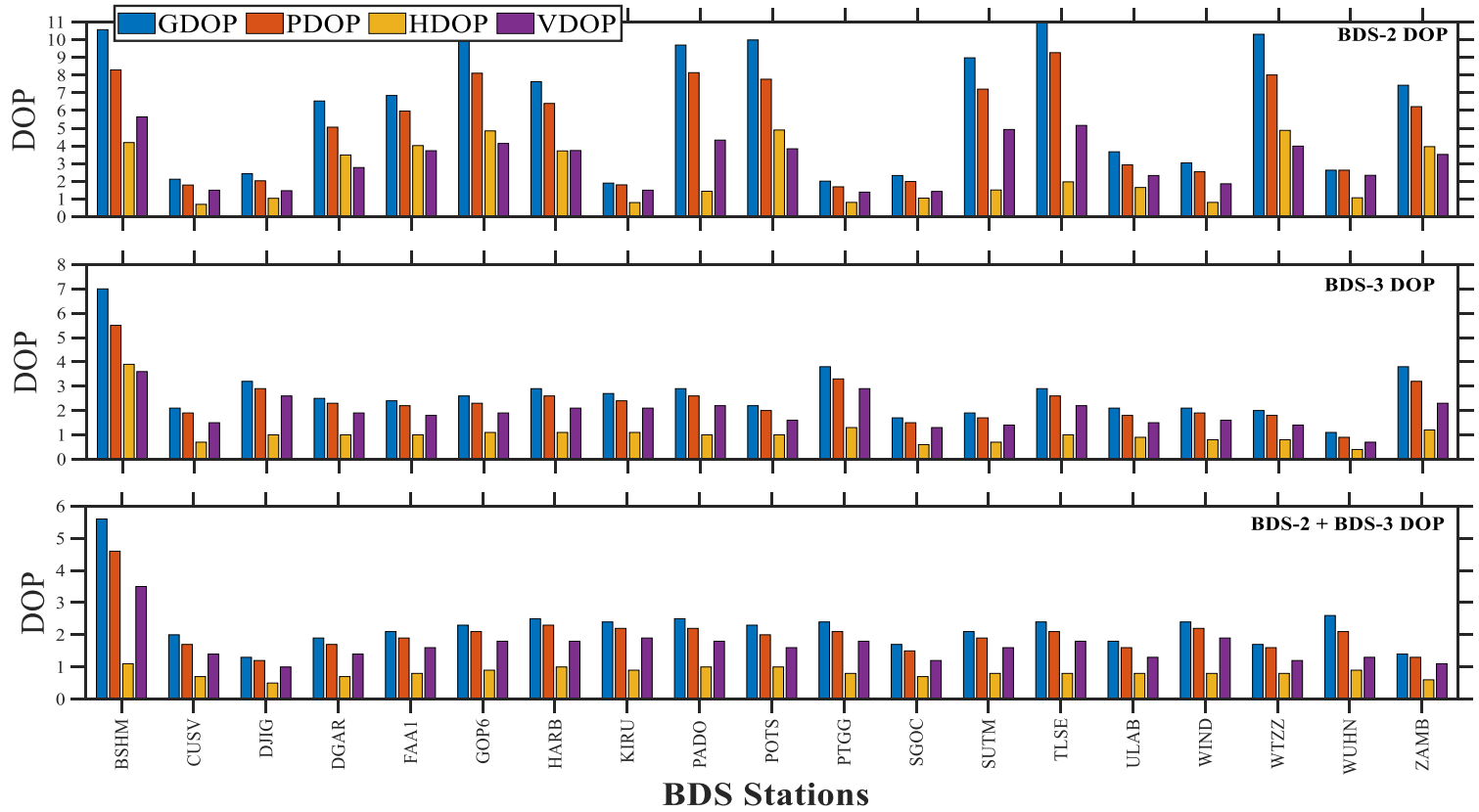


Figure 12: Averaged DOP

Table 6: Averaged DOP statistics

	BDS-2				BDS-3				BDS-2 + BDS-3				Improvement [%]			
	GDOP	PDOP	HDOP	VDOP	GDOP	PDOP	HDOP	VDOP	GDOP	PDOP	HDOP	VDOP	GDOP	PDOP	HDOP	VDOP
Min	1.90	1.69	0.70	1.39	1.05	0.91	0.41	0.71	1.32	1.18	0.53	0.96	3.01	5.41	0.35	5.47
Max	11.00	9.27	4.90	5.64	6.96	5.48	3.92	3.55	5.58	4.56	1.06	3.55	83.47	80.63	85.94	69.41
Average	6.29	5.15	2.47	3.14	2.72	2.39	1.08	1.93	2.29	2.01	0.81	1.63	56.09	54.56	52.49	49.08

SPP Performance

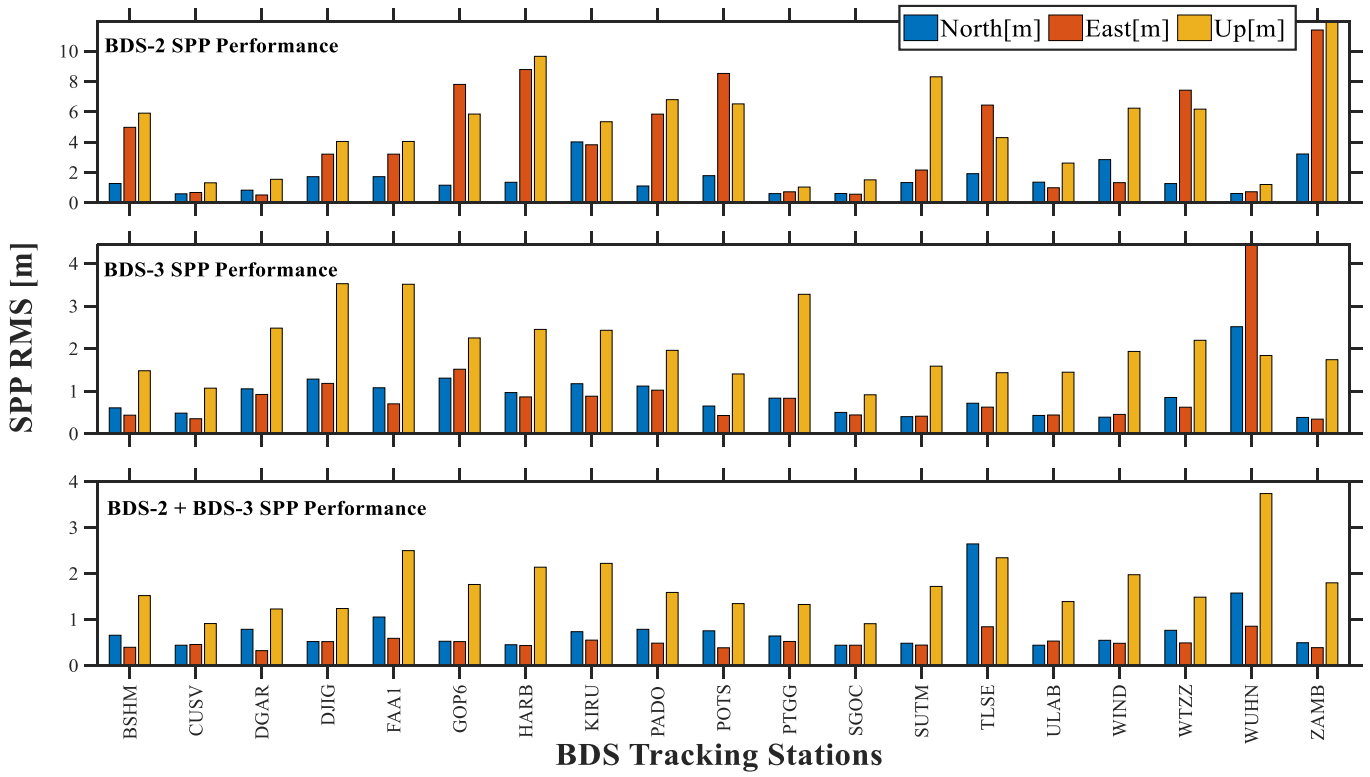


Figure 13: SPP performance

Table 7: SPP performance statistics

Station	BDS-2 [m]			BDS-3 [m]			BDS-2 + BDS-3 [m]			Improvement [%]		
	N	E	U	N	E	U	N	E	U	N	E	U
Min [m]	0.59	0.52	1.04	0.38	0.34	0.92	0.44	0.32	0.91	5.76	22.40	20.77
Max [m]	4.01	11.39	11.96	2.52	4.44	3.53	2.64	0.85	3.74	84.65	96.60	84.98
Average [m]	1.54	4.16	4.97	0.88	0.89	2.05	0.78	0.51	1.74	52.71	72.57	60.99