EPN Data Quality in a Multi-GNSS Environment

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ROYAL OBSERVATORY OF BELGIUM

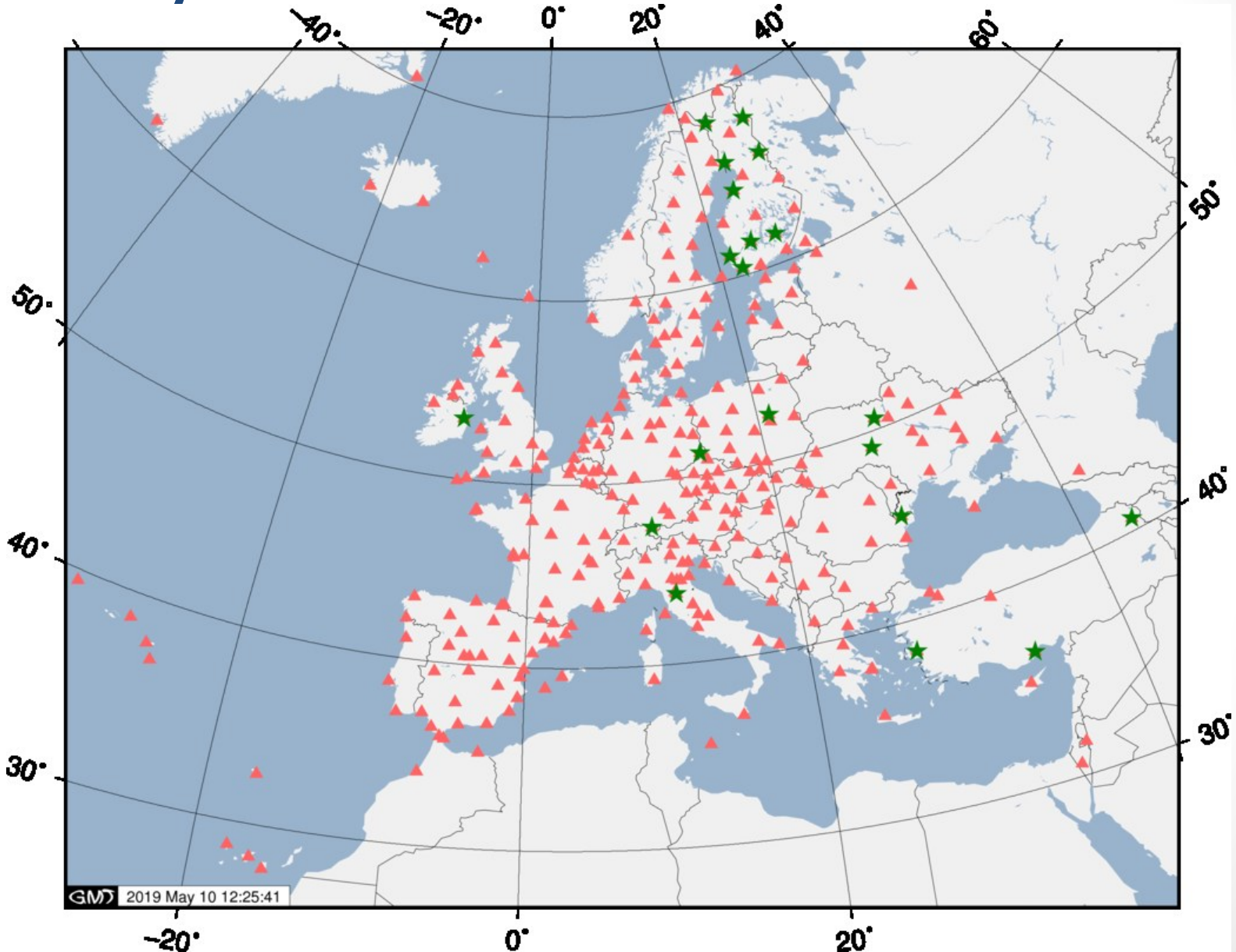
EUREF Symposium, May 22-24, 2019 Tallinn, Estonia

EUREF2019

Update since last year

341 EPN stations

★ 21 new EPN stations



Update since last year

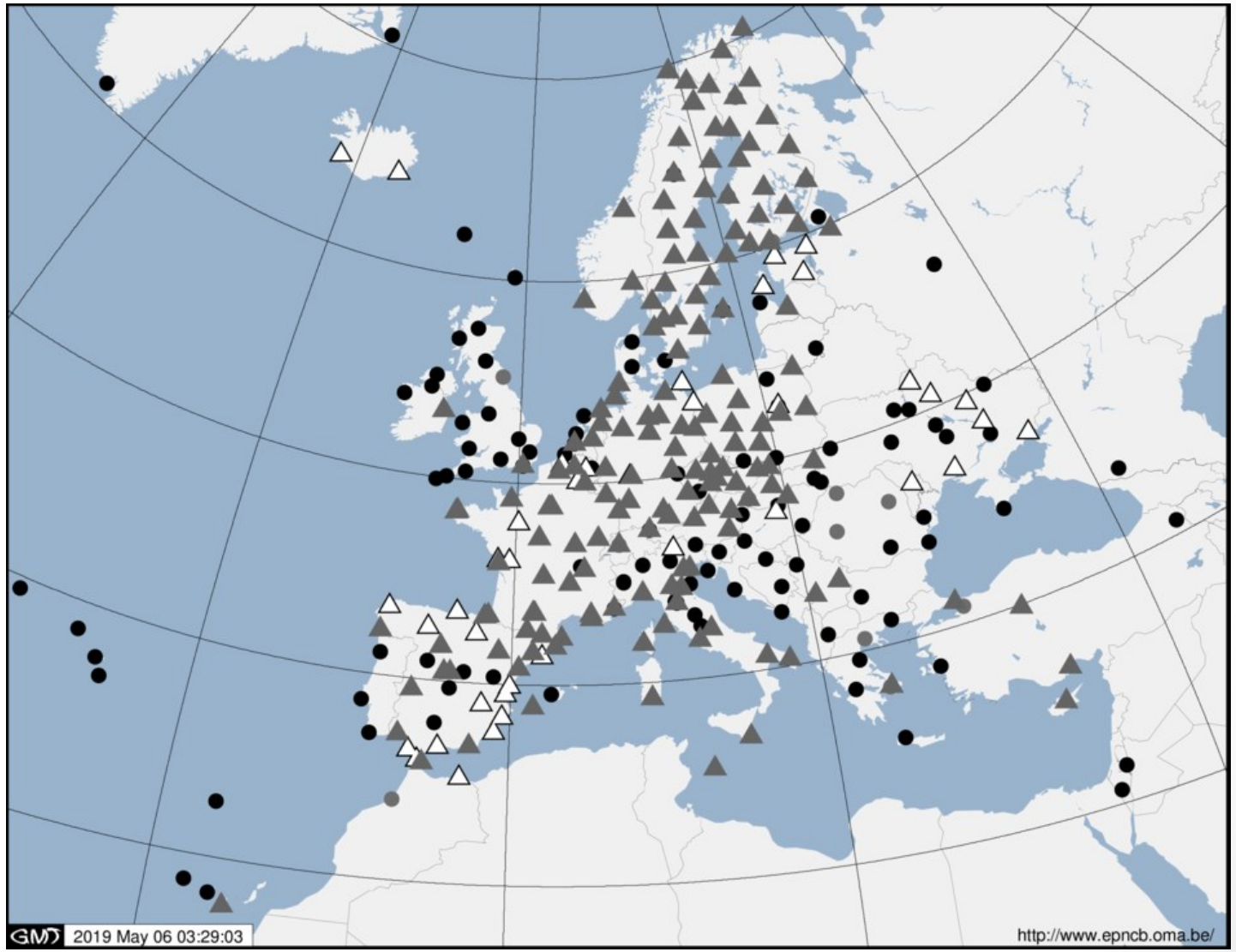
G=GPS, R=GLONASS, E=Galileo,
C= BeiDou, J=IRNSS, S=SBAS

9-char ID	City	Country	Replacement / New	Sat. Sys.	R-T	Antenna Calib.	IGS
BOGE00POL	Borowa Gora	POL	new	GPS GLO GAL BDS QZSS SBAS		Type	
BAUT00DEU	Bautzen	DEU	new	GPS GLO GAL BDS SBAS		Indiv. (GRECJS-CHAMBER)	
GDRS00UKR	Gorodok	UKR	new	GPS GLO		Type	
HETT00FIN	Hetta	FIN	new	GPS GLO GAL BDS SBAS	RT	Indiv. (GR-ROBOT)	
IGM200ITA	Firenze	ITA	new	GPS GLO GAL BDS SBAS		Type	
IZMI00TUR	izmir	TUR	new	GPS GLO		Type	IGS
IZRS00UKR	Izmail	UKR	new	GPS GLO		Type	
KRS100TUR	Kars	TUR	new	GPS GLO		Type	IGS
KUU200FIN	Kuusamo	FIN	new	GPS GLO GAL BDS SBAS	RT	Indiv. (GR-ROBOT)	
MERS00TUR	Erdemli	TUR	new	GPS GLO GAL BDS QZSS SBAS		Type	IGS
MIK300FIN	Mikkeli	FIN	new	GPS GLO GAL BDS SBAS	RT	Indiv. (GR-ROBOT)	
NYA200NOR	Ny Alesund	NOR	replaces NYAL	GPS GLO GAL QZSS SBAS	RT	Indiv. (GRE-CHAMBER)	IGS
OLK200FIN	Rauma	FIN	new	GPS GLO GAL BDS SBAS	RT	Indiv. (GR-ROBOT)	
ORIV00FIN	Orivesi	FIN	new	GPS GLO GAL BDS SBAS	RT	Indiv. (GR-ROBOT)	
PFA300AUT	Bregenz	AUT	replaces PFAN	GPS GLO GAL BDS	RT	Type	
PYHA00FIN	Pyhajoki	FIN	new	GPS GLO GAL BDS SBAS	RT	Indiv. (GR-ROBOT)	
SAVU00FIN	Savukoski	FIN	new	GPS GLO GAL BDS SBAS	RT	Indiv. (GR-ROBOT)	
TLL100IRL	Dublin	IRL	replaces TLLG	GPS GLO GAL BDS		Type	
TORN00FIN	Tornio	FIN	new	GPS GLO GAL BDS SBAS	RT	Indiv. (GR-ROBOT)	
TUO200FIN	Kaarina	FIN	new	GPS GLO GAL BDS SBAS	RT	Indiv. (GR-ROBOT)	
VNRS00UKR	Vinnytsia	UKR	new	GPS GLO		Type	

EPN Tracking Network

- GPS: all stations
- GPS+GLO: 95%
- GPS+GLO+GAL: 64% (+11%)
- GPS+GLO+GAL+BDS: 53%

QZSS tracked by 8%
IRNSS tracked by 2%



EPN real-time streams 2018-2019

2018

~ 160 EPN stations provide their data in real-time (50% of EPN)

According to site logs:

69% of RT stations are Galileo-capable

From real-time streams

- 7% GPS-only
- 64% GPS+GLO
- 29% GPS+GLO+GAL+…

2019

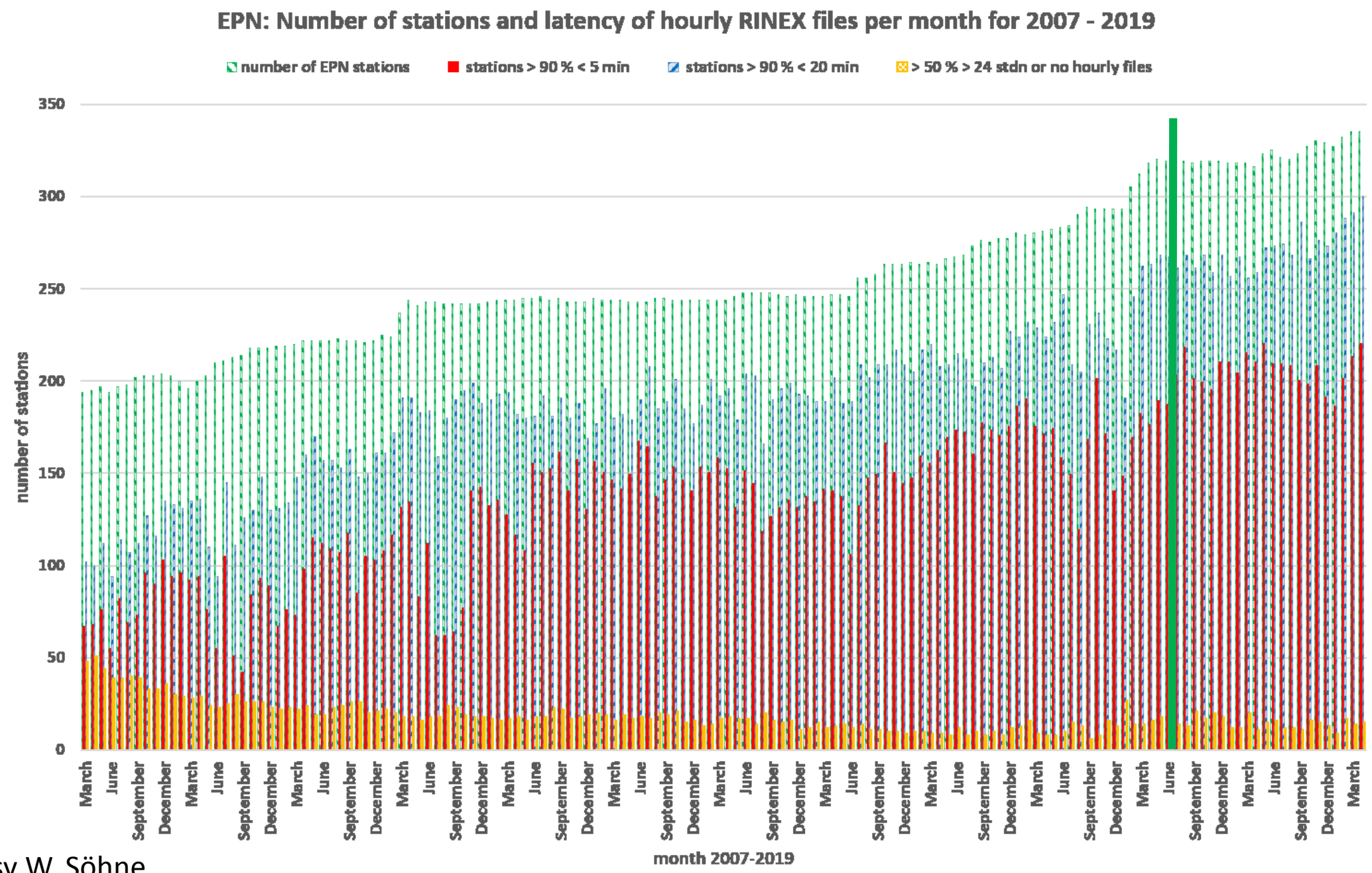
~ 174 EPN stations provide their data in real-time (51% of EPN)

According to site logs:

76% of RT stations are Galileo-capable

From real-time streams

- 3% GPS-only
- 45% GPS+GLO
- 52% GPS+GLO+GAL+…



Courtesy W. Söhne

Update of EPN Guidelines

Present EPN guidelines:

Stations tracking more than two frequencies or tracking satellite systems in addition to GPS and GLONASS must submit data files in both the RINEX 2 (dual frequency GPS and GLONASS) and RINEX 3 format (GPS, GLONASS plus other GNSS, SBAS, etc.).

GPS L1 & L2
GLO L1 & L2
} RINEX 2
mandatory

GPS L1 & L2 & L5
GLO L1 & L2 & L3
GAL
BDS
....
} RINEX 3

Presently: RINEX 2 + RINEX 3

Stations with Galileo data in RINEX 2 and which should provide RINEX 3, but do not: COBA00ESP, COMO00ITA, NEWL00GBR, SALA00ESP, SCOR00GRL, SJDV00FRA, SULD00DNK, TORI00ITA, UNTR00ITA

Update of EPN Guidelines

New EPN guidelines:

GPS L1 & L2
GLO L1 & L2
} RINEX 2
~~mandatory~~

GPS L1 & L2 & L5
GLO L1 & L2 & L3
GAL
BDS
....
} RINEX 3

Preferred format

Consequence : Some stations providing RINEX 3 will stop providing RINEX 2

March 1st, 2019, EUREF mail 9760: Preparation of RINEX 3 data processing capability

Users need to start using RINEX 3!

Update of EPN Guidelines

From ??? 2019

Future EPN guidelines:

Stations tracking more than two frequencies or tracking satellite systems in addition to GPS and GLONASS (GPS, GLONASS plus other GNSS, SBAS, etc.) must submit data files in the RINEX 3 format. Optionally, in addition, data in the RINEX 2 format can be provided.

Stations tracking only dual frequency GPS and GLONASS can submit data files in the RINEX 2 or/and RINEX 3 format. Repeated switching between RINEX 2-only or RINEX 3-only submissions is not allowed.

RINEX 2 and RINEX 3 to be created from RAW receiver data

RINEX 3 → RINEX 2 not allowed

RINEX 2.11 format

https://kb.igs.org/hc/en-us/articles/115003980188-RINEX-2-11

System	Freq.Band	Frequency	RINEX 2-character Code			
			Ps.Range	Carr.Phase	Doppler	Sign.Strength
GPS	L1	1575.42	C1,P1	L1	D1	S1
	L2	1227.60	C2,P2	L2	D2	S2
	L5	1176.45	C5	L5	D5	S5
Glonass	G1	1602+k*9/16	C1,P1	L1	D1	S1
	G2	1246+k*7/16	C2,P2	L2	D2	S2
Galileo	E2-L1-E1	1575.42	C1	L1	D1	S1
	E5a	1176.45	C5	L5	D5	S5
	E5b	1207.140	C7	L7	D7	S7
	E5a+b	1191.795	C8	L8	D8	S8
	E6	1278.75	C6	L6	D6	S6
SBAS	L1	1575.42	C1	L1	D1	S1
	L5	1176.45	C5	L5	D5	S5

Not allowed : GLONASS L3, L7, … BeiDou → Several EPN stations provide incorrectly formatted RINEX 2 data!

New

Extractions of observables in RINEX 2 and RINEX 3 files

ftp://epncb.oma.be/station/frequencies/YYYY/DDD

			GALILEO																								
STATION	RECEIVER TYPE	FIRMWARE VERSION	C1B	C1C	C1X	L1B	L1C	L1X	C5Q	C5X	L5Q	L5X	C7I	C7Q	C7X	L7I	L7Q	L7X	C8Q	C8X	L8Q	L8X	C6B	C6C	C6X	L6B	L6C	L6X
KRAW00POL	ASHTECH UZ-12	CJ10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RABT00MAR	ASHTECH UZ-12	CQ00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
THU300GRL	ASHTECH UZ-12	CK00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PTBB00DEU	ASHTECH Z-XII3T	1L01-1D04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
POTS00DEU	JAVAD TRE_3	3.7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BORJ00DEU	JAVAD TRE_3 DELTA	3.7.5 DEC,06,2018	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
DIEP00DEU	JAVAD TRE_3 DELTA	3.7.5 DEC,06,2018	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
DRAG00ISR	JAVAD TRE_3 DELTA	3.6.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FINS00FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
HELG00DEU	JAVAD TRE_3 DELTA	3.7.5 DEC,06,2018	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
HETT00FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
JOE200FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
JOEN00FIN	JAVAD TRE_3 DELTA	3.7.4 Oct,29,2018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KARL00DEU	JAVAD TRE_3 DELTA	3.7.5 DEC,06,2018	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
KEV200FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
KILP00FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
KIV200FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
KUU200FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
MET300FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
METS00FIN	JAVAD TRE_3 DELTA	3.7.4 Oct,29,2018	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MIK300FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
OLK200FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
ORIV00FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
OUL200FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
PYHA00FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
ROM200FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X

New

Extractions of observables in RINEX 2 and RINEX 3 files

ftp://epncb.oma.be/station/frequencies/YYYY/DDD

Quick comparison of firmware and tracked observables

Example for RINEX 3 - Galileo

SODA00FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TORN00FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
TUO200FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
VAA200FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
VAAS00FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VIR200FIN	JAVAD TRE_3 DELTA	3.7.5p1 Jan,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	C8X	-	L8X	-	-	C6X	-	-	L6X
BOGI00POL	JAVAD TRE_G3T DELTA	3.6.14 Nov,19,2018	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NYA200NOR	JAVAD TRE_G3TH DELTA	3.7.6	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OBE400DEU	JAVAD TRE_G3TH DELTA	3.7.6	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RANT00DEU	JAVAD TRE_G3TH DELTA	3.7.3 FEB,02,2018	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	-	-	-	-	-	-	-	-	-
WARN00DEU	JAVAD TRE_G3TH DELTA	3.7.5P1 JAN,23,2019	-	-	C1X	-	-	L1X	-	C5X	-	L5X	-	-	C7X	-	-	L7X	-	-	-	-	-	-	-	-	-	-
ACOR00ESP	LEICA GR10	4.31/6.525	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
BCLN00ESP	LEICA GR10	3.11.1639/6.522	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
CANT00ESP	LEICA GR10	4.00/6.522	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
CNIV00UKR	LEICA GR10	4.11/6.523	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
DNMU00UKR	LEICA GR10	4.11/6.523	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
IGEO00MDA	LEICA GR10	4.31/6.525	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
IGM200ITA	LEICA GR10	4.10/6.523	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
LAMP00ITA	LEICA GR10	4.31/6.525	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
MARP00UKR	LEICA GR10	4.11/6.523	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
MATG00ITA	LEICA GR10	4.20/6.524	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
MEDI00ITA	LEICA GR10	4.20/6.524	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
MELI00ESP	LEICA GR10	4.00/6.522	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
MIKL00UKR	LEICA GR10	4.11/6.523	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
PASA00ESP	LEICA GR10	4.20/6.525	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-
POLV00UKR	LEICA GR10	4.11/6.523	-	C1C	-	-	L1C	-	C5Q	-	L5Q	-	-	C7Q	-	-	L7Q	-	C8Q	-	L8Q	-	-	-	-	-	-	-

RINEX 3

RINEX 3 file naming convention applied for site logs

- xml (GeodesyML)
- log_9chr
- new_9char

Agreed upon with IGS CB

VALC00ESP / VALC00ITA
TREB00SVK / TREB00CZE
AMUR00ITA / AMUR00ESP

Recommend to start using site logs in log_9char as standard.

'Classic' site logs continue to be available (but some stations are missing)

ftp://epncb.oma.be/station/log

Index of /ftp/station

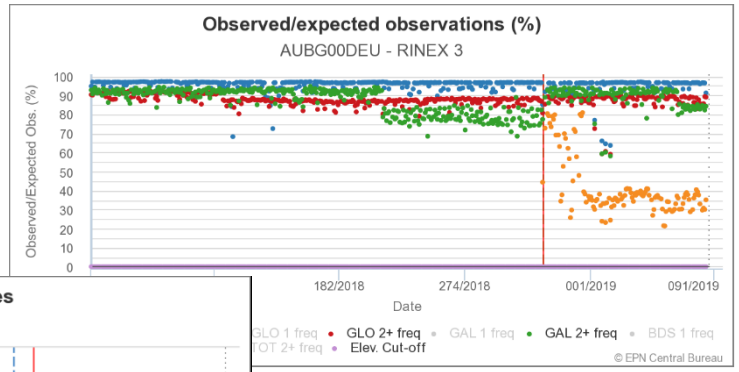
Name	Last modified	S
Parent Directory		
coord/	24-Jan-2019 08:49	
densification/	03-Oct-2018 13:49	
general/	31-Jan-2019 02:10	
log/	04-Feb-2019 10:45	
log_9char/	04-Feb-2019 10:45	
new/	14-Jan-2019 06:57	
new_9char/	14-Jan-2019 06:57	
old/	04-Feb-2019 10:45	
real_time/	28-Jan-2019 14:10	
skl/	21-Dec-2018 21:56	
tie/	22-Jan-2007 12:35	
xml/	03-Nov-2014 13:54	

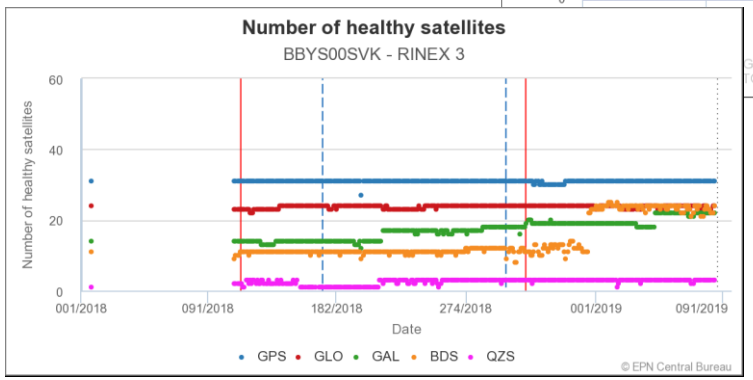
Index of /ftp/station/log_9char

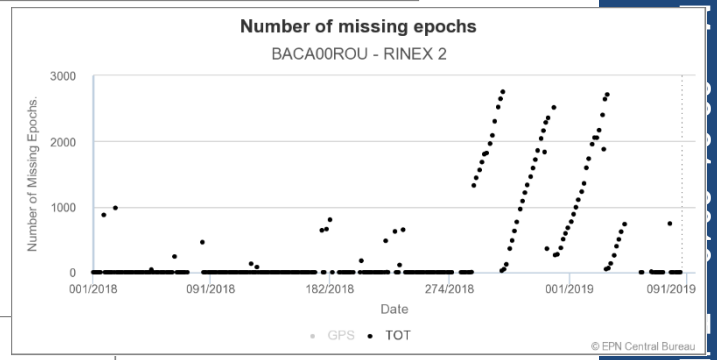
Name	Last modified	Size	Descript
Parent Directory		-	
acor00esp_20190204.log	04-Feb-2019 13:30	18K	
adar00gbr_20181023.log	21-Nov-2018 07:30	13K	
ajac00fra_20181017.log	21-Nov-2018 07:30	18K	
alac00esp_20170306.log	06-Jul-2018 15:54	20K	
alba00esp_20160830.log	06-Jul-2018 15:54	15K	
alci00ukr_20111207.log	06-Jul-2018 15:54	11K	
alme00esp_20180612.log	06-Jul-2018 15:54	15K	
ammn00jor_20000407.log	06-Jul-2018 15:54	11K	
ankr00tur_20181019.log	21-Nov-2018 07:30	23K	
aqui00ita_20180725.log	25-Jul-2018 14:45	15K	
argi00fro_20170419.log	06-Jul-2018 15:54	13K	
aris00gbr_20181024.log	21-Nov-2018 07:30	14K	
arj600swe_20181022.log	21-Nov-2018 07:30	16K	
aubg00deu_20181128.log	28-Nov-2018 05:45	20K	
aut100grc_20180416.log	06-Jul-2018 15:54	13K	
autn00fra_20181129.log	29-Nov-2018 15:15	18K	
axpv00fra_20181017.log	21-Nov-2018 07:30	18K	
baca00rou_20180522.log	06-Jul-2018 15:54	13K	
badh00deu_20181211.log	11-Dec-2018 09:15	18K	

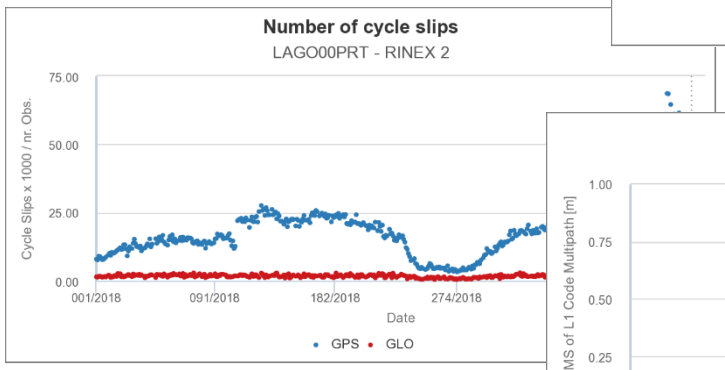
Time Series of Daily QC Metrics

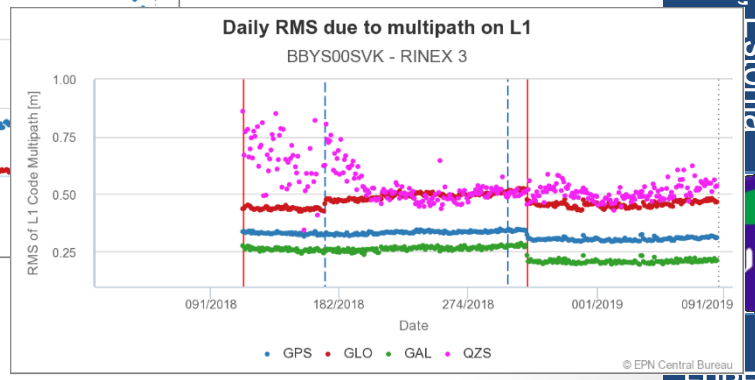
- % observed vs. expected observations
- Number of observed satellites
- Number of missing epochs
- Number of cycle slips (x1000/nr. Obs)
- Average RMS of code multipath











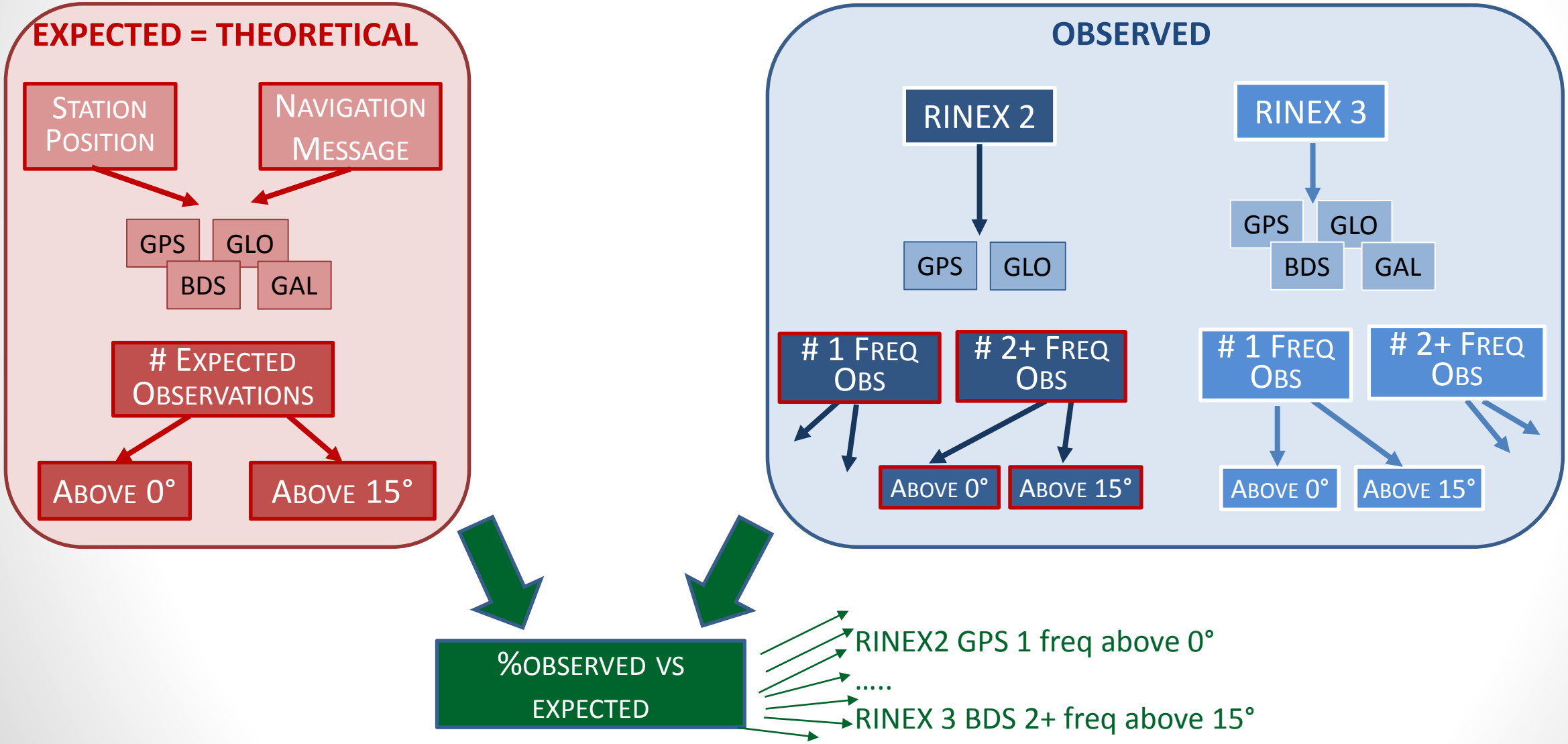
Since start of EPN (1996 → 2019, 1.2 million files)

Based on G-nut/Anubis (Václavovic P, Dousa J, 2016) and self-developed scripts

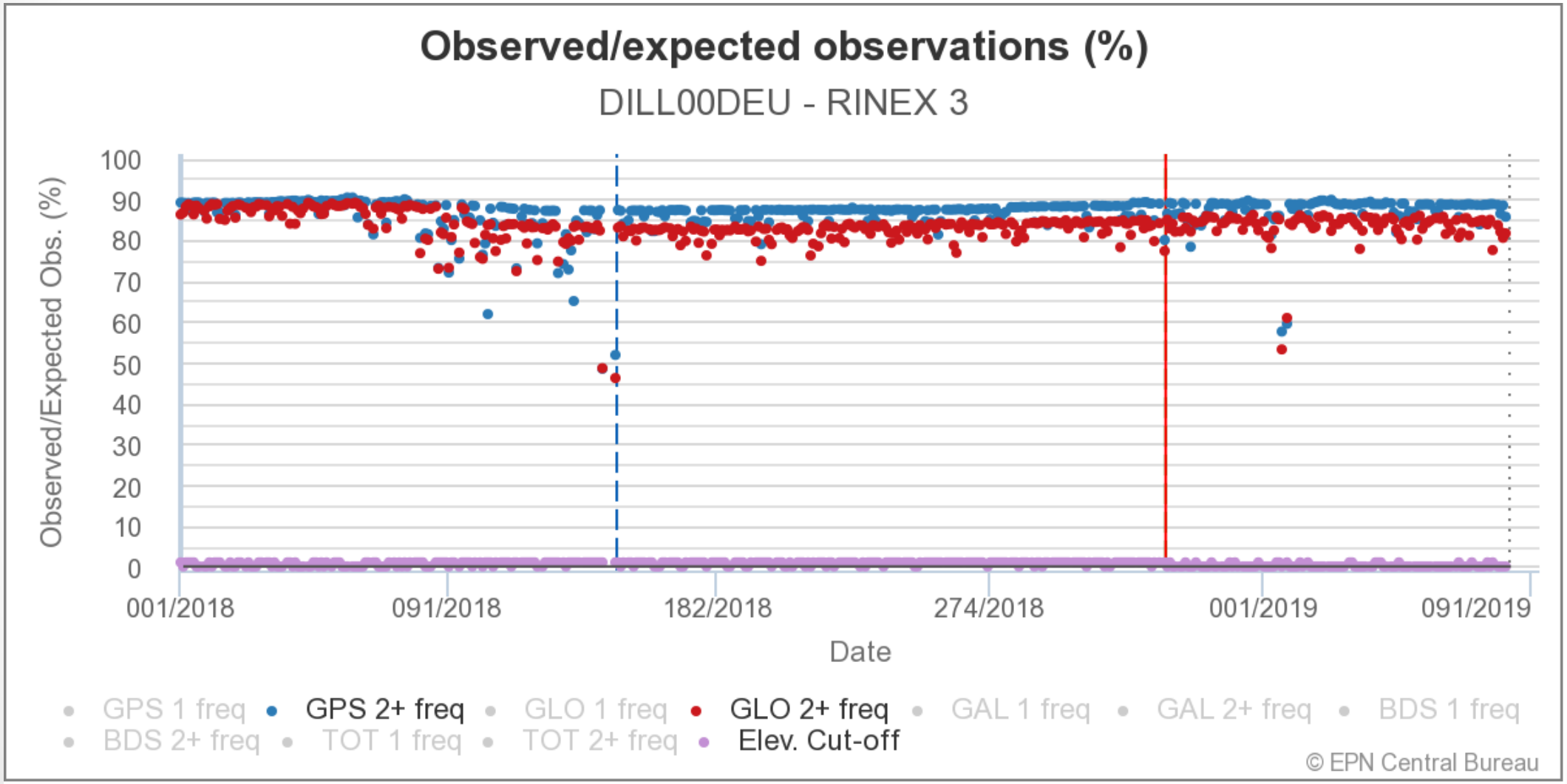
Time Series of Daily QC Metrics

- % observed vs. expected observations
- Number of observed satellites
- Number of missing epochs
- Number of cycle slips (x1000/nr. Obs)
- Average RMS of code multipath

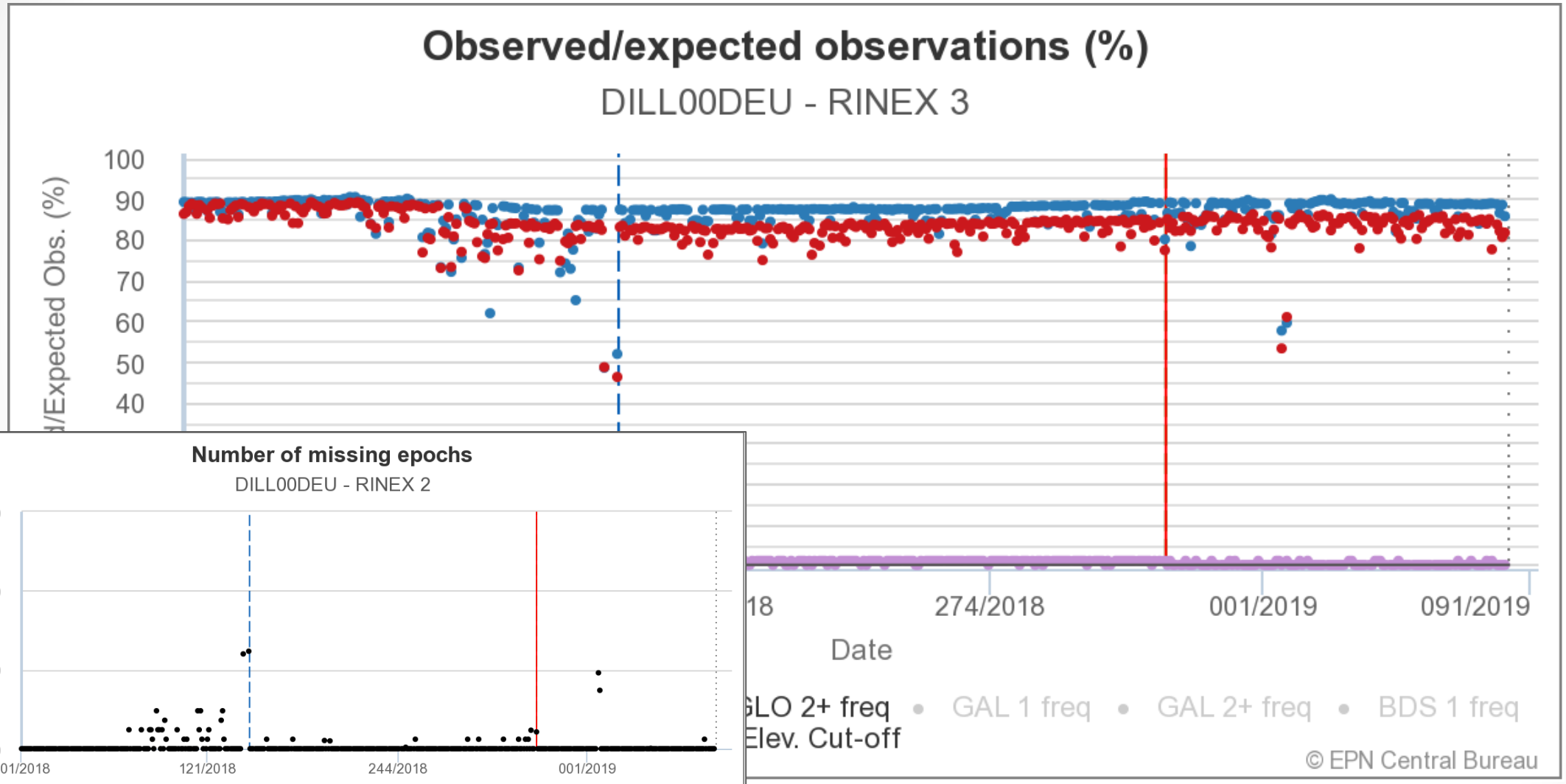
% observed vs. expected observations

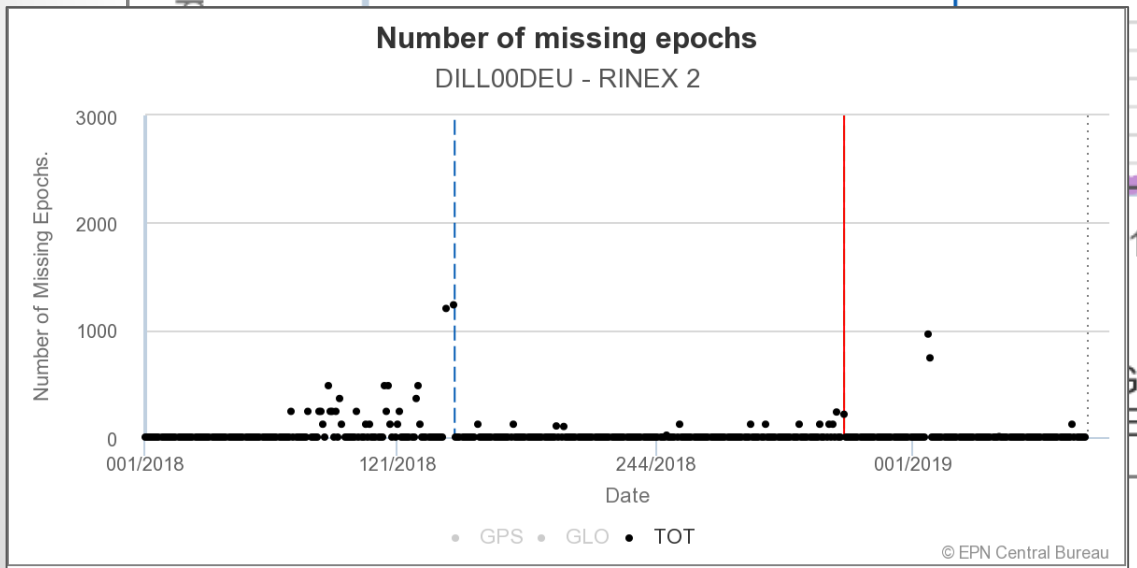


Completeness of Multi-GNSS Observations

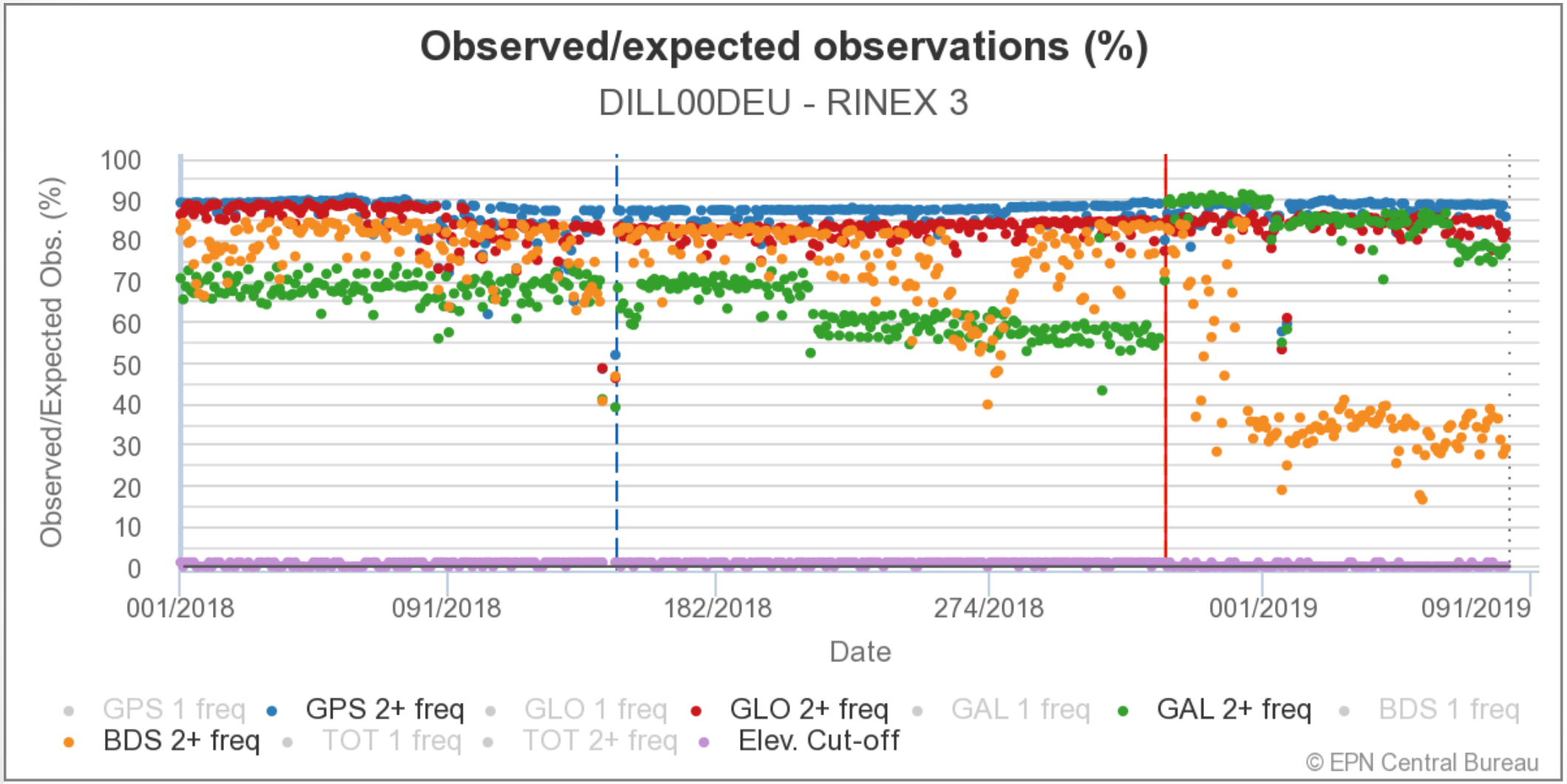


Completeness of Multi-GNSS Observations

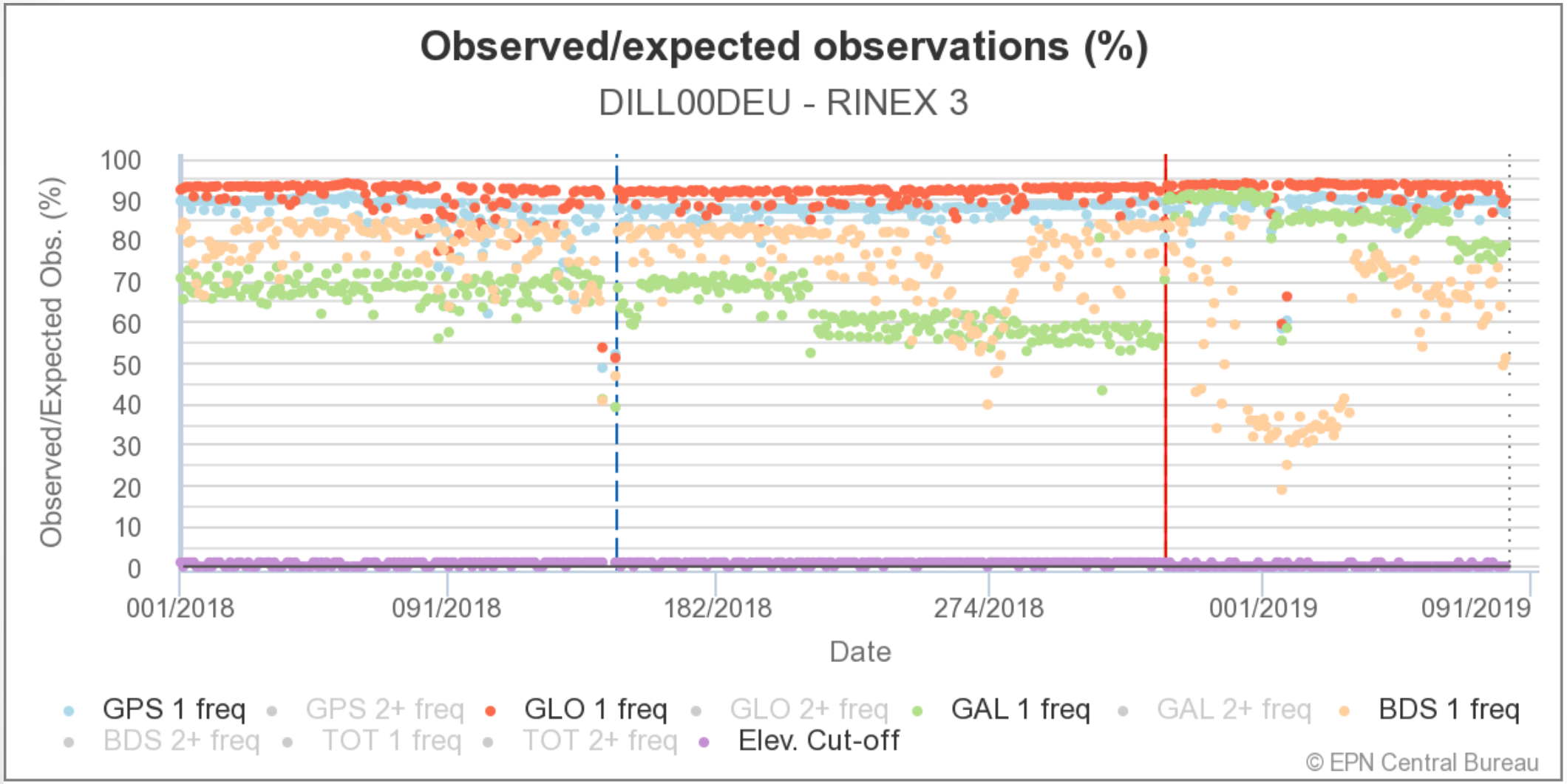




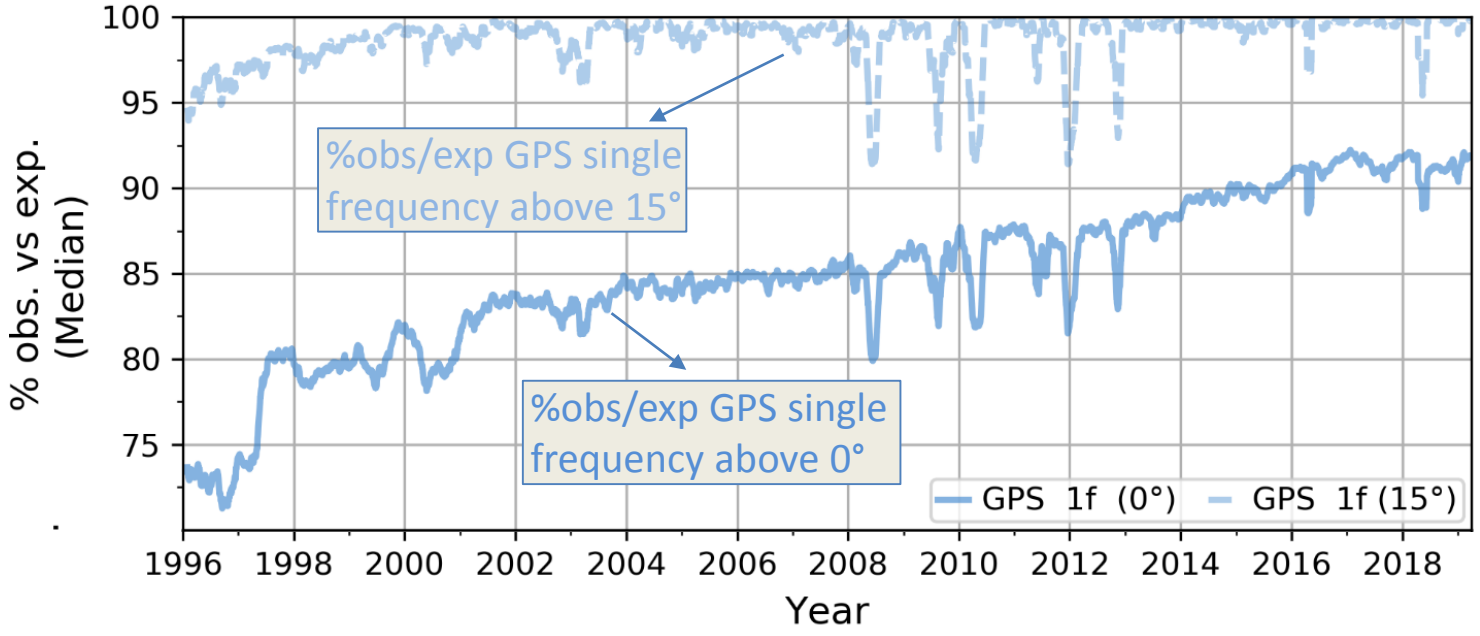
Completeness of Multi-GNSS Observations



Completeness of Multi-GNSS Observations



1996-2019 RINEX 2 : single frequency



Daily median of %obs vs expected over all EPN stations → smoothing

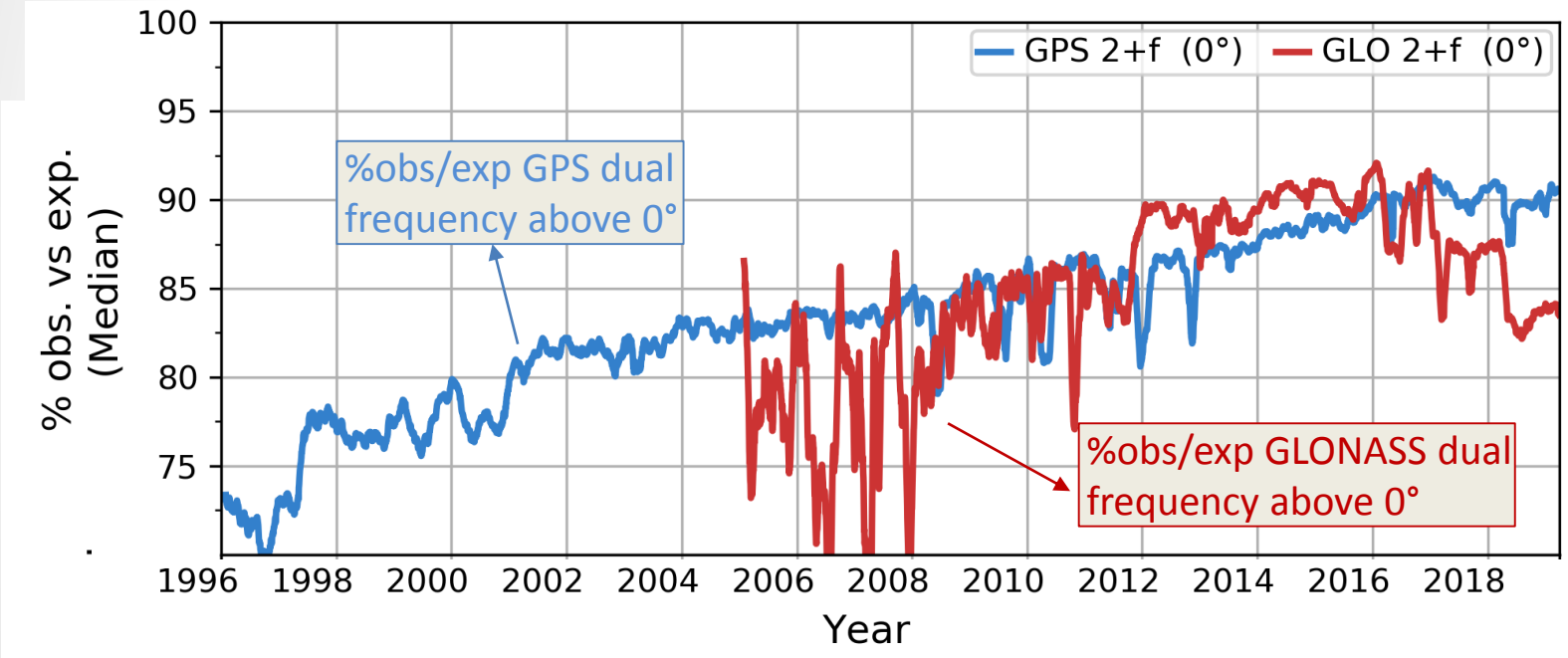
GPS

Early years: a lot of satellites not tracked at all at low elevations

Receiver improvements:
- Number of tracking channels
- Tracking algorithms

But also changing EPN guidelines for minimal elevation
Early 15°, then 5°, then 0° (from 2013)

1996-2019 RINEX 2 : dual frequency



GPS: improves over time

Early years: less observations at low elevation

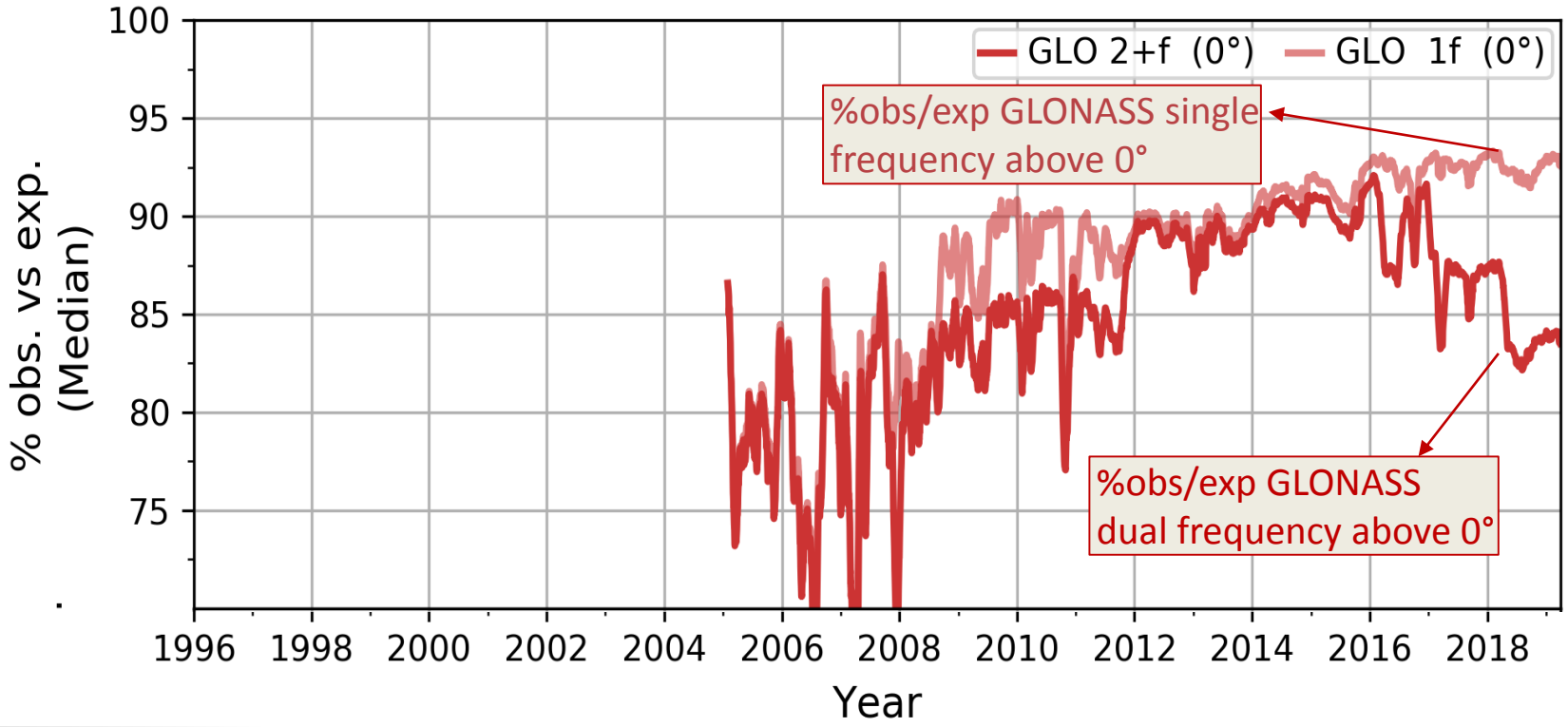
(receivers + EPN guidelines)

GLONASS: irregular

(Smoothed daily median values)

1996-2019

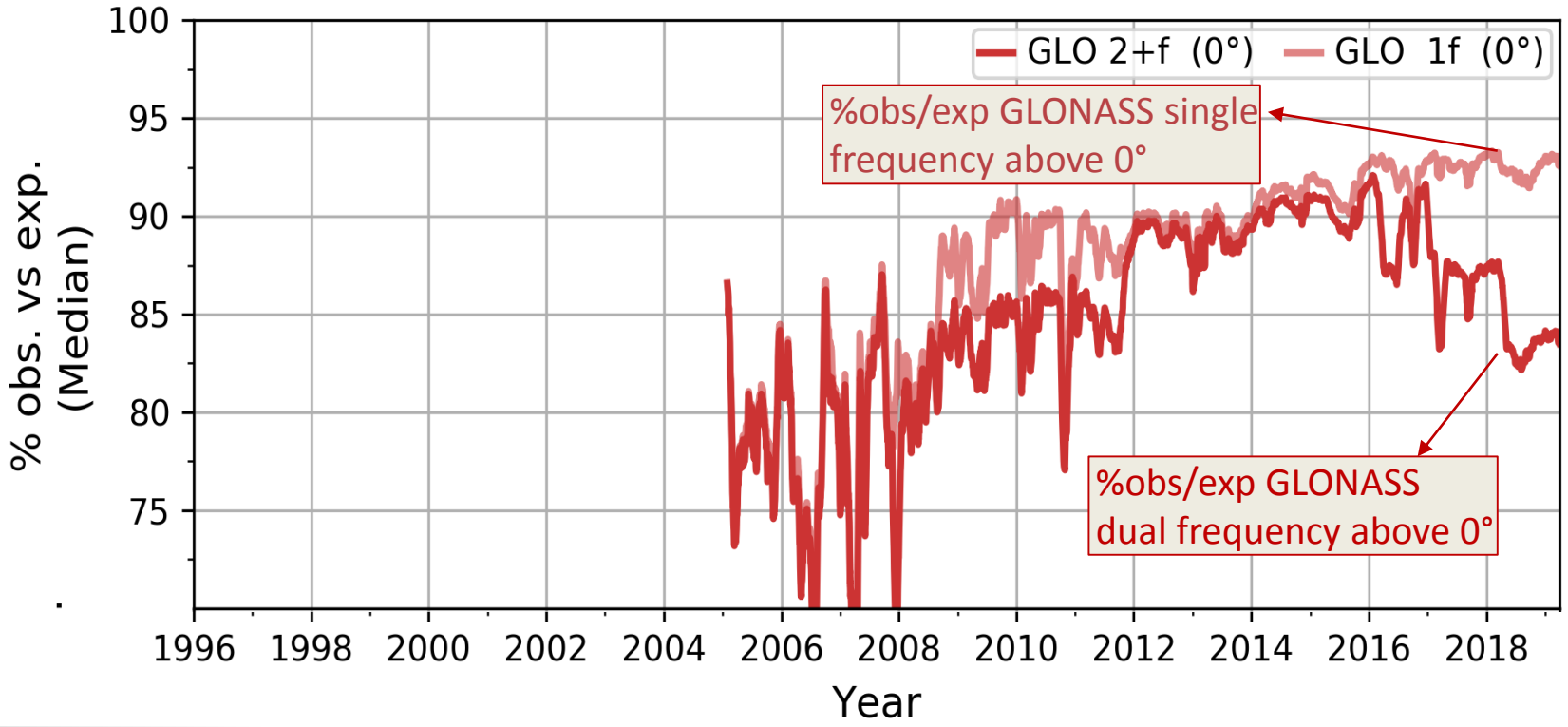
RINEX 2: GLONASS



Comparison single and dual frequency tracking

Single frequency: general improvement over years

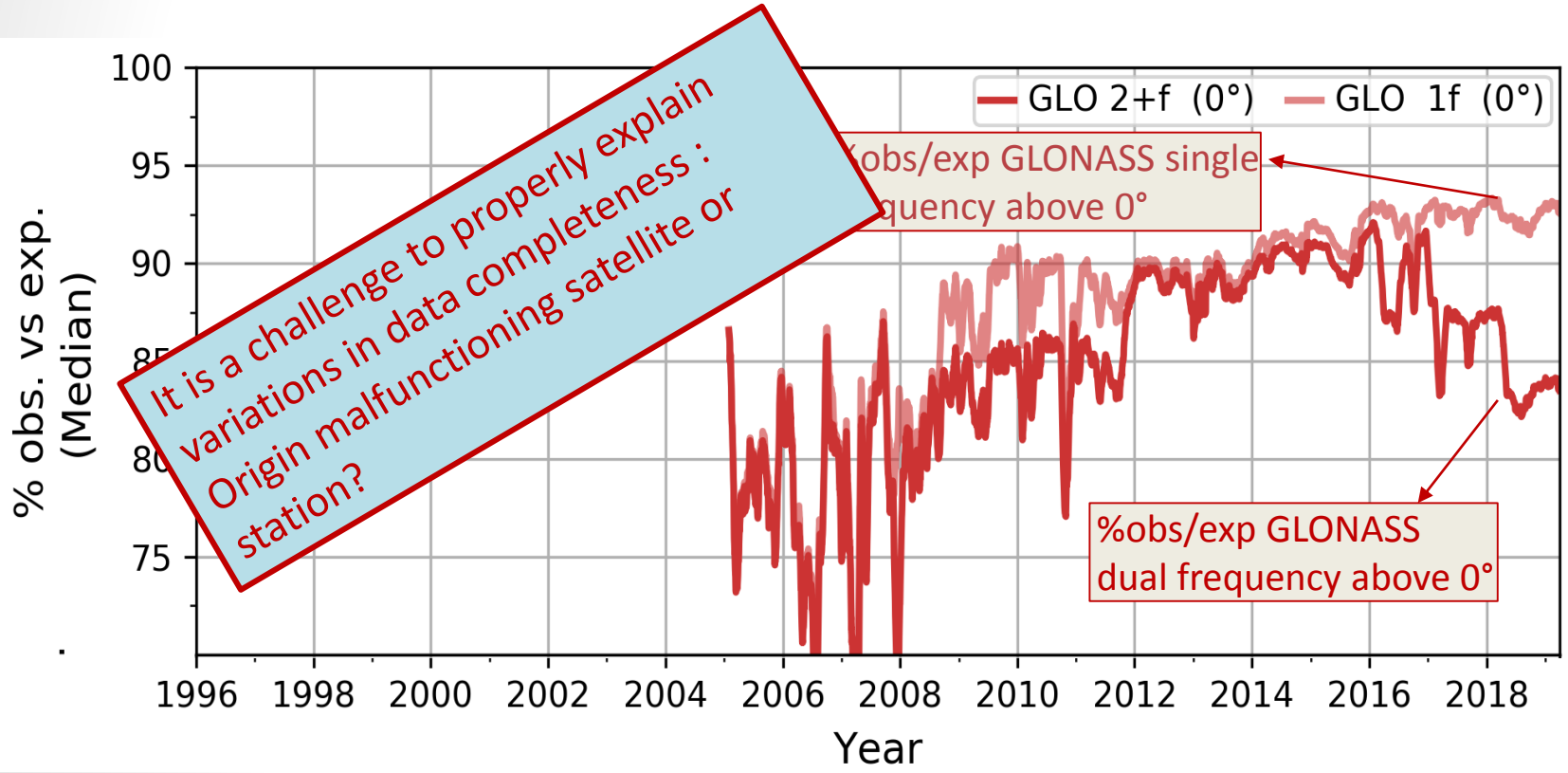
1996-2019 RINEX 2: GLONASS



Healthy GLONASS satellites with problems **with impaired L2 observations**:

1. R06: 2017-02-13 → 2017-03-30, bad code and phase data
2. R12: 15-12-2016 → now, impaired L2 frequency
3. R06: 08-04-2018 → now, impaired L2 frequency

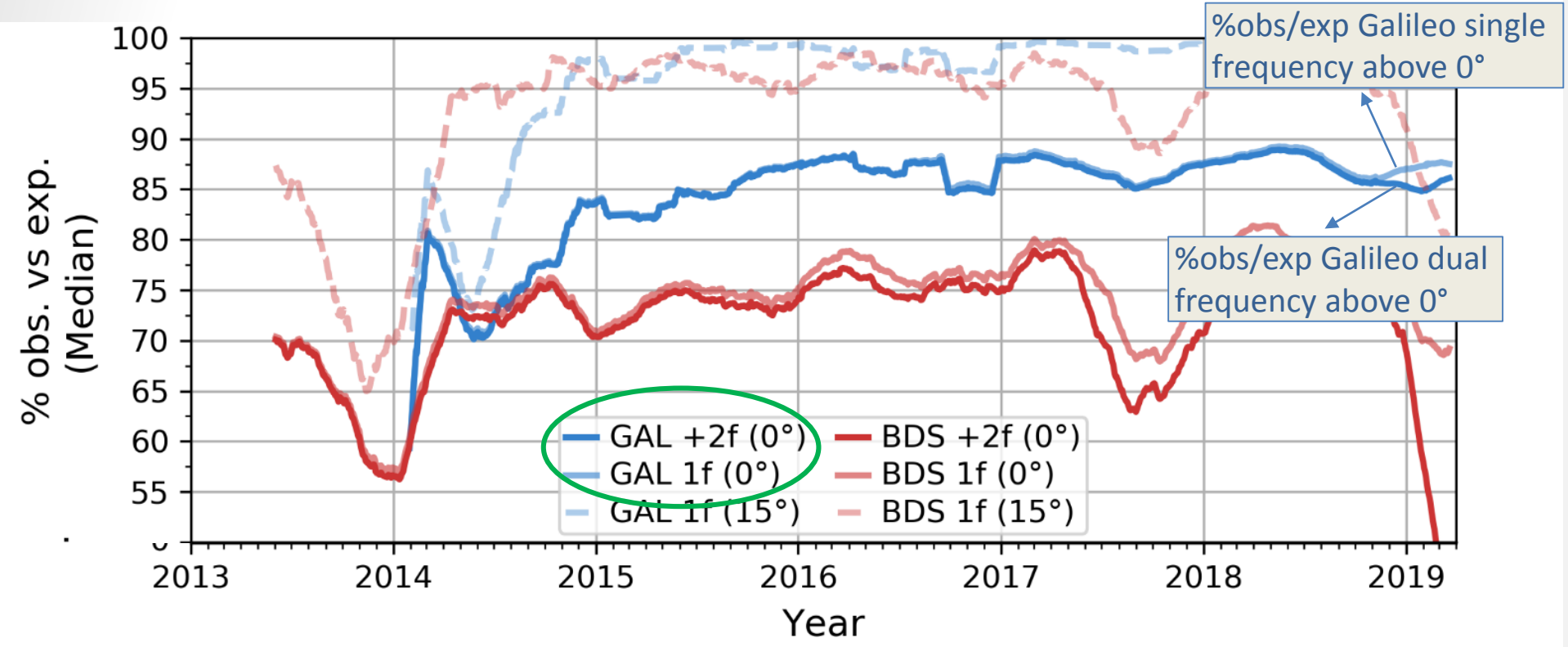
1996-2019 RINEX 2: GLONASS



Healthy GLONASS satellites with problems with impaired L2 observations:

1. R06: 2017-02-13 → 2017-03-30, bad code and phase data
2. R12: 15-12-2016 → now, impaired L2 frequency
3. R06: 08-04-2018 → now, impaired L2 frequency

2014-2019 RINEX 3 : Galileo



Galileo single and dual frequency tracking are comparable

Not much dual frequency observations are lost compared to single frequency (something that happens mostly at low elevations)

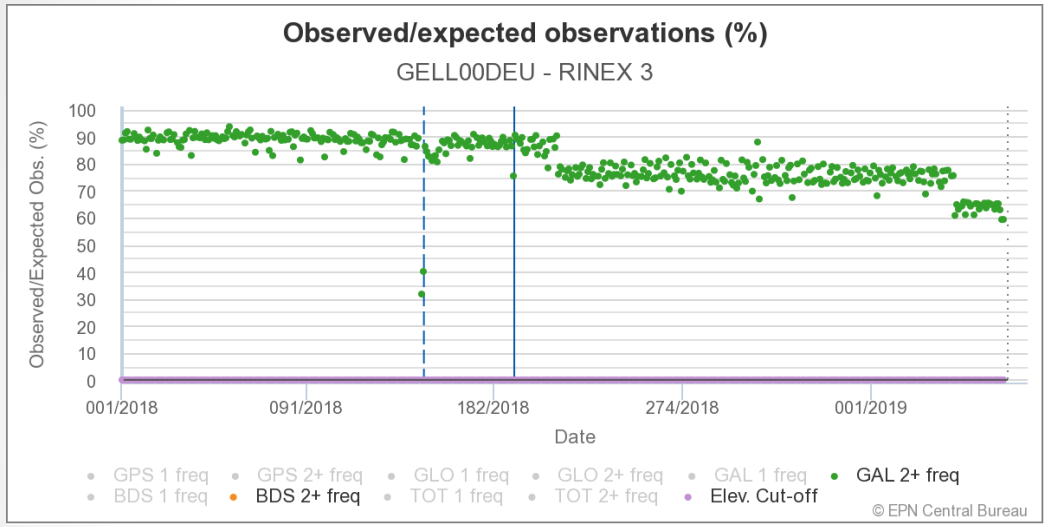
Galileo Tracking

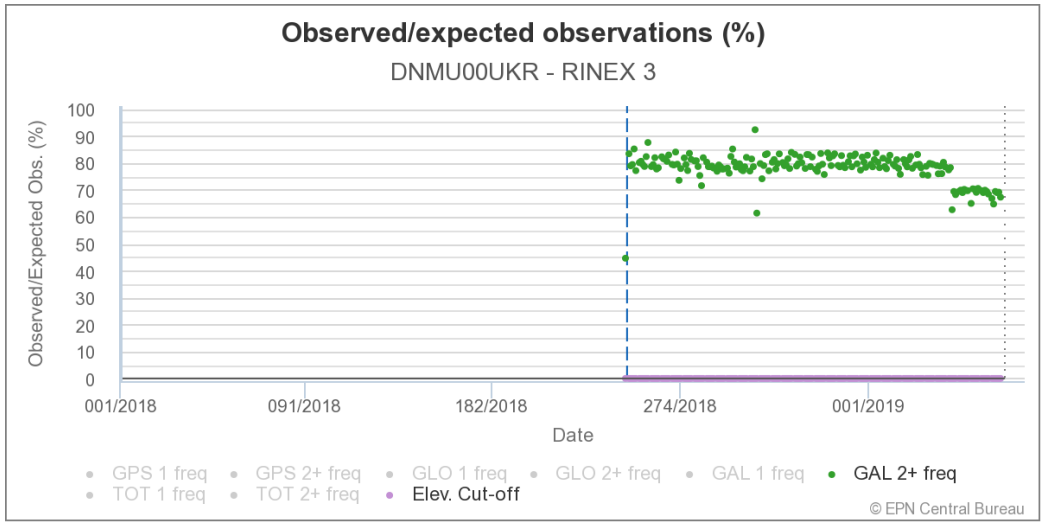
Drops of Galileo tracking at several stations

at well-determined dates:

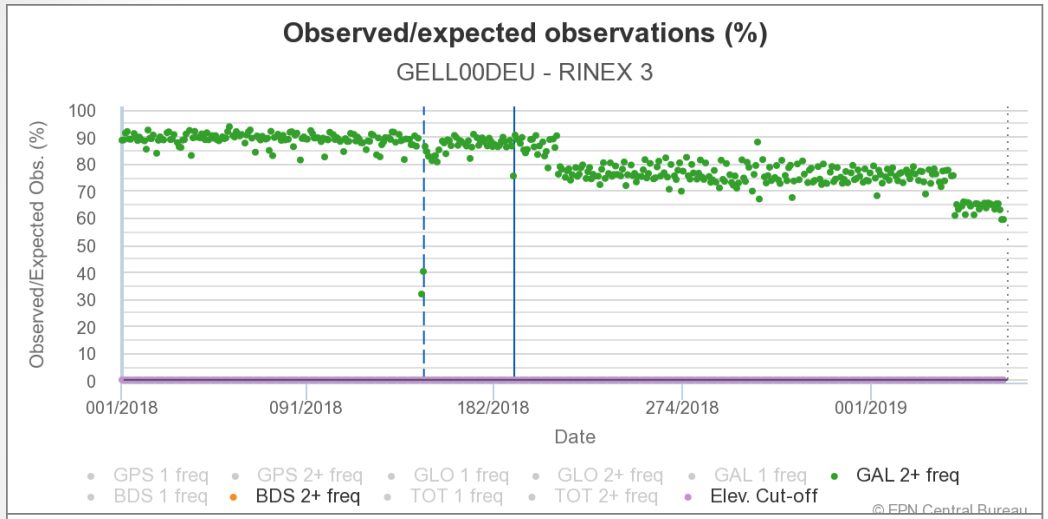
155/2018, 215/2018, 335/2018, 043/2019, …

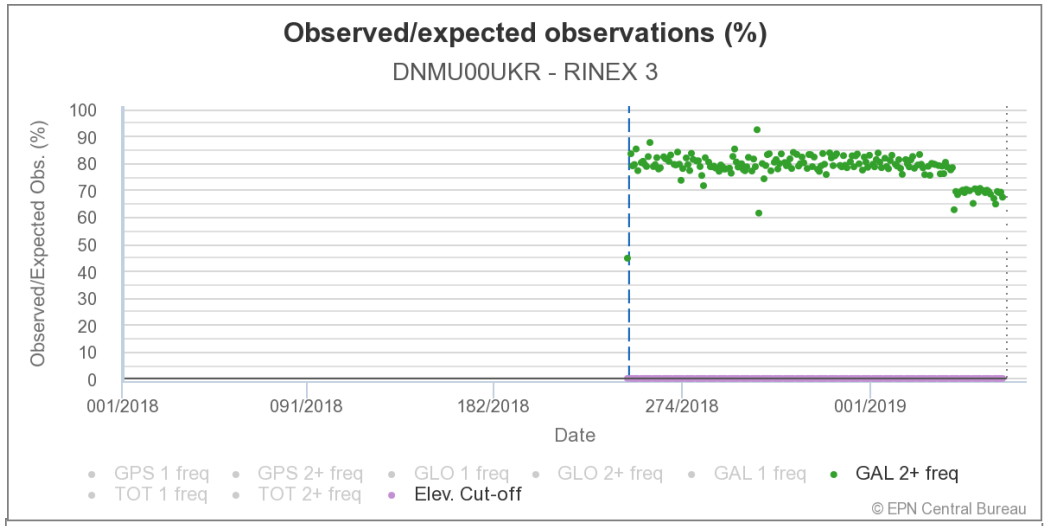
Galileo Tracking

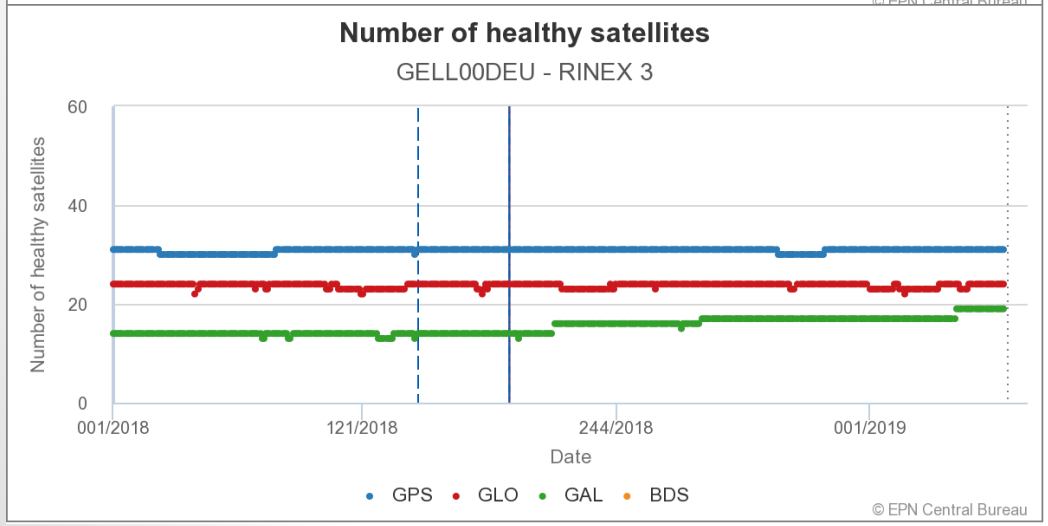


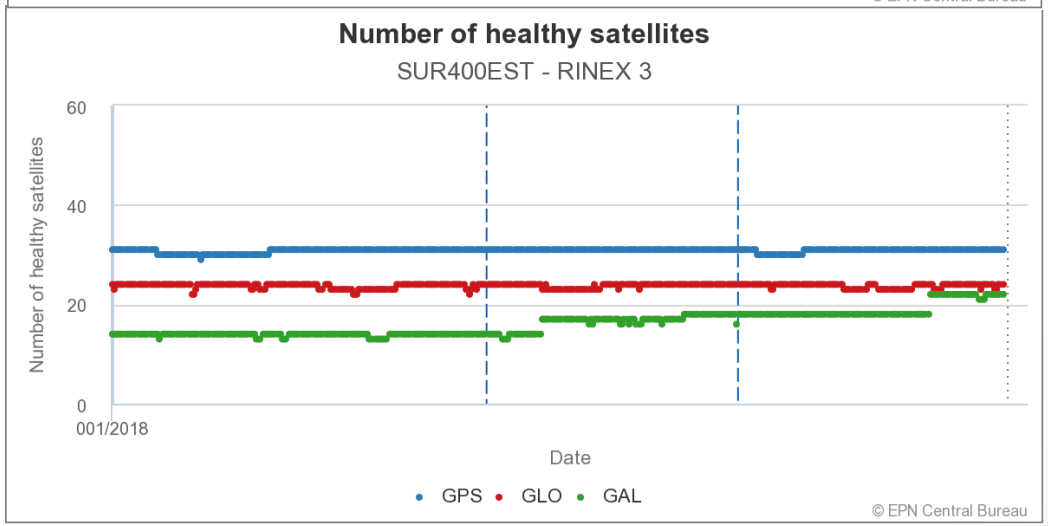


Galileo Tracking

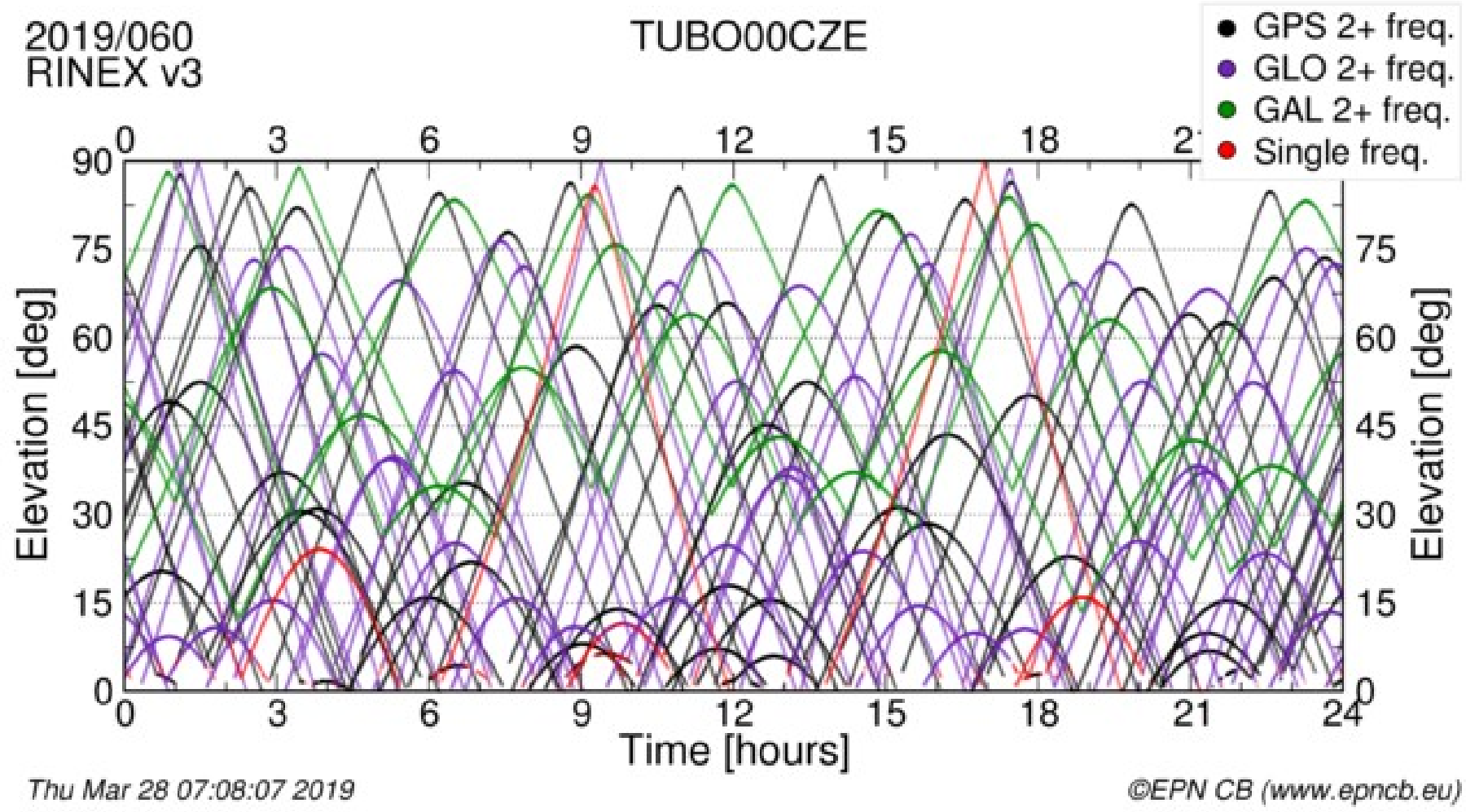




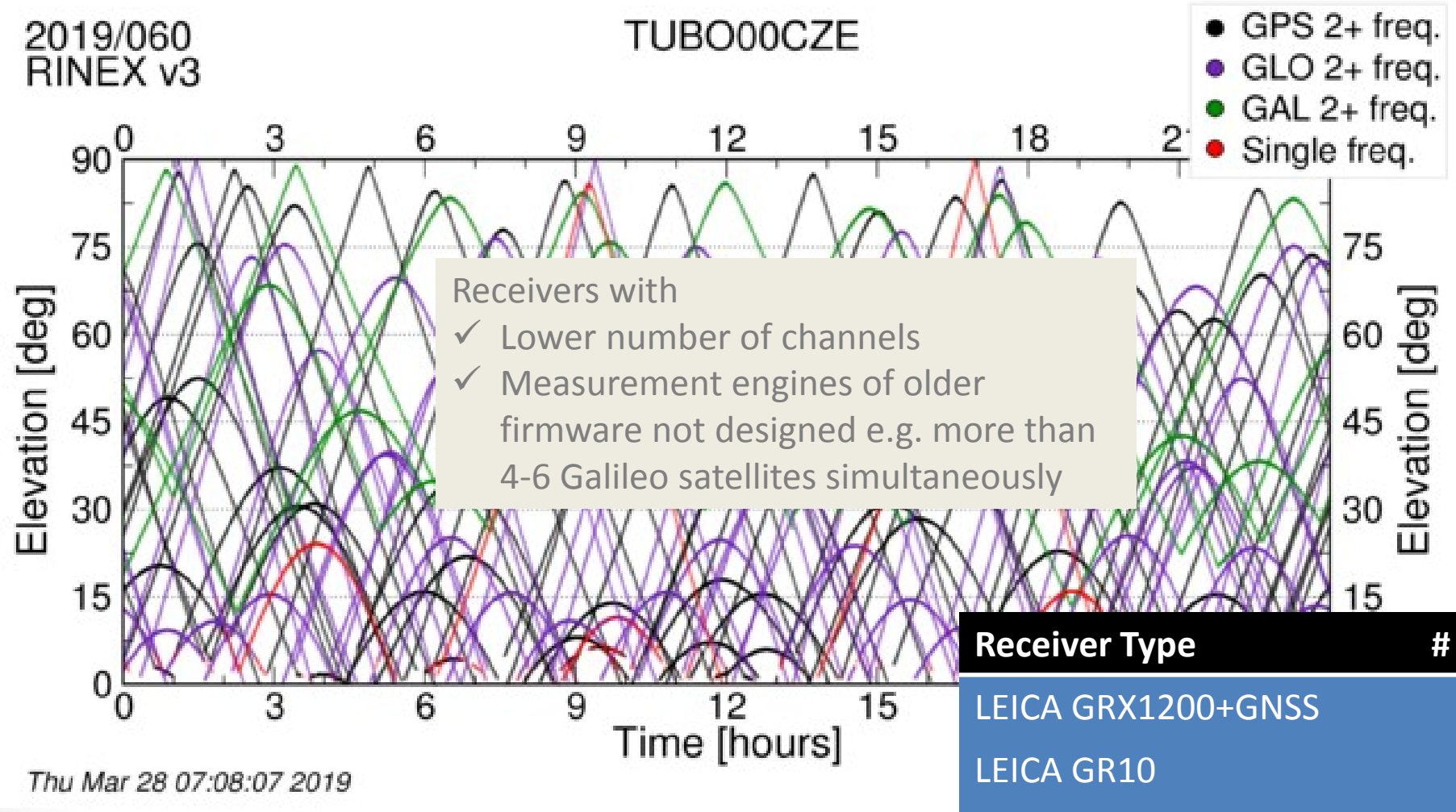




Galileo Tracking



Galileo Tracking



Receivers with
- ✓ Lower number of channels
- ✓ Measurement engines of older firmware not designed e.g. more than 4-6 Galileo satellites simultaneously

Receiver Type	# Channels
LEICA GRX1200+GNSS	120
LEICA GR10	120
LEICA GR25	120

of channels in EPN receivers tracking Galileo

Receiver Type	# Channels
LEICA GRX1200+GNSS	120
LEICA GR10	120
LEICA GR25	120
LEICA GR30	555
LEICA GR50	555
SEPT POLARX4	264
SEPT POLARX4TR	264
SEPT POLARX5	544
SEPT POLARX5TR	544

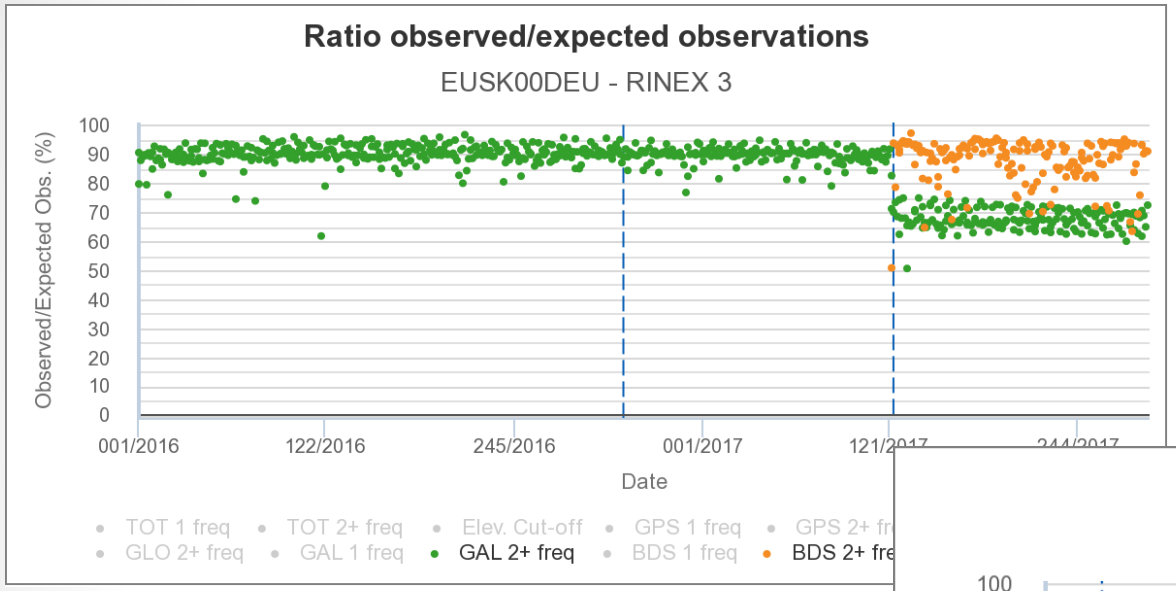
Receiver Type	# Channels
TRIMBLE ALLOY	672
TRIMBLE NETR9	440
TRIMBLE SPS855	440
TPS NET-G5	452
JAVAD TRE_3	864
JAVAD TRE_3 DELTA	864
JAVAD TRE_G3T DELTA	216
JAVAD TRE_G3T DELTA	216
JAVAD TRE_G3TH SIGMA	216

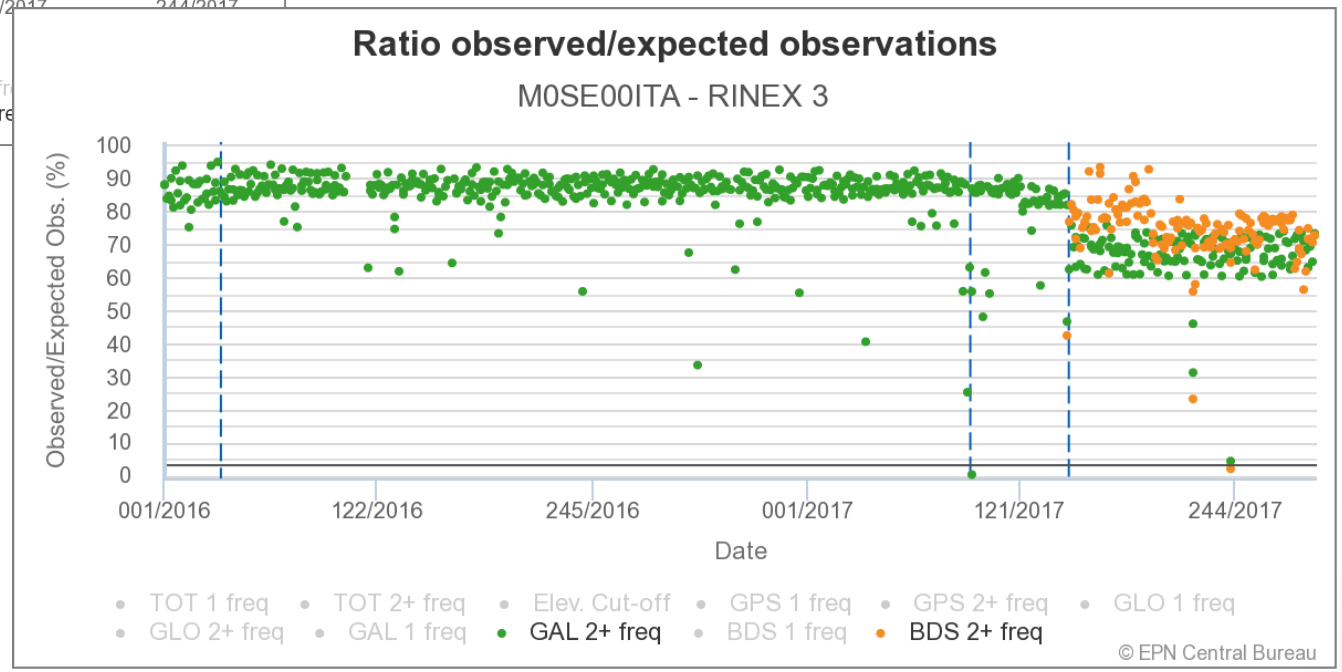
March 2019

Galileo Tracking

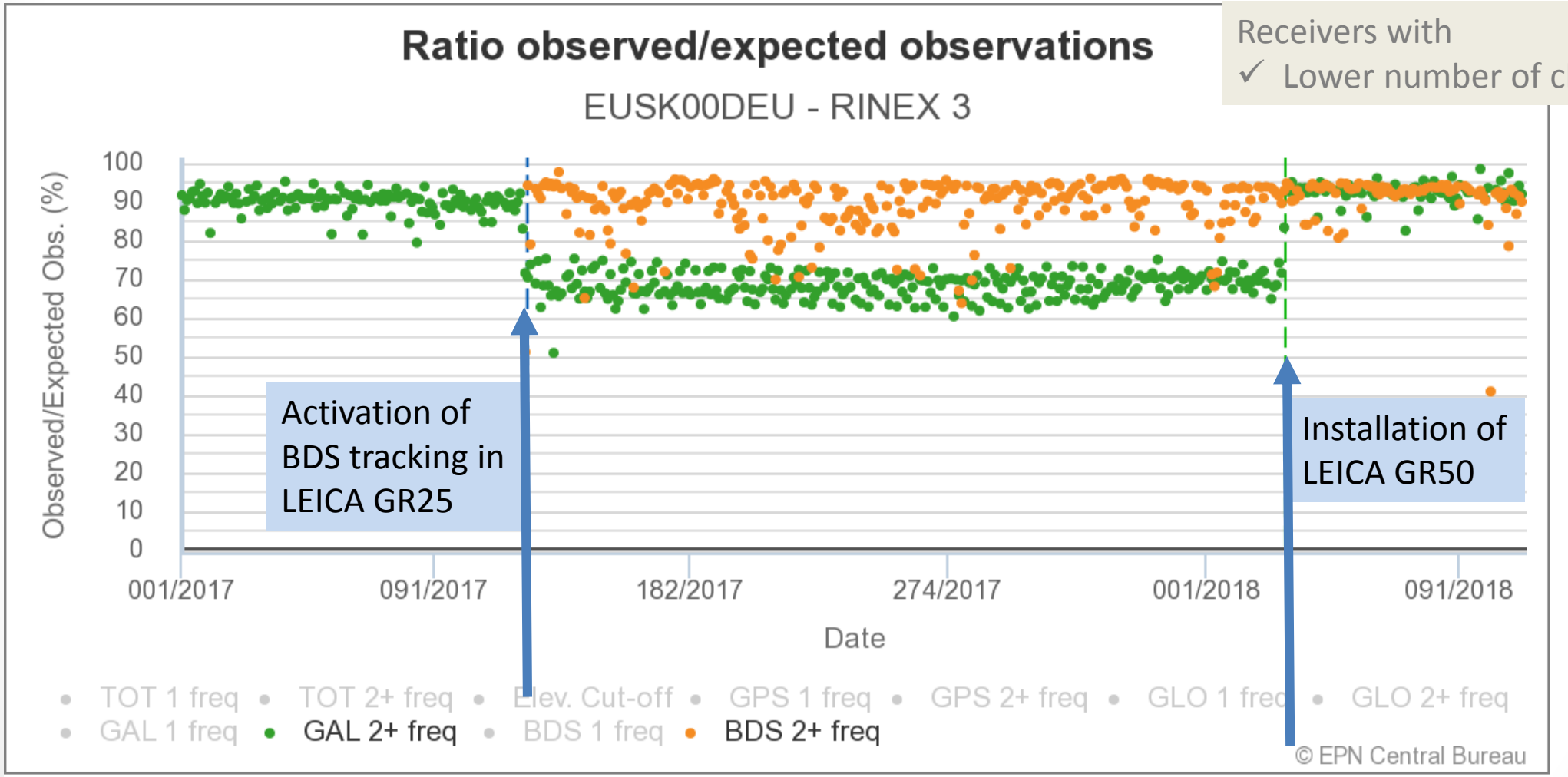
"Random" sudden drops of Galileo tracking

Simultaneous Galileo and BeiDou tracking



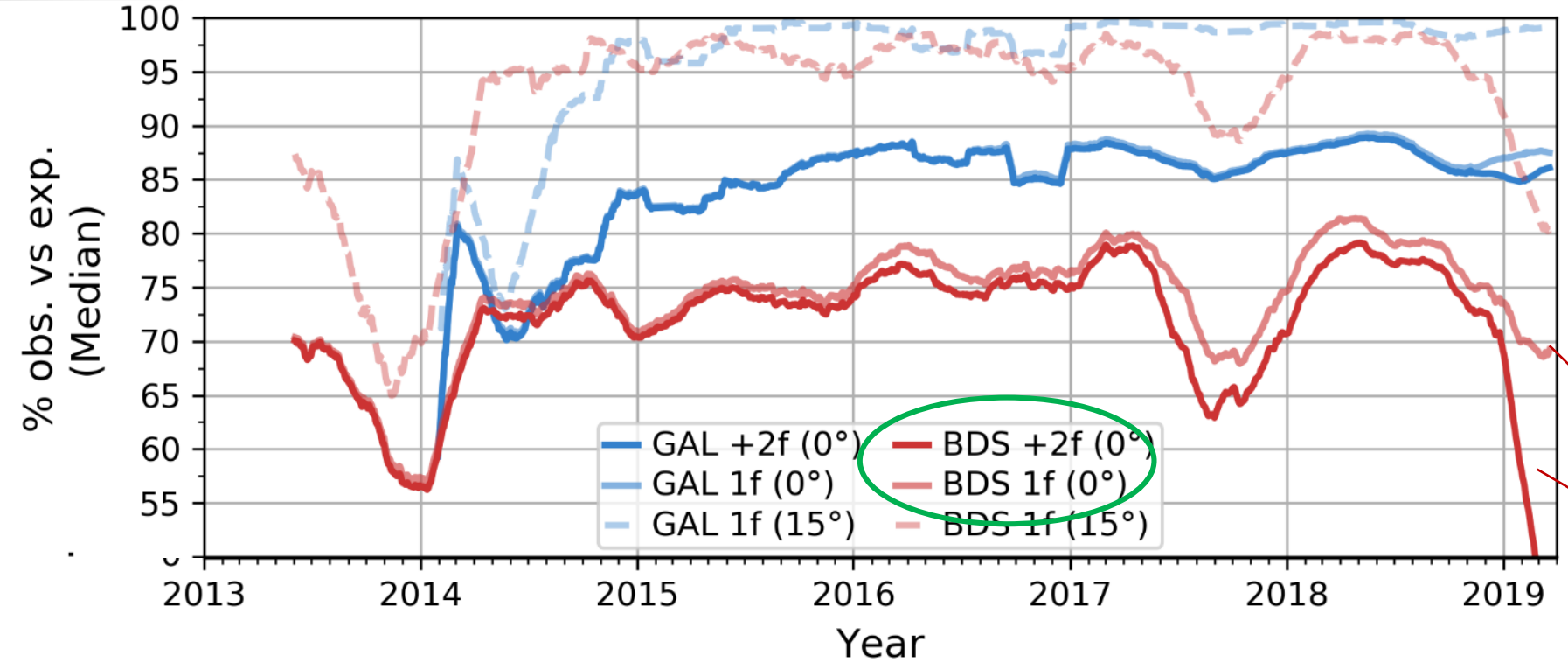


Simultaneous Galileo and BeiDou Tracking



Receivers with
✓ Lower number of channels

2014-2019 RINEX 3 : BeiDou



Beidou dual frequency degradion

%obs/exp BeiDou single frequency above 0°

%obs/exp BeiDou dual frequency above 0°

360/2018: commissioning of BeiDou satellites with new signals not tracked by several receivers types.

Frequency band	B1 (L2x)	B2b (L7x)	B3 (L6x)
"Classic" BeiDou tracking	X	X	OPTION

Receiver Type	B1 L2x	B2b L7x	B3 L6x
LEICA GRX1200+GNSS	1	1	-
LEICA GR10	6	6	-
LEICA GR25	21	21	-
LEICA GR30	18	18	5
LEICA GR50	16	16	-
SEPT POLARX4	7	7	-
SEPT POLARX4TR	1	1	-
SEPT POLARX5	7	7	7
SEPT POLARX5TR	1	1	1

Receiver Type	B1 L2x	B2b L7x	B3 L6x
TRIMBLE ALLOY	2	2	1
TRIMBLE NETR9	54	54	38
TRIMBLE SPS855	2	2	-
TPS NET-G5	2	2	-
JAVAD TRE_3	1	1	1
JAVAD TRE_3 DELTA	25	25	25
JAVAD TRE_G3TH DELTA	2	2	-

Status April 2019

Frequency band	B1 (L2x)	B2b (L7x)	B3 (L6x)
"Classic" BeiDou tracking	X	X	OPTION

B2a(L5x) B2b(L7x) B2(L8x)

18 NEW BDS-3 satellites healthy from 360/2018

Receiver Type	B1 L2x	B2b L7x	B3 L6x	NEW BDS-3
LEICA GRX1200+GNSS	1	-	-	-
LEICA GR10	6	-	-	-
LEICA GR25	21	-	-	-
LEICA GR30	18	-	5	-
LEICA GR50	16	-	-	-
SEPT POLARX4	7	-	-	-
SEPT POLARX4TR	1	-	-	-
SEPT POLARX5	7	-	7	-
SEPT POLARX5TR	1	-	1	-

Receiver Type	B1 L2x	B2b L7x	B3 L6x	NEW BDS-3
TRIMBLE ALLOY	2	-	1	2
TRIMBLE NETR9	54	-	38	-
TRIMBLE SPS855	2	-	-	-
TPS NET-G5	2	-	-	-
JAVAD TRE_3	1	-	1	1
JAVAD TRE_3 DELTA	25	-	25	-
JAVAD TRE_G3TH DELTA	2	-	-	-

Status April 2019

Frequency band	B1 (L2x)	B2b (L7x)	B3 (L6x)
"Classic" BeiDou tracking	X	X	OPTION

B2a(L5x) B2b(L7x) B2(L8x)

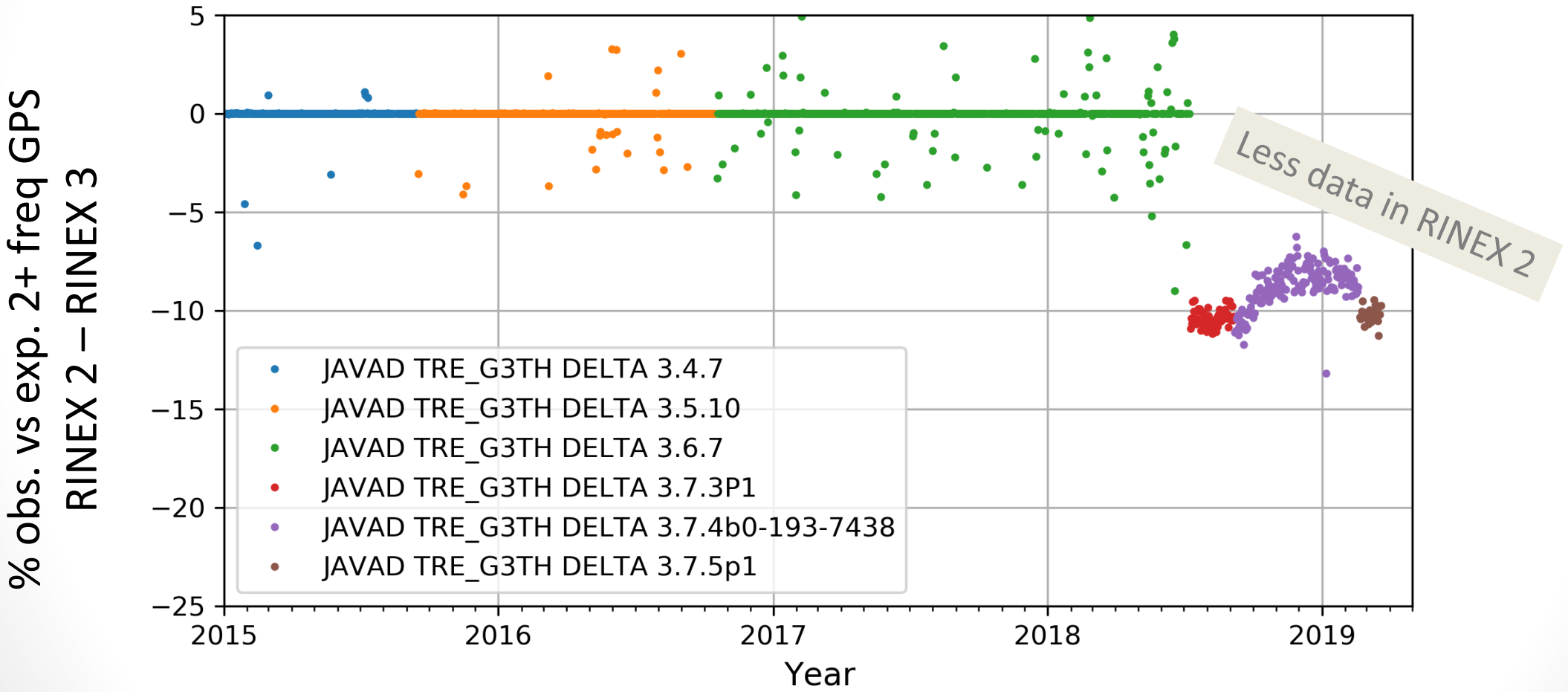
18 NEW BDS-3 satellites healthy from 360/2018

Receiver Type	B1 L2x	B2b L7x	B3 L6x	NEW BDS-3
LEICA GRX1200+GNSS	1	-	-	-
LEICA GR10	6	-	-	-
LEICA GR25	21	-	-	-
LEICA GR30	18	-	5	-
LEICA GR50	16	-	-	-
SEPT POLARX4	7	-	-	-
SEPT POLARX4TR	1	-	-	-
SEPT POLARX5	7	-	7	-
SEPT POLARX5TR	1	-	1	-

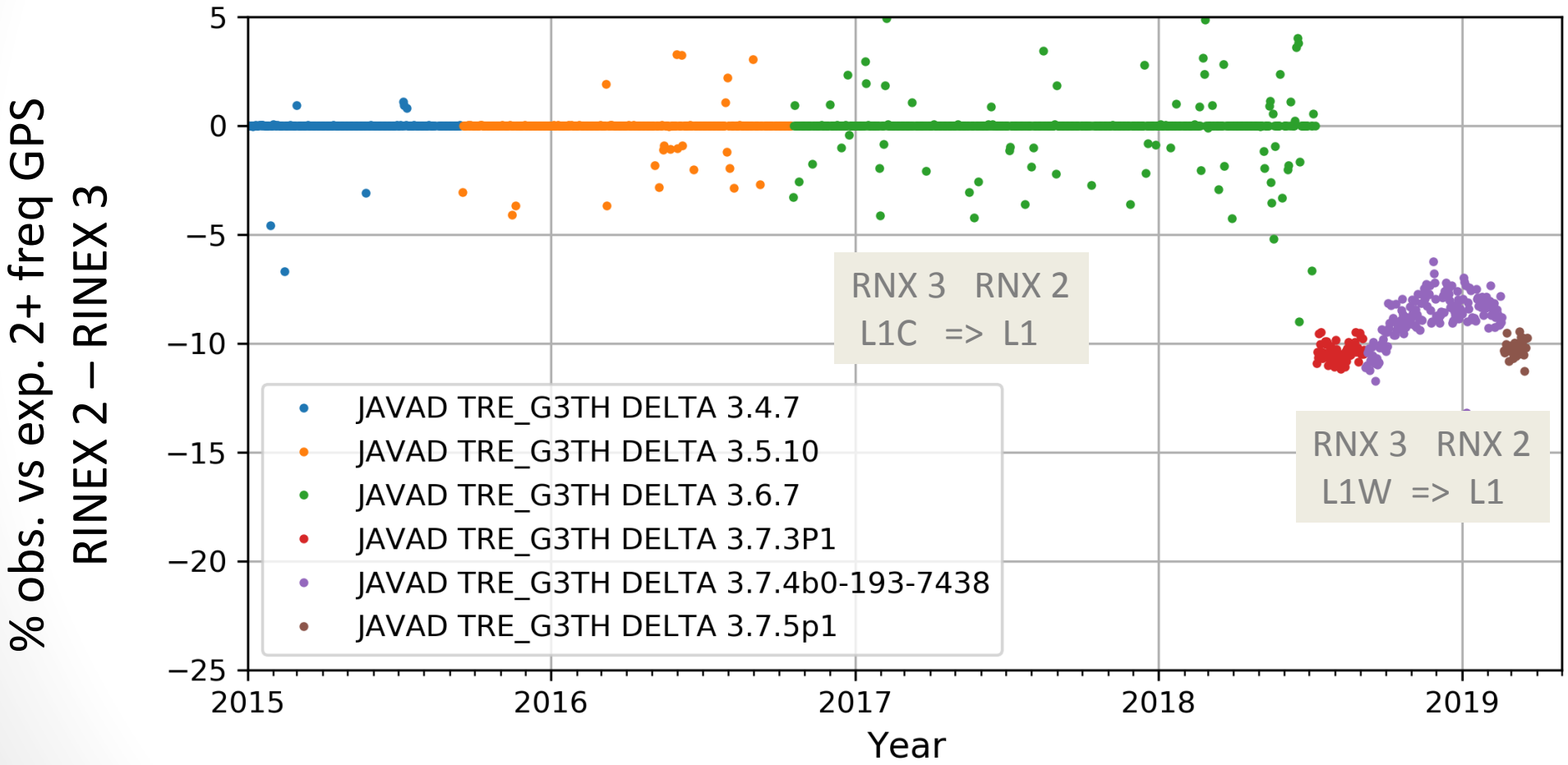
Receiver Type	B1 L2x	B2b L7x	B3 L6x	NEW BDS-3
TRIMBLE ALLOY	2	-	1	2
TRIMBLE NETR9	54	-	38	-
TRIMBLE SPS855	2	-	-	-
TPS NET-G5	2	-	-	-
JAVAD TRE_3	1	-	1	1
JAVAD TRE_3 DELTA	25	-	25	-
JAVAD TRE_G3TH DELTA	2	-	-	-

Status April 2019

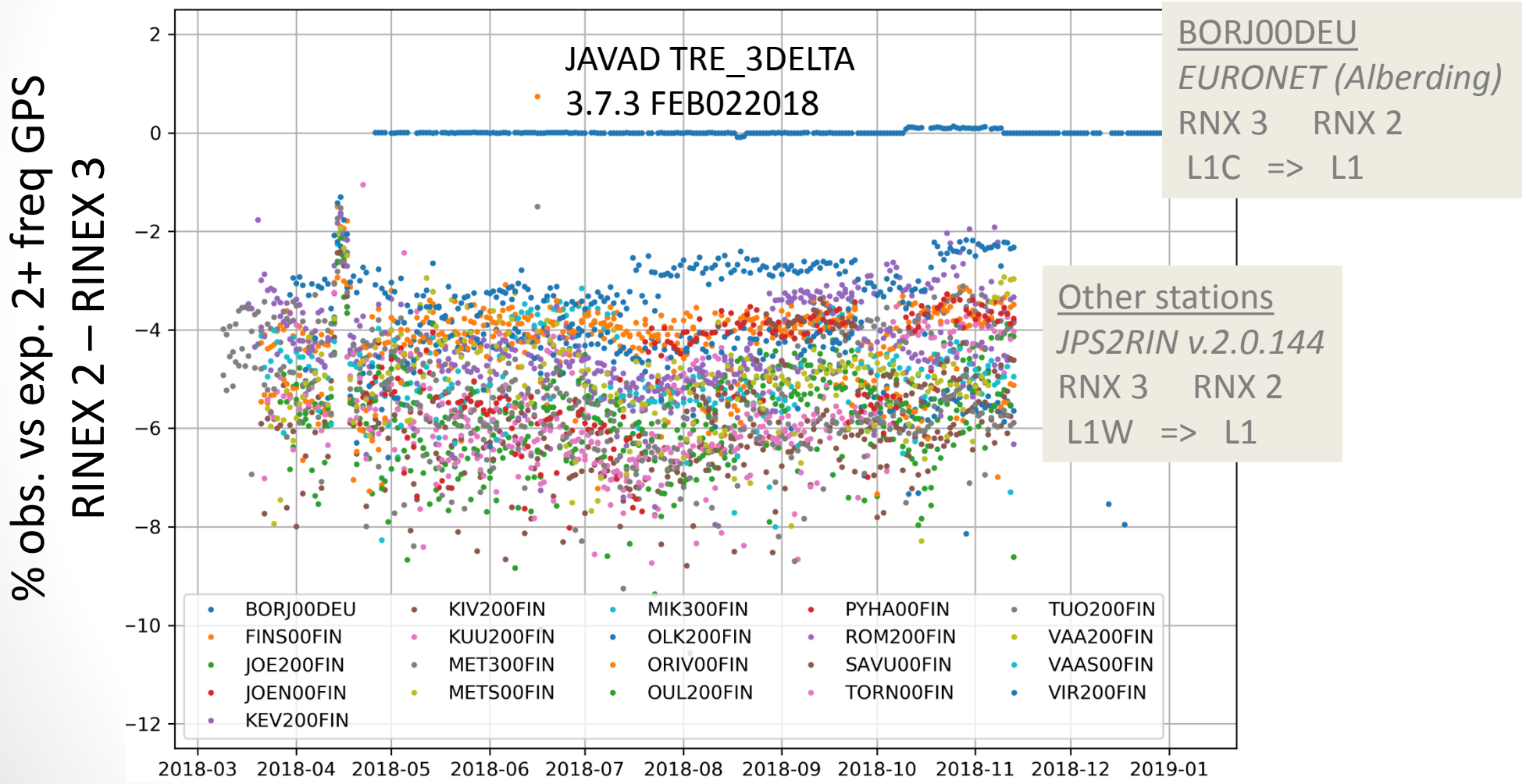
Difference GPS RINEX 2 – RINEX 3



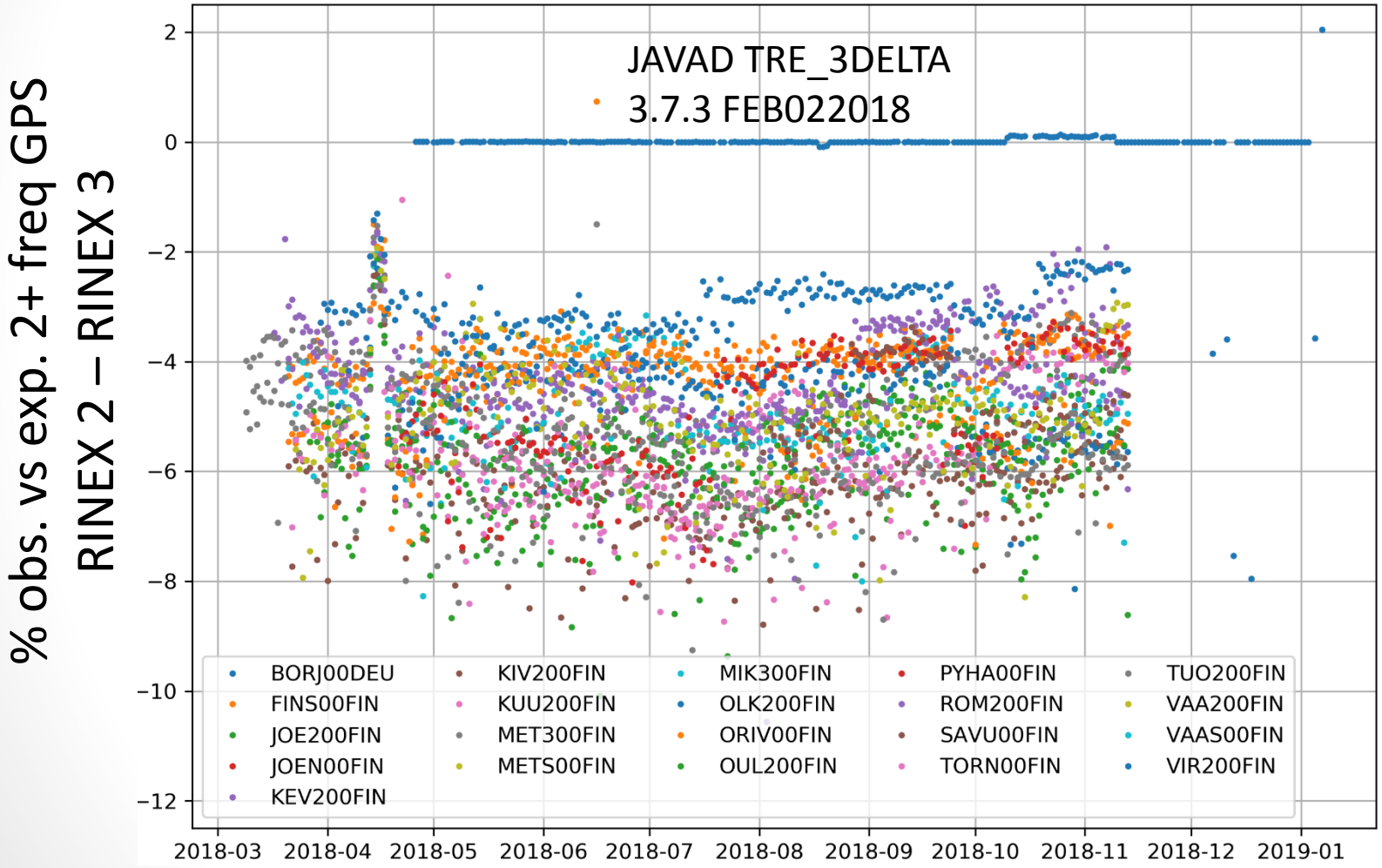
Difference GPS RINEX 2 – RINEX 3



Difference RINEX 2 – RINEX 3 : GPS



Difference RINEX 2 – RINEX 3 : GPS



Seen for
JAVAD TRE_3
JAVAD TRE_3 DELTA
JAVAD TRE-G3T DELTA
JAVAD TRE-G3TH DELTA
TRIMBLE NETR9
(but not all of them)

Depends on receiver firmware and raw → RINEX conversion software

Conclusions

Impressive increase of Galileo data in EPN

Evaluation of 23 years of EPN data quality checks

- Focus on % observed vs. expected observations
- GPS: Improvement of low elevation tracking
  - RINEX 2 data with up to 10% less GPS data than RINEX 3 (choice of observables)
- GLONASS: General degradation since 2016 (satellite-related)
- Galileo/ BeiDou: less satellites tracked at low elevations
  - Receivers with lower number of channels
- BeiDou drop of dual frequency tracking due new BDS-3 signals
- + ……

Re-gereneration of RINEX 2 data might be useful

Using standardized firmware names would help

Monitoring of multi-GNSS RINEX quality checks remain challenging : separation of satellite-specific degradations from station/receiver/firmware-specific degradations

Thanks to all EPN station managers for their support to the EPN

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