Zero, single and double difference analysis of GPS and GIOVE-A/B L1 and L5/E5a pseudo range and carrier phase measurements

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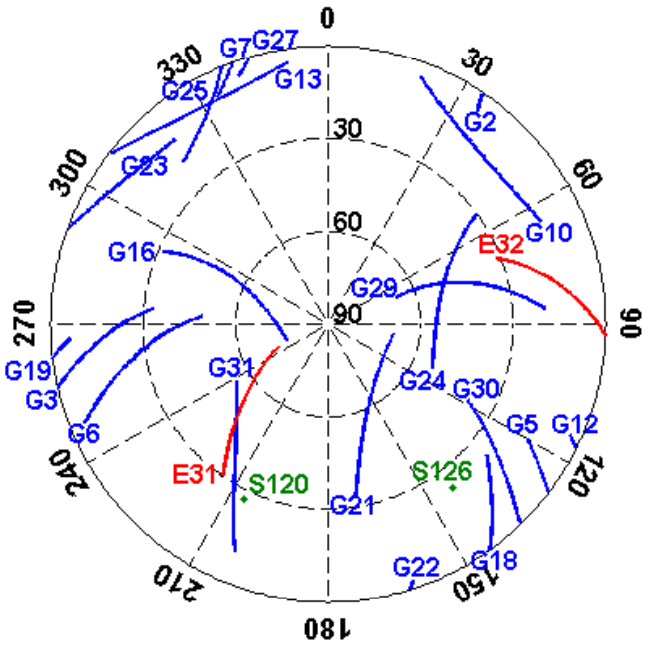
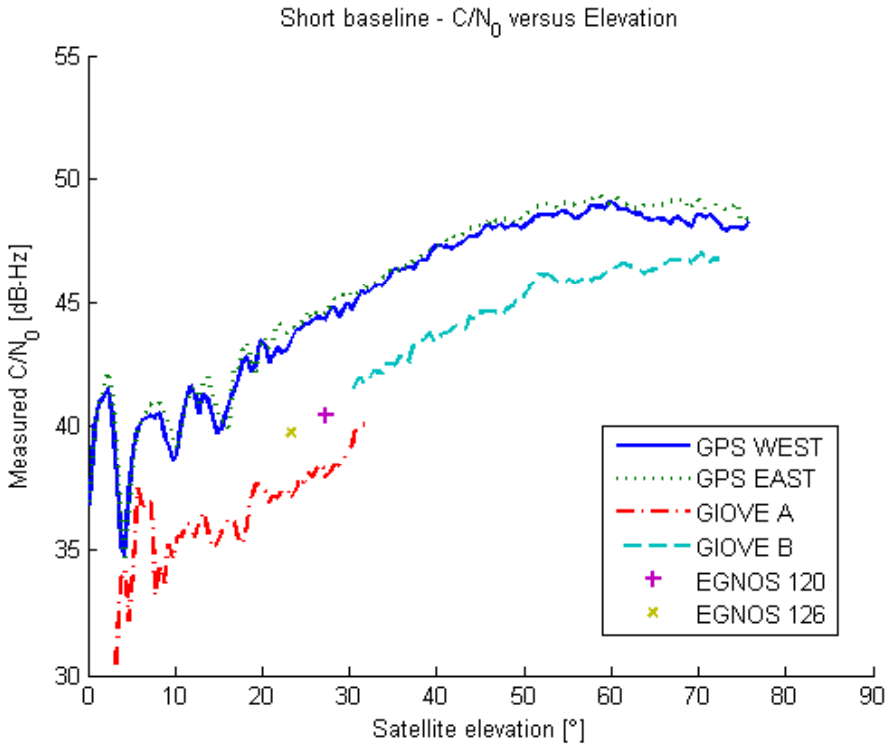
Overview

- Short and zero baseline measurements
- Part I
  - Analysis of L1 pseudo range noise for GPS, GIOVE A/B and EGNOS
  - Analysis of L1 carrier phase noise for GPS, GIOVE A/B and EGNOS
  - Conclusions
- Part II
  - Analysis of L5 pseudo range noise for GIOVE A/B and GPS 01
  - Conclusions

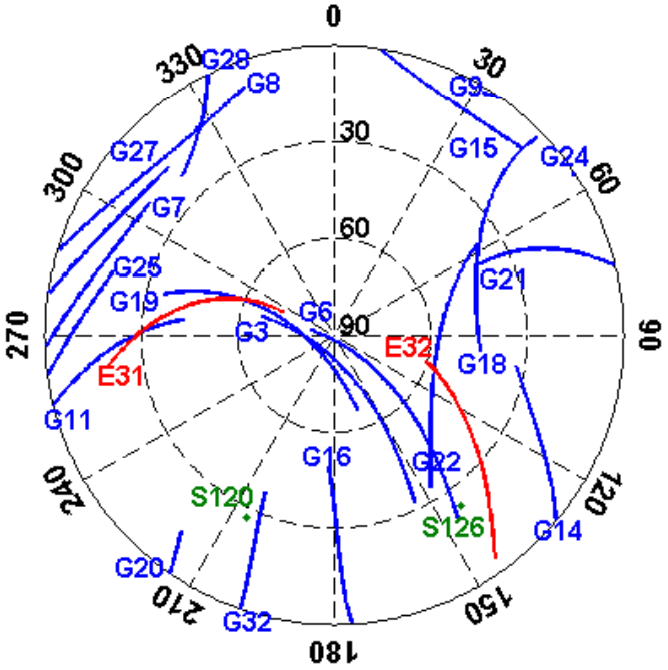
Short baseline measurement in field near Delft with simultaneous tracking to GIOVE A and B.

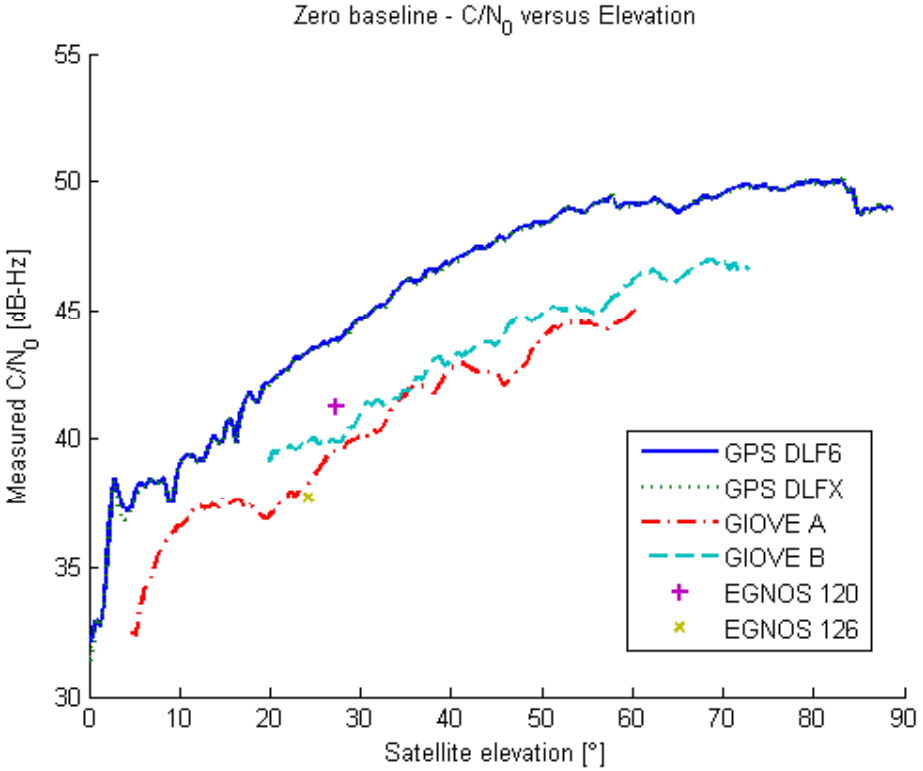
Short Baseline

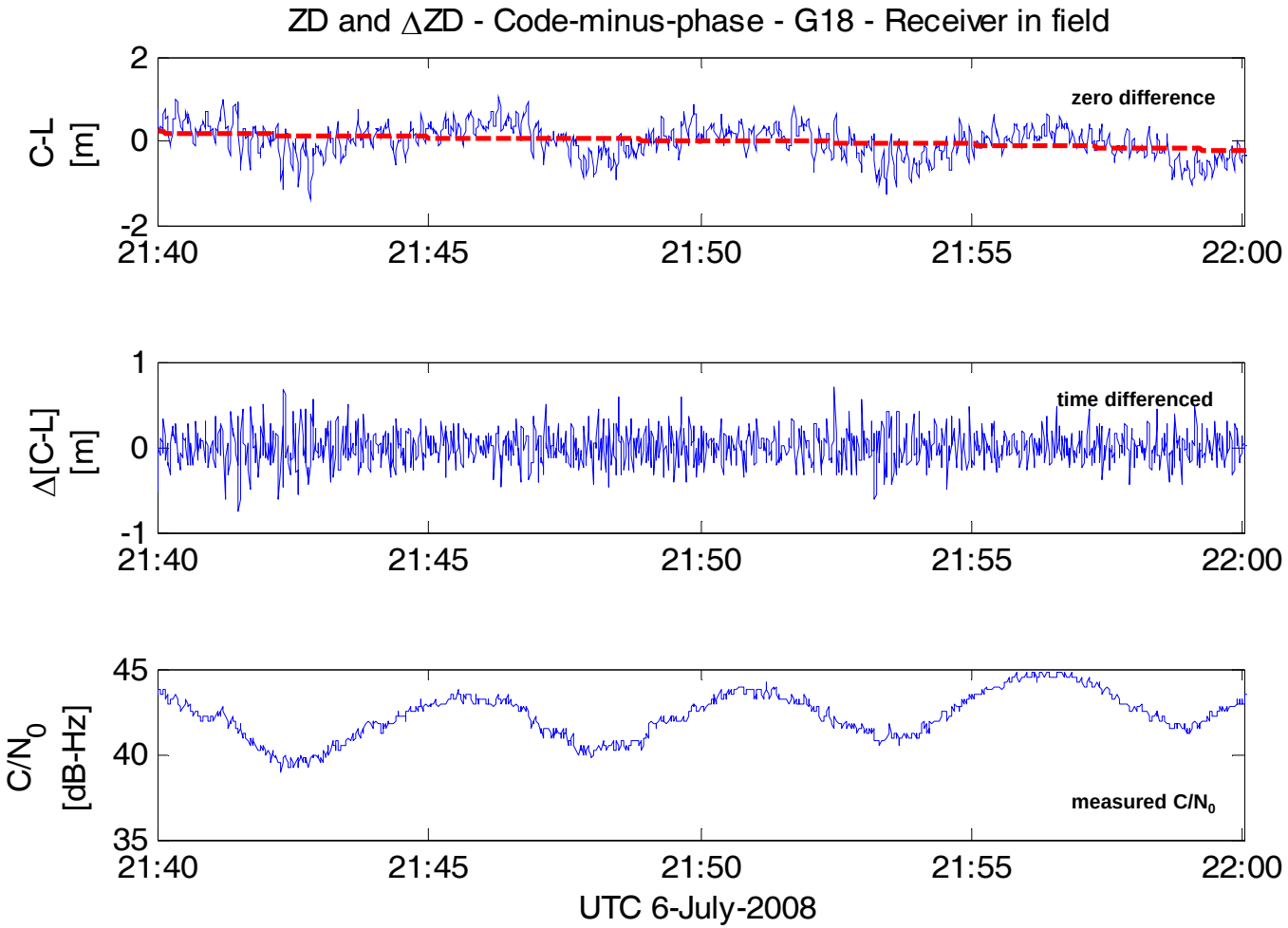




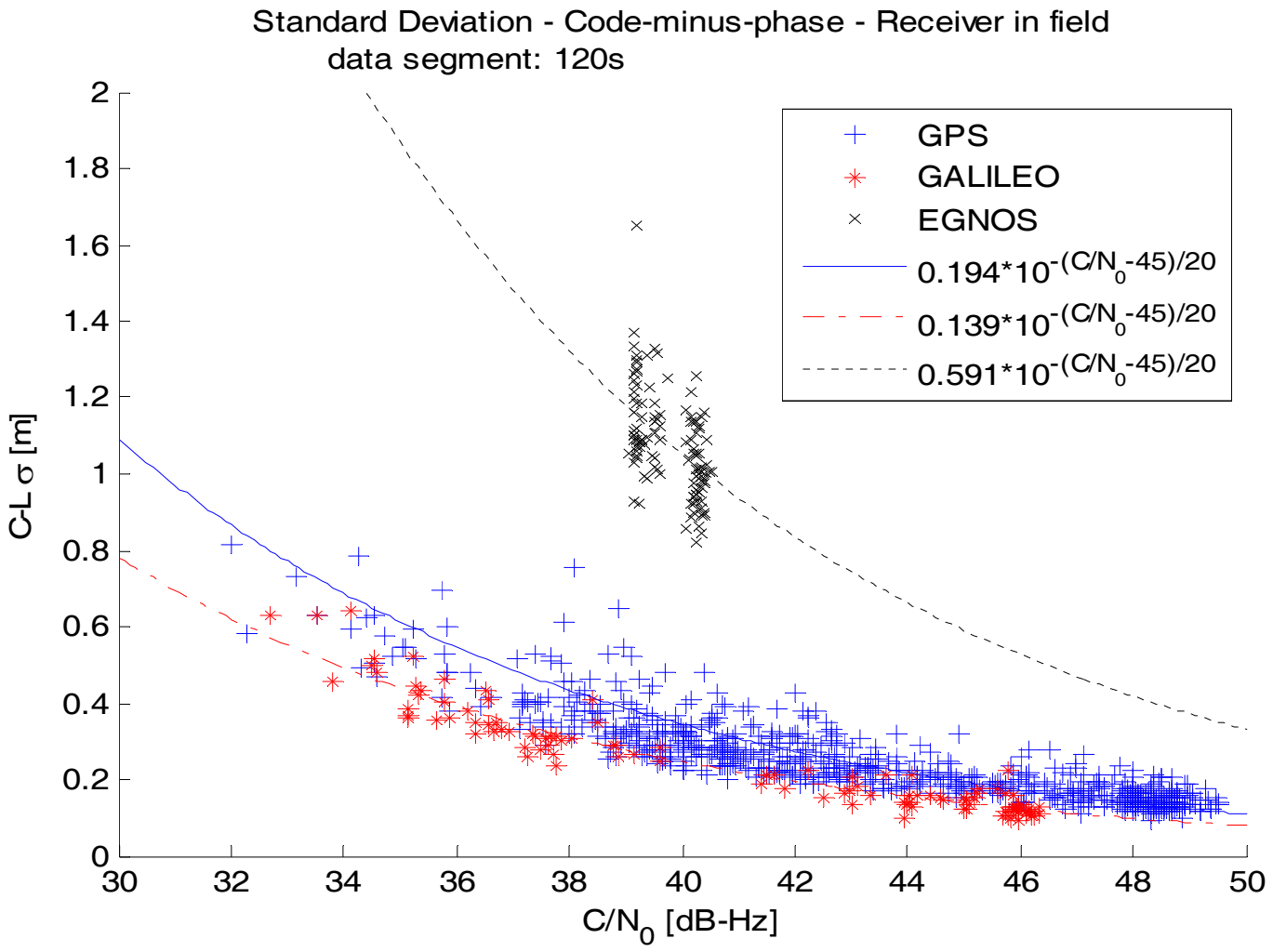
Zero baseline







Stand alone receiver code-minus-phase observations for GPS PRN 18. Both the zero difference observations and the measured C/N_0 show a periodic effect, most likely caused by multipath. The time differenced observations do not show these variations but the variance of the noise *does* change with the C/N_0.



Standard deviation of code-minus-phase versus measured C/N_0 of standalone receiver for data segments of 120s after removing instrumental delays, ambiguities, and low frequency multipath and ionospheric delay. The standard deviation for a C/N_0 of 45 dB-Hz is estimated by fitting an exponential curve.

Analysis and grouping of the results

- **Short and zero baseline measurements were used to determine the measurement noise of GPS, EGNOS and GIOVE-A/B pseudo range and carrier phase observations, under real operational conditions.**
- **Zero, single, double and time differences were used to estimate the different stochastic properties of the observations, and group the estimated stochastic properties according to their noise properties.**
- **Were able to group the different results into 4 groups.**
- **See Table on next slide…**

Normalized standard deviations of the code noise in meters for C/N0 = 45 dB-Hz for each GNSS and multiple analyses techniques. The results are grouped in 4 groups based on noise characteristics.

Analysis	Thermal noise…	GPS	Galileo	EGNOS
Standalone & Short baseline	+ multipath	0.20	0.14	0.59
Standalone & Short baseline; Time difference	- time correlation	0.10	0.07	0.39
Zero baseline	- common LNA noise	0.11	0.06	0.21
Zero baseline; Time difference	- time correlation - common LNA noise	0.07	0.04	0.16

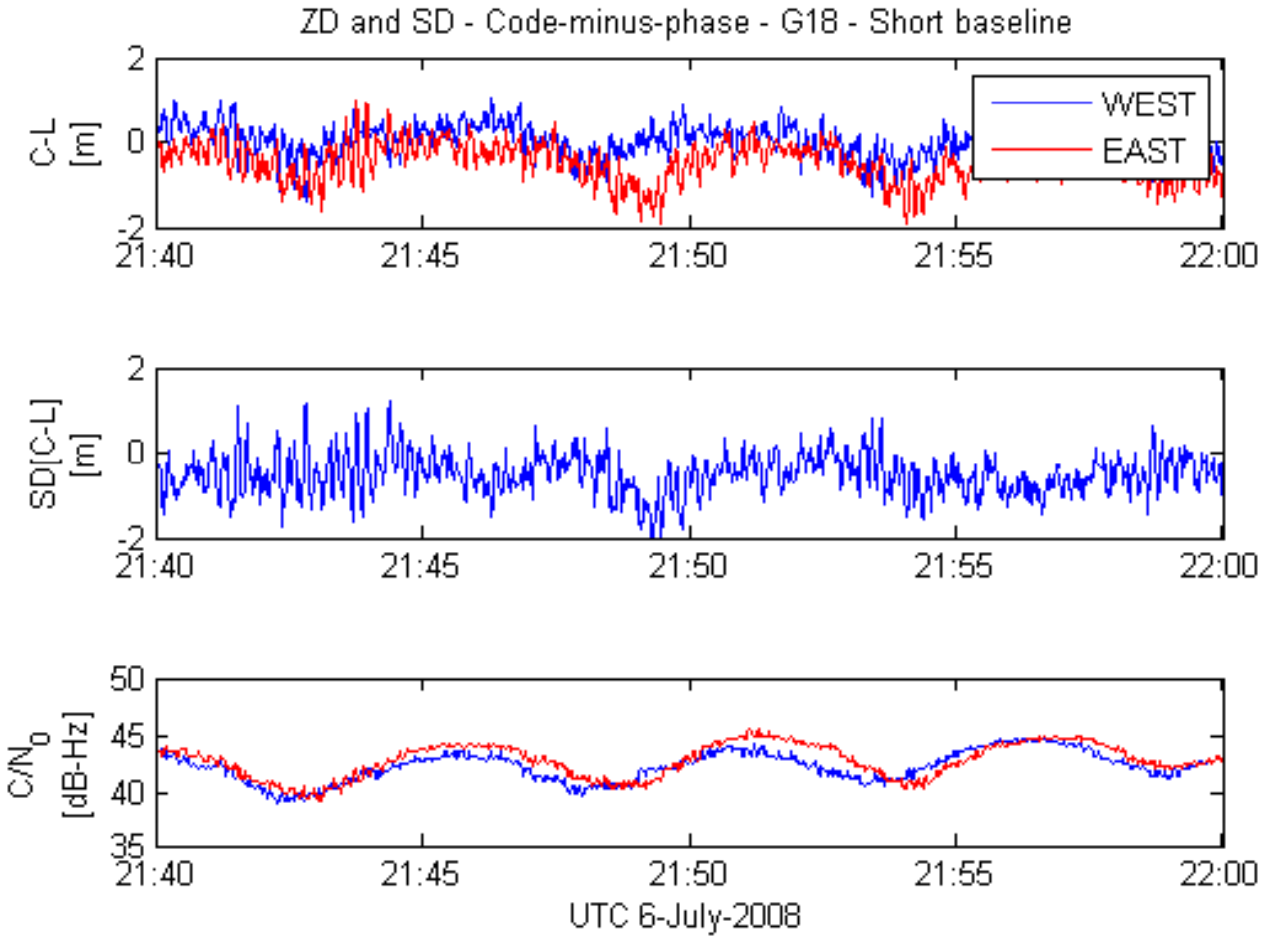
Zero baseline (LNA) cross-correlation, time correlation and thermal noise (without multipath) as determined from Table on previous slide.

	Group	GPS	Galileo	EGNOS
Time correlation [-]	3 and 4	0.63	0.56	0.46
LNA correlation [-]	2 and 4	0.57	0.77	0.85
Thermal noise [m]	2, 3 and 4	0.18	0.12	0.57

Results

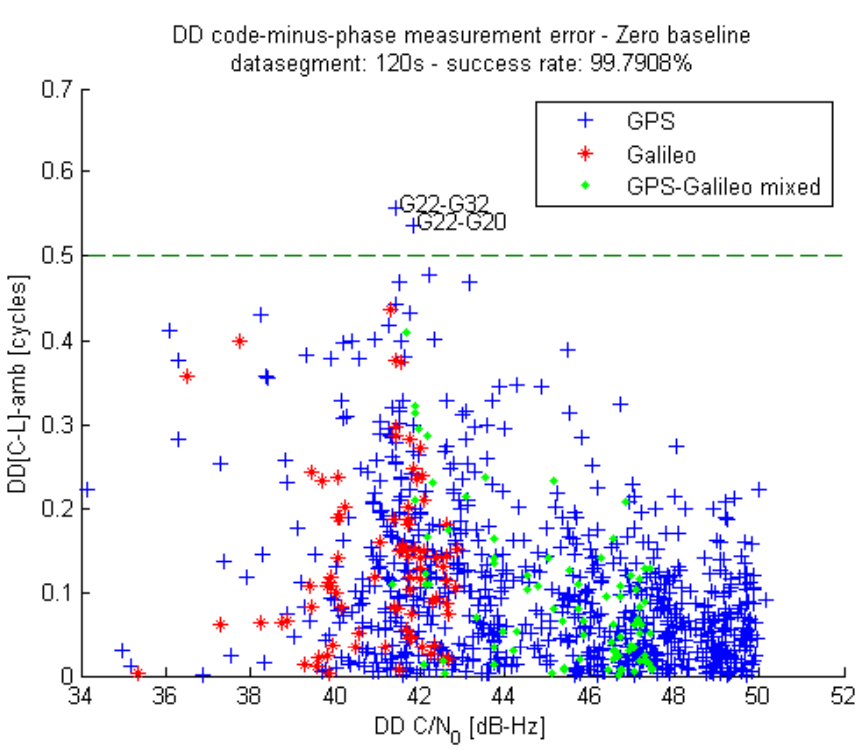
- **The Galileo E1BC signal has less thermal noise (σ=±.12m) than GPS L1C/A (σ=±.18m) and EGNOS signals (σ=±.5m).**
- **There is significant time correlation on the code observations (.4<ρΔ<.6)**
- **Code and phase observations show strong cross-correlation (.5<ρLNA<.9) for the zero baseline setup.**

Short Baseline

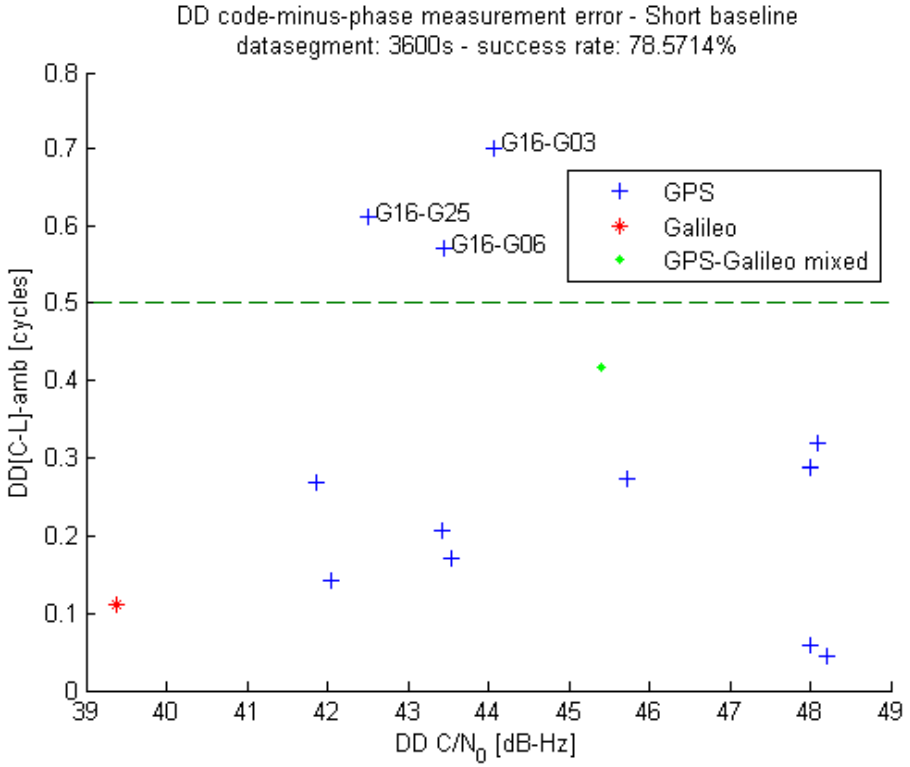


Ambiguity Resolution

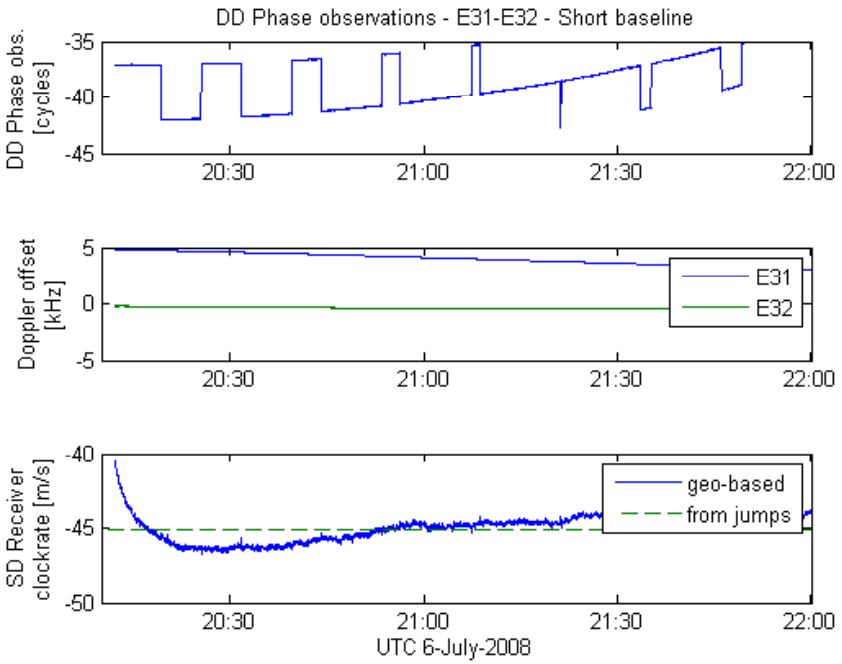
Zero baseline



Short baseline

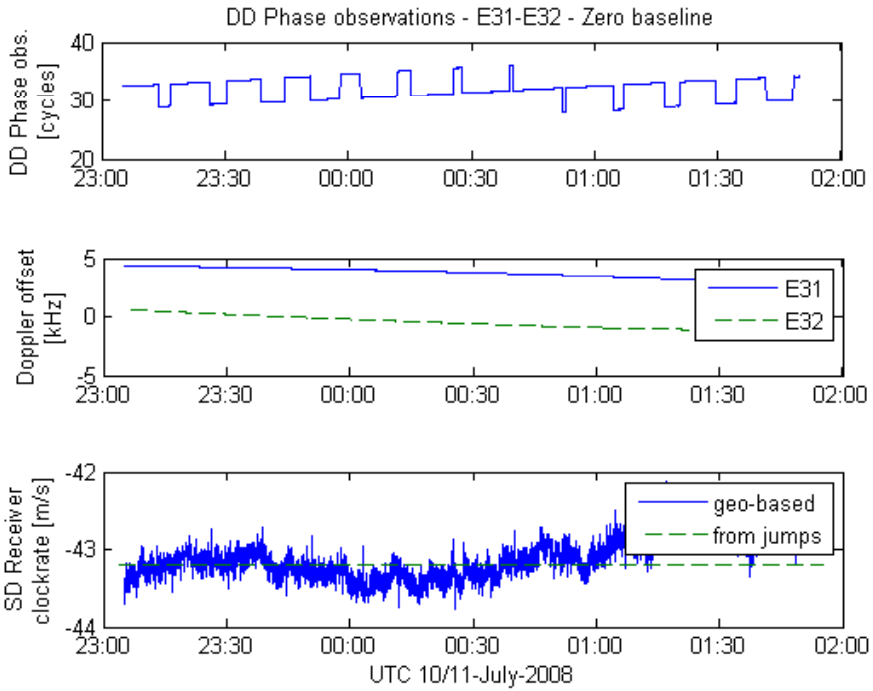


Double Difference Carrier Phase



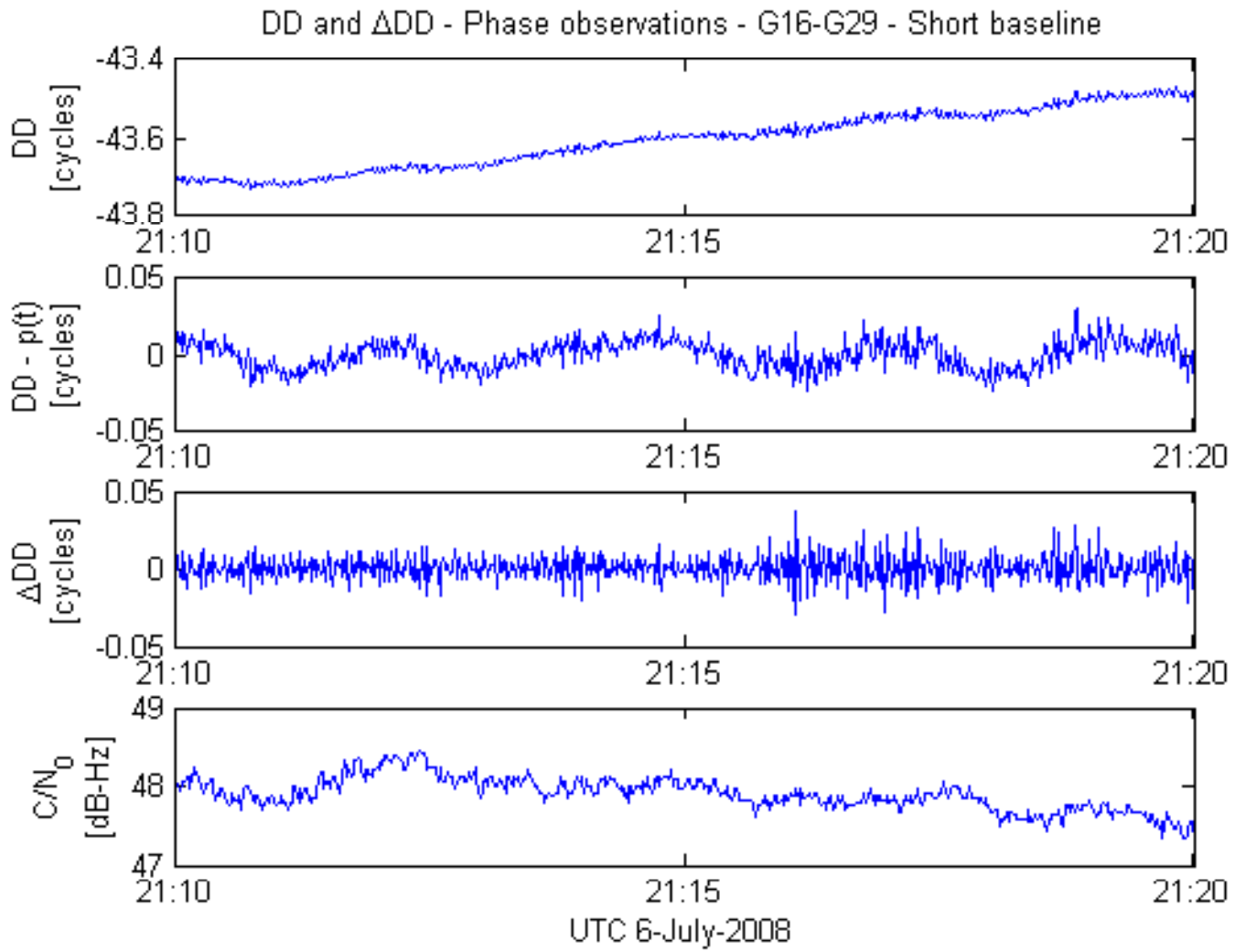
Short baseline DD phase observations,

Doppler offsets and receiver clock rates

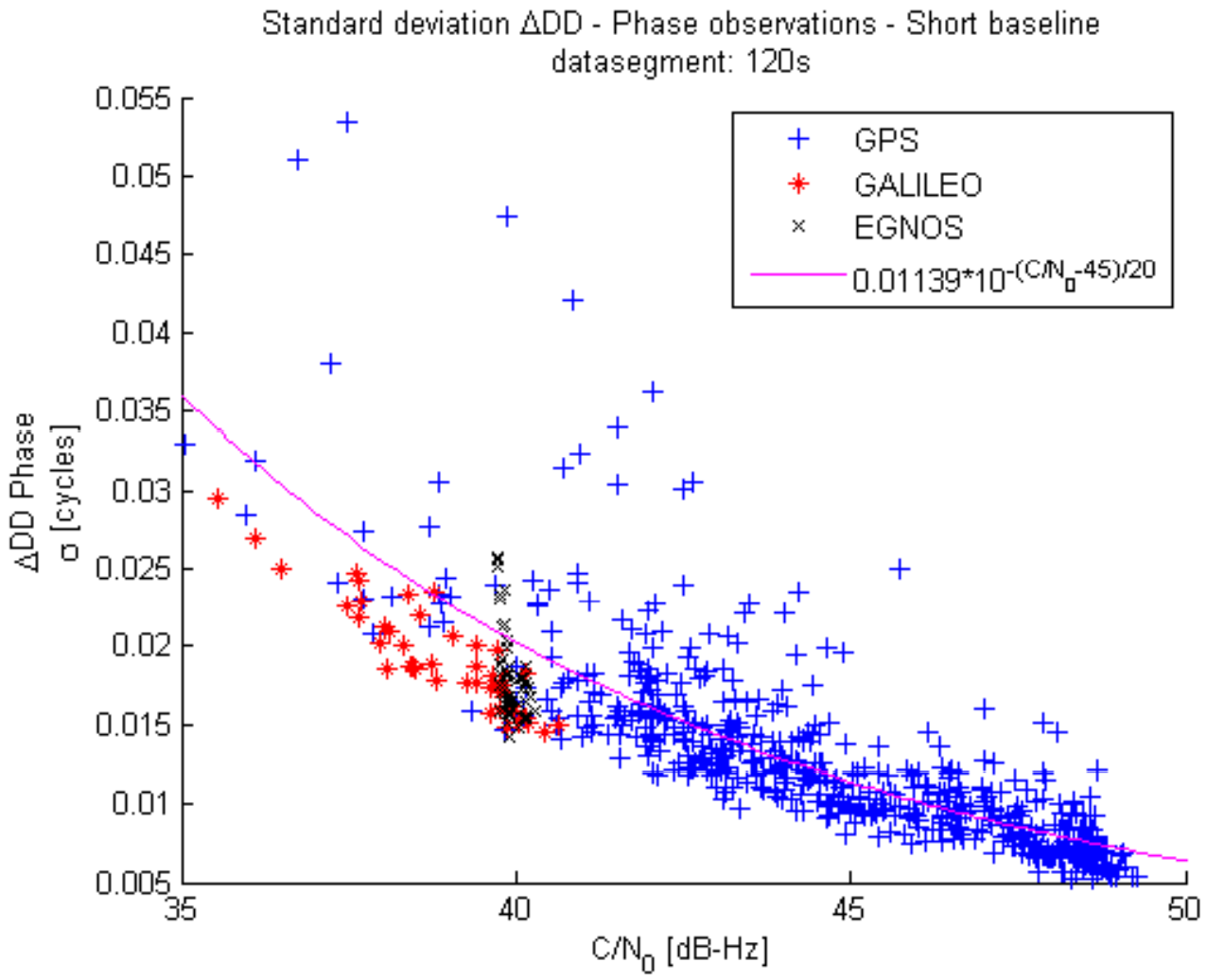


Zero baseline DD phase observations, Doppler

offsets and receiver clock rates

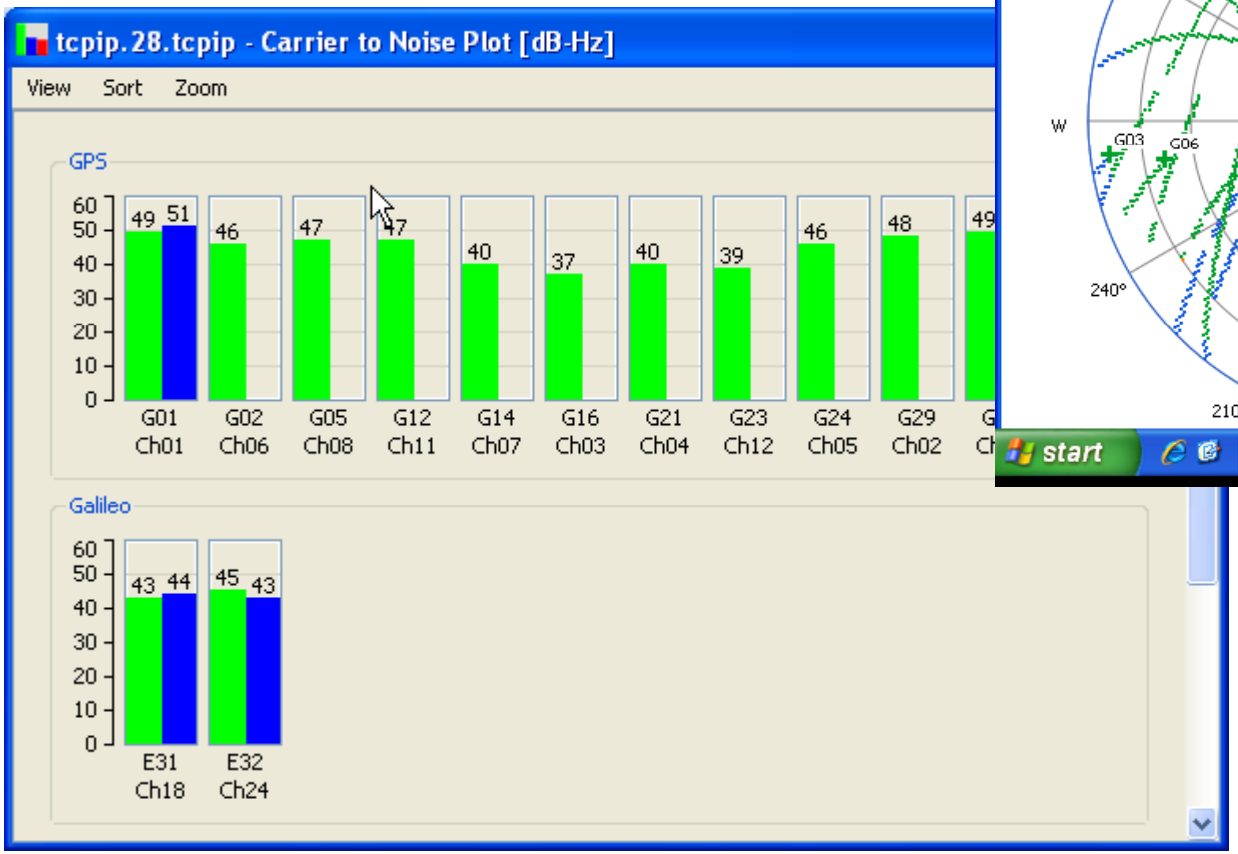


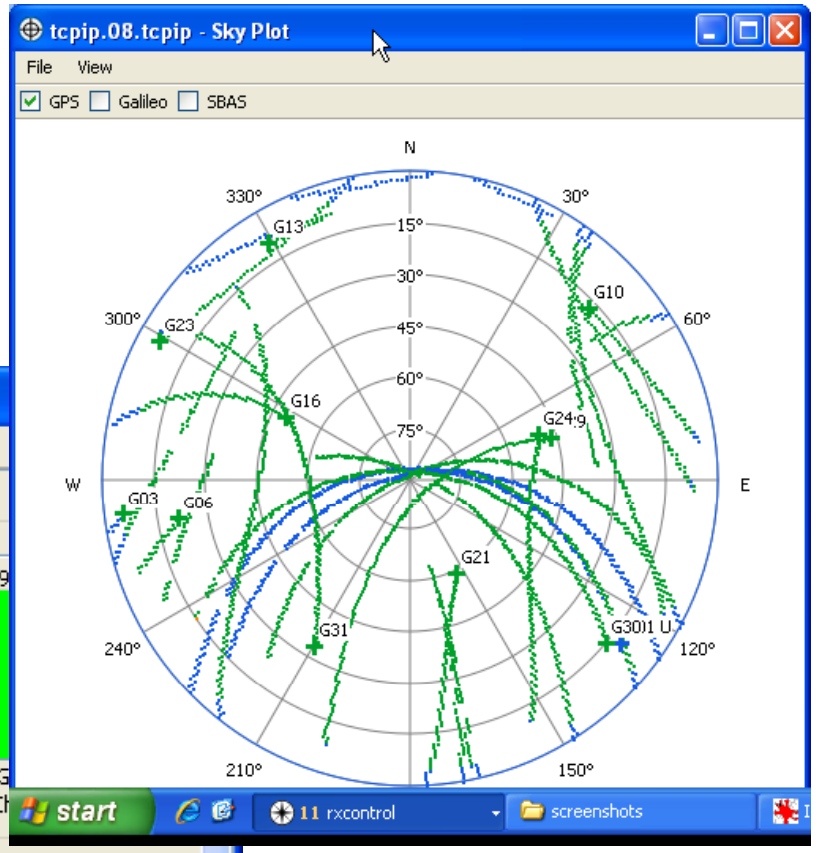
Short baseline DD phase observations, ΔDD phase observations and measured C/N0

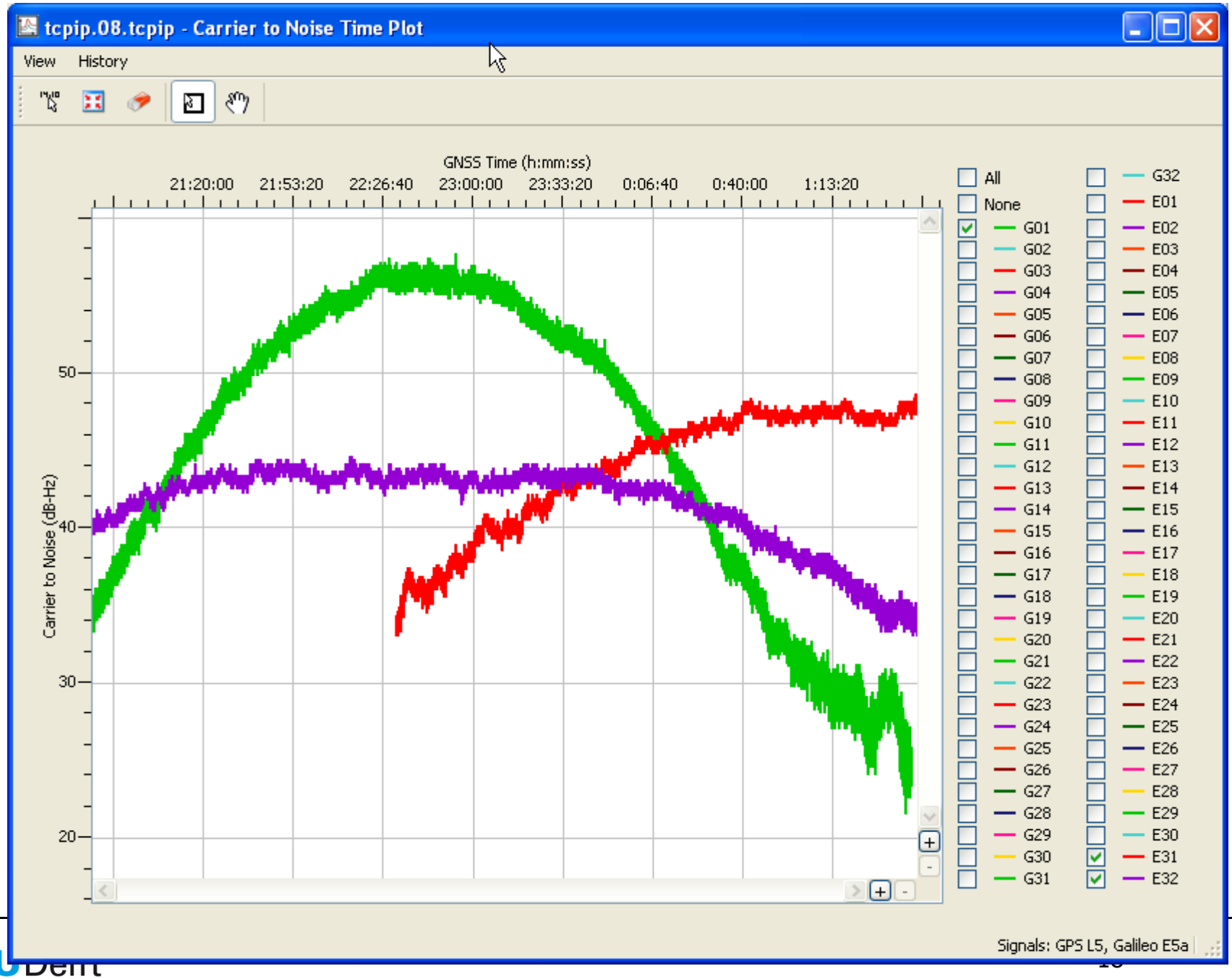


Short baseline ΔDD phase observations versus measured C/N0

L5 Tracking (Part II)






tcpip.08.tcpip - Carrier to Noise Time Plot
View
History
GNSS Time (h:mm:ss)
21:20:00
21:53:20
22:26:40
23:00:00
23:33:20
0:06:40
0:40:00
1:13:20
Carrier to Noise (dB-Hz)
50
40
30
20
All
None
G01
G02
G03
G04
G05
G06
G07
G08
G09
G10
G11
G12
G13
G14
G15
G16
G17
G18
G19
G20
G21
G22
G23
G24
G25
G26
G27
G28
G29
G30
G31
G32
E01
E02
E03
E04
E05
E06
E07
E08
E09
E10
E11
E12
E13
E14
E15
E16
E17
E18
E19
E20
E21
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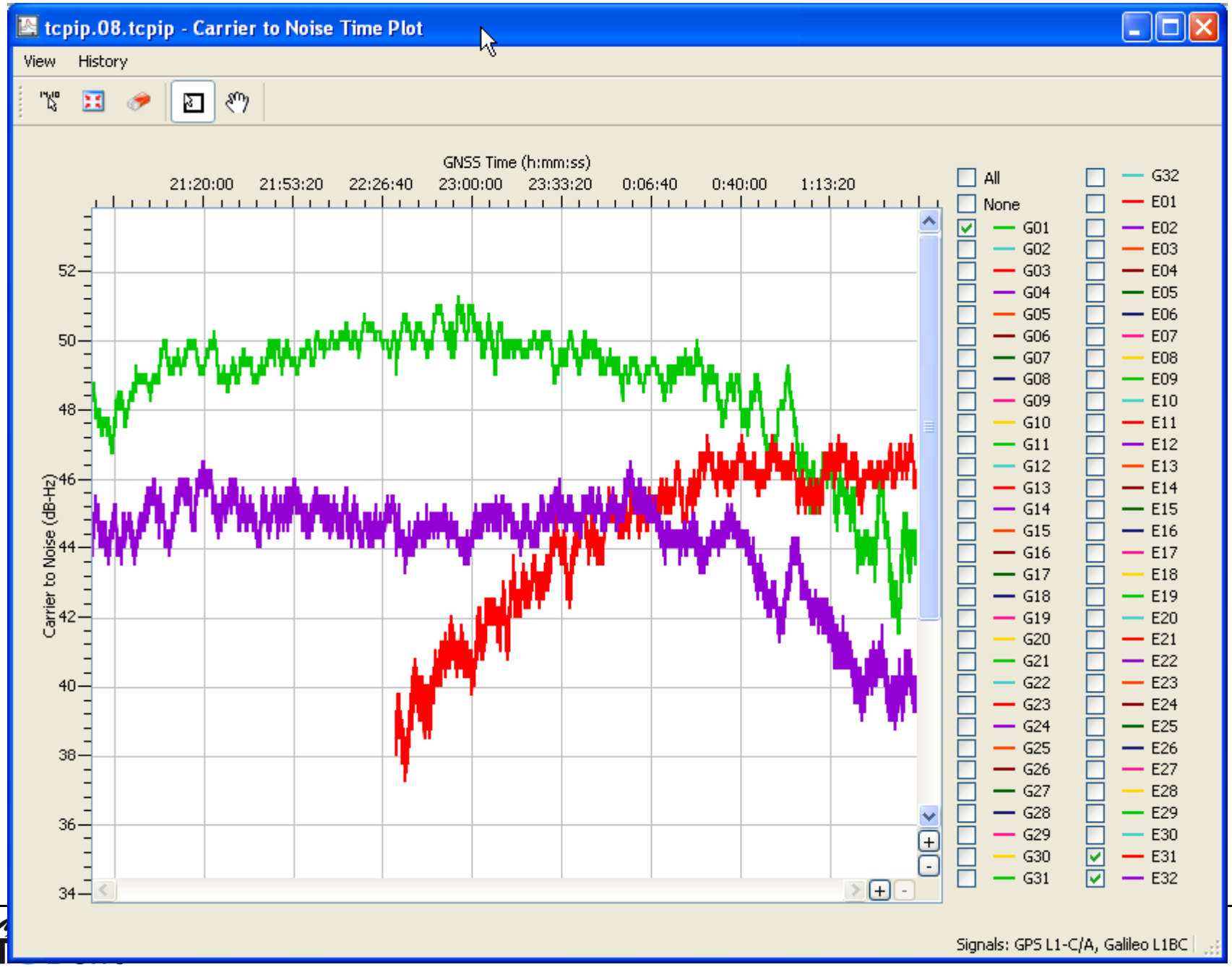
E31
E32
Signals: GPS L5, Galileo E5a


tcpip.08.tcpip - Carrier to Noise Time Plot
View
History
GNSS Time (h:mm:ss)
21:20:00
21:53:20
22:26:40
23:00:00
23:33:20
0:06:40
0:40:00
1:13:20
Carrier to Noise (dB-Hz)
52
50
48
46
44
42
40
38
36
34
All
None
G01
G02
G03
G04
G05
G06
G07
G08
G09
G10
G11
G12
G13
G14
G15
G16
G17
G18
G19
G20
G21
G22
G23
G24
G25
G26
G27
G28
G29
G30
G31
G32
E01
E02
E03
E04
E05
E06
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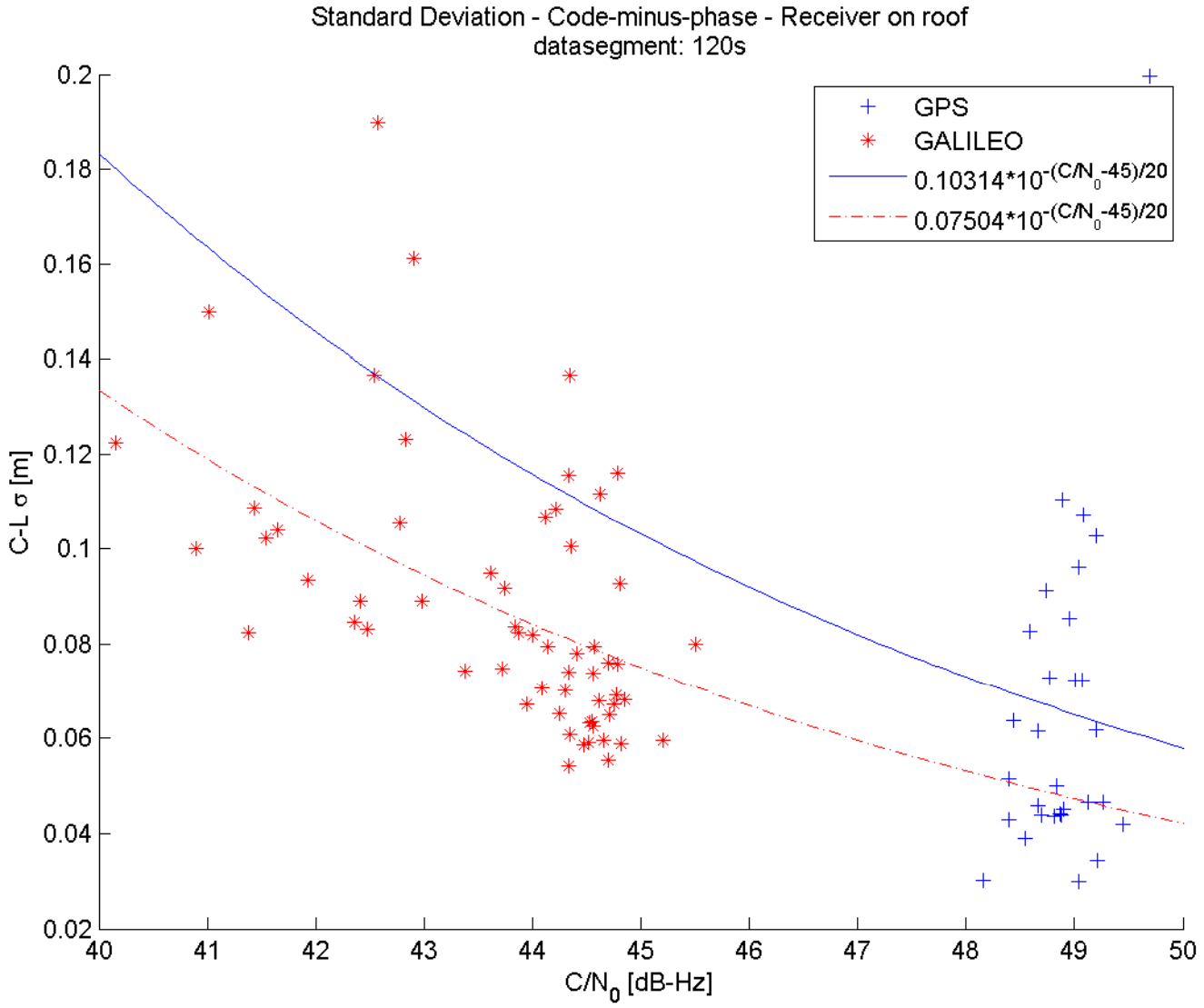
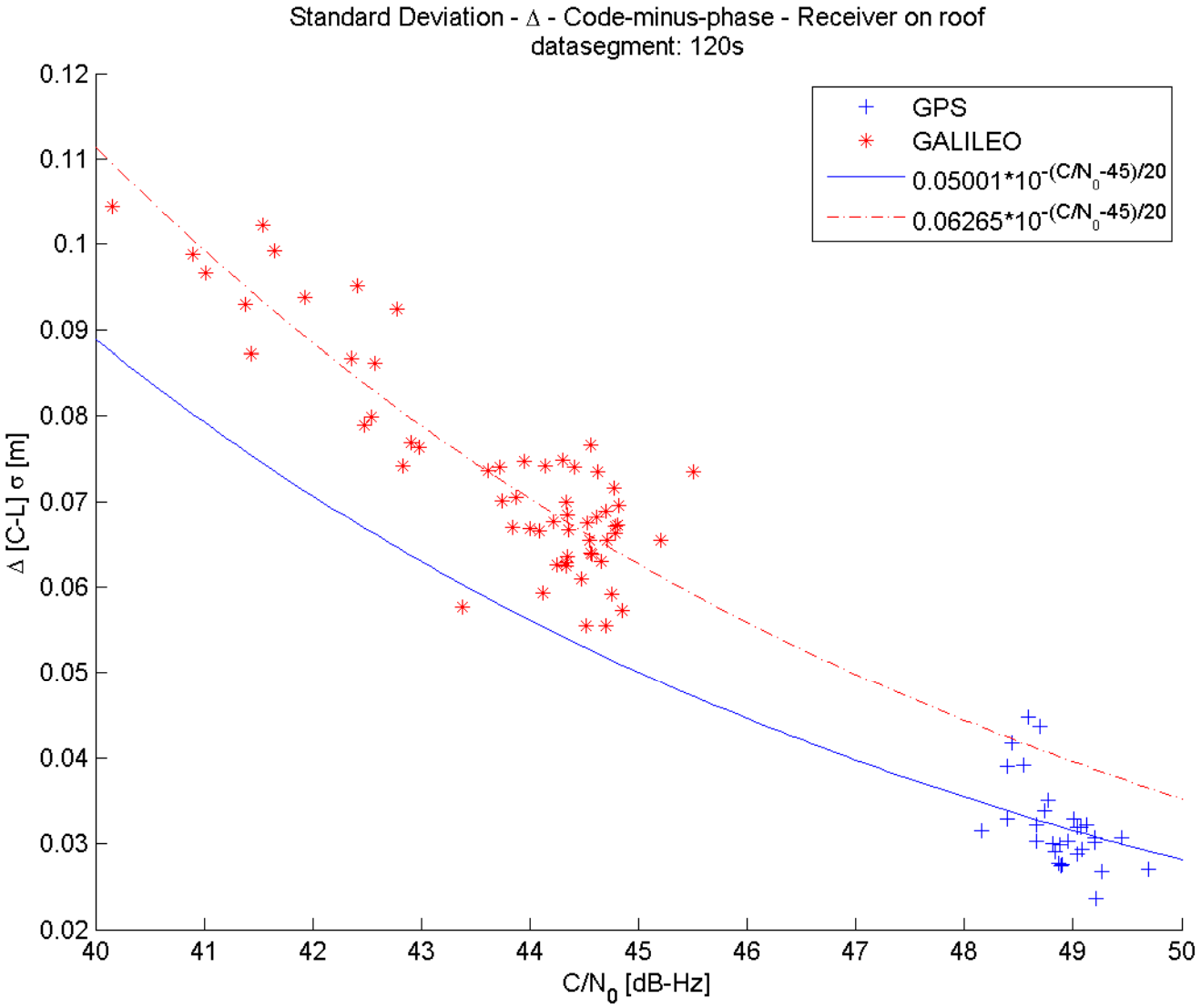
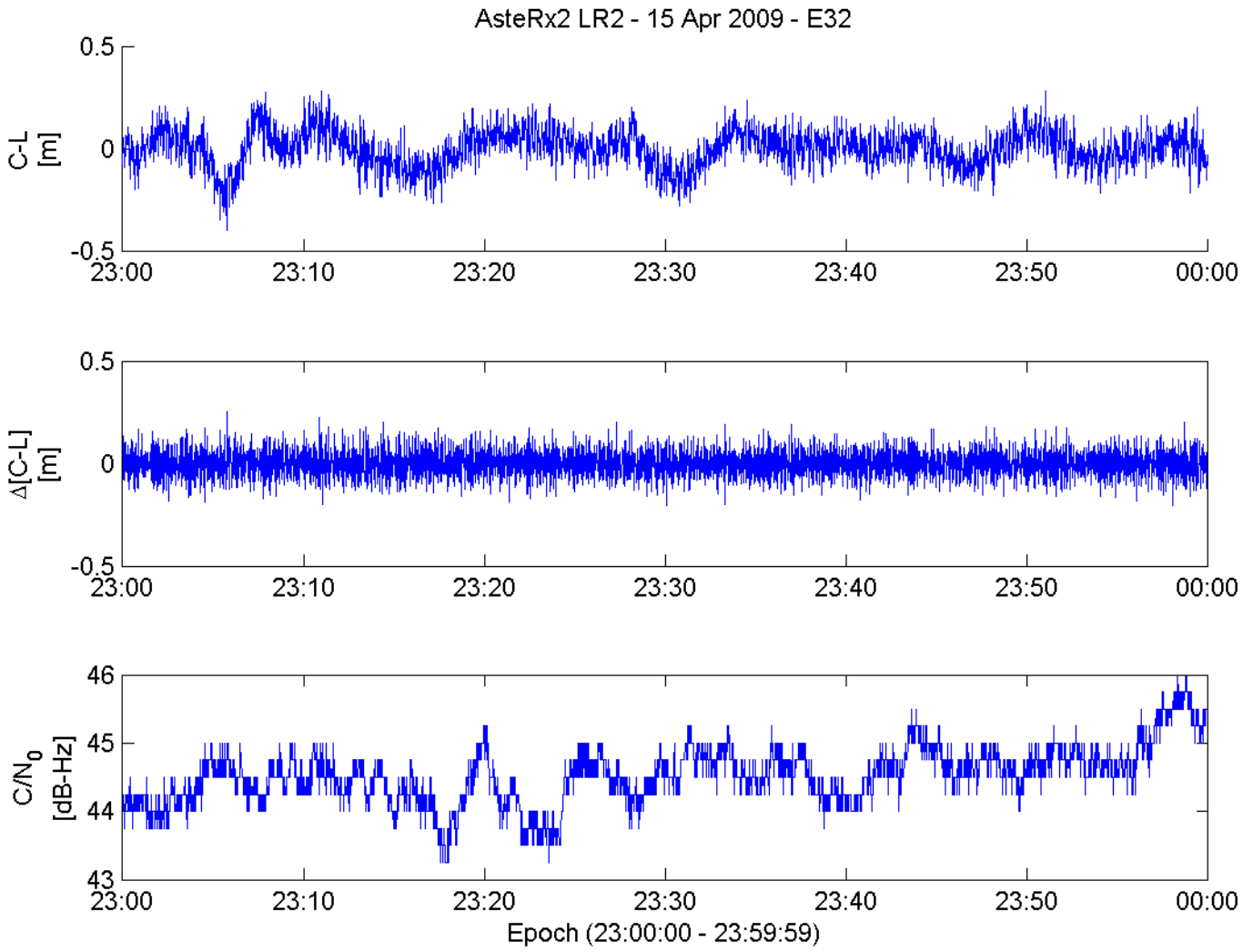
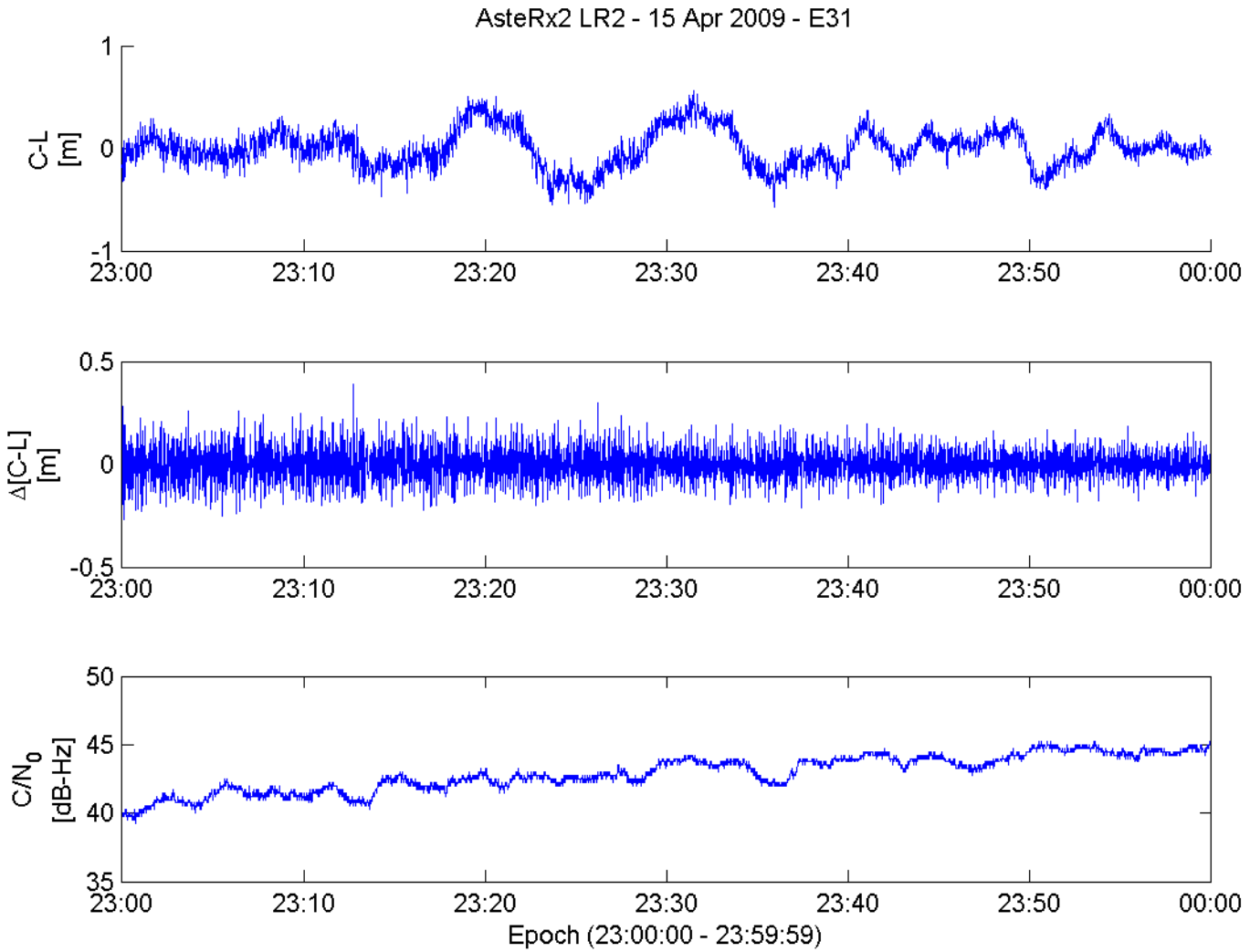
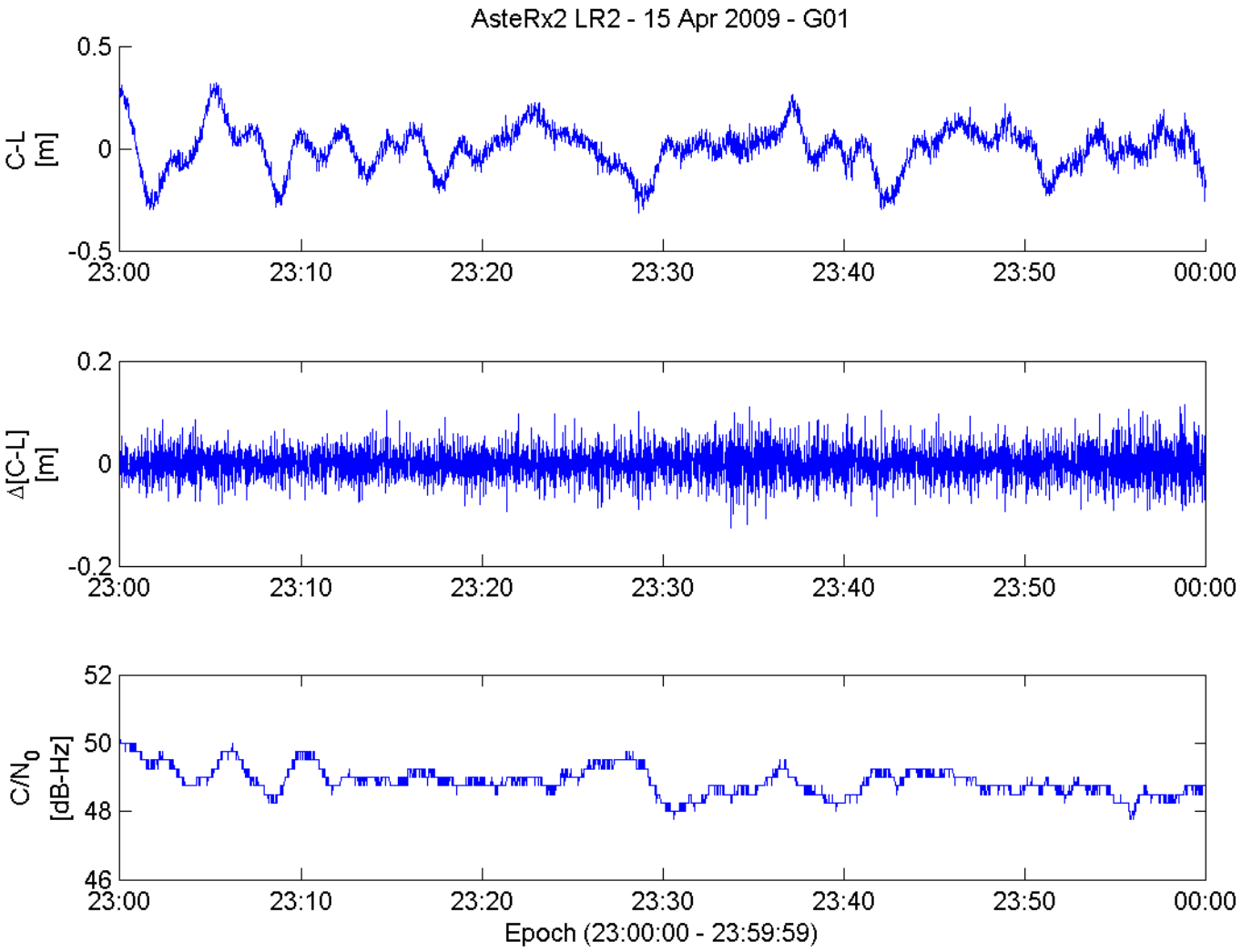
E32
Signals: GPS L1-C/A, Galileo L1BC


Standard Deviation - Code-minus-phase - Receiver on roof
datasegment: 120s
GPS
GALILEO
0.10314*10^-(C/N0-45)/20
0.07504*10^-(C/N0-45)/20
C-L σ [m]
C/N0 [dB-Hz]
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
40
41
42
43
44
45
46
47
48
49
50


Standard Deviation - Δ - Code-minus-phase - Receiver on roof
datasegment: 120s
GPS
GALILEO
0.05001*10^-(C/N0-45)/20
0.06265*10^-(C/N0-45)/20
Δ [C-L] σ [m]
C/N0 [dB-Hz]
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
40
41
42
43
44
45
46
47
48
49
50


AsteRx2 LR2 - 15 Apr 2009 - E32
C-L [m]
Δ[C-L] [m]
C/N0 [dB-Hz]
0.5
0
-0.5
46
45
44
43
23:00
23:10
23:20
23:30
23:40
23:50
00:00
Epoch (23:00:00 - 23:59:59)


AsteRx2 LR2 - 15 Apr 2009 - E31
C-L [m]
Δ[C-L] [m]
C/N0 [dB-Hz]
1
0
-1
0.5
-0.5
50
45
40
35
23:00
23:10
23:20
23:30
23:40
23:50
00:00
Epoch (23:00:00 - 23:59:59)


AsteRx2 LR2 - 15 Apr 2009 - G01
C-L [m]
0.5
0
-0.5
Δ[C-L] [m]
0.2
0
-0.2
C/N0 [dB-Hz]
52
50
48
46
23:00
23:10
23:20
23:30
23:40
23:50
00:00
Epoch (23:00:00 - 23:59:59)

Conclusions

- **The Galileo E1BC signal has less thermal noise (σ=±.12m) than GPS L1C/A (σ=±.18m) and EGNOS signals (σ=±.5m).**
- **There is significant time correlation on the L1 code observations (.4<ρΔ<.6)**
- **L1 Code and phase observations show strong cross-correlation (.5<ρLNA<.9) for the zero baseline setup.**

- **The L1 phase observations perform very similar for all three systems (σ<1mm).**

- **L5 code noise is much smaller than L1 both for GPS and GIOVE A/B**