NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

Analysis of GNSS Receiver Biases and Noise using Zero Baseline Techniques

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Plenary #3: Antenna and Biases
IGS Workshop, July 3-7/2017, Paris

Overview

- Shirley's Bay Zero Baseline hardware
  - Purpose is to access receiver interoperability for GPS, GLONASS and Galileo: NOT to RANK Receivers or measure precision
- GNSS Receivers used and signals tracked
- GPS, GLN and GLL(collected RTCM-MSM 7-RINEX 3.03):
  - Code biases between receivers tracking the same signal
  - Phase alignment between constellation signals with common frequencies
  - Phase Noise
- Summary

Shirley's Bay Test Site Configuration

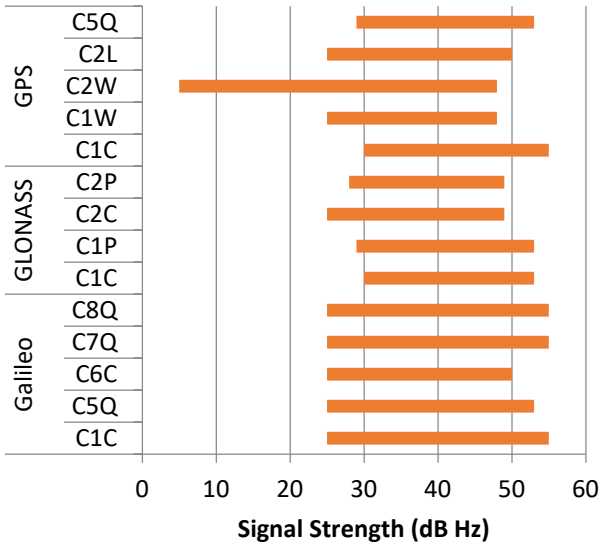
Septentrio PolaRx5 Novatel OEM6 Trimble NetR9 Javad Delta 3N Topcon NetG5

GNSS Signals Tracked(RINEX 3 Notation)

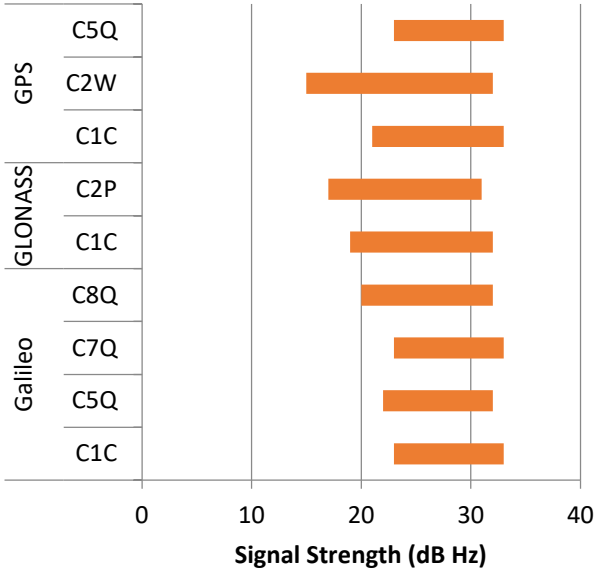
Frequency Band	Septentrio PolaRx5 (5.1.1)	Novatel OEM6 (OMP060600RN0000)	Trimble Net R9 (5.20)	Javad Delta 3N (3.6.9 Nov,28,2016)	Topcon Net G5 (5.1 Sep,07,2016)
GPS					
L1/1575.42	C1C/C1W	C1C	C1C	C1C/C1W	C1C
L2/1227.6	C2W/C2L	C2W	C2W/C2X	C2W/C2X	C2W
L5/1176.45	C5Q	C5Q	C5X	C5X	C5Q
GLONASS					
G1	C1C/C1P	C1C	C1C	C1C/C1P	C1C
G2	C2C/C2P	C2P	C2C	C2C/C2P	C2P
Galileo					
E1/1575.42	C1C	C1C	C1X	C1X	C1B
E5a/1176.45	C5Q	C5Q	C5X	C5X	C5I
E6/1278.75	C6C				C6B
E5b/1207.14	C7Q	C7Q	C7X	C7X	C7I
E5a+E5B/1191.795	C8Q	C8Q	C8X	C8X	C8Q

Effective SNR by Receiver type and signal

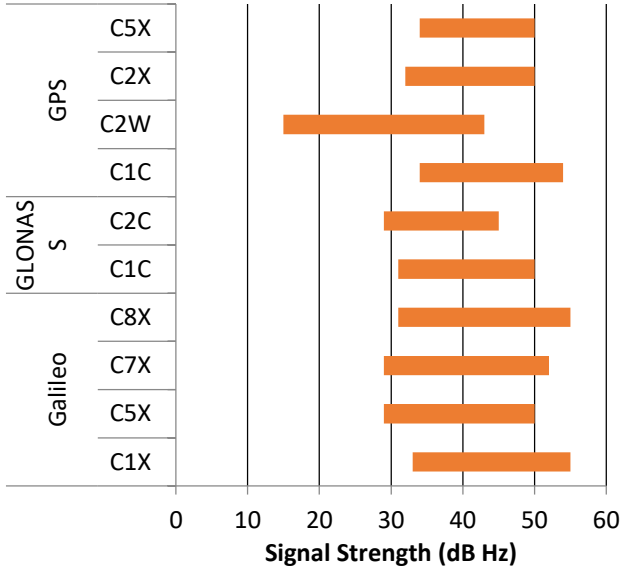
Septentrio PolaRx5



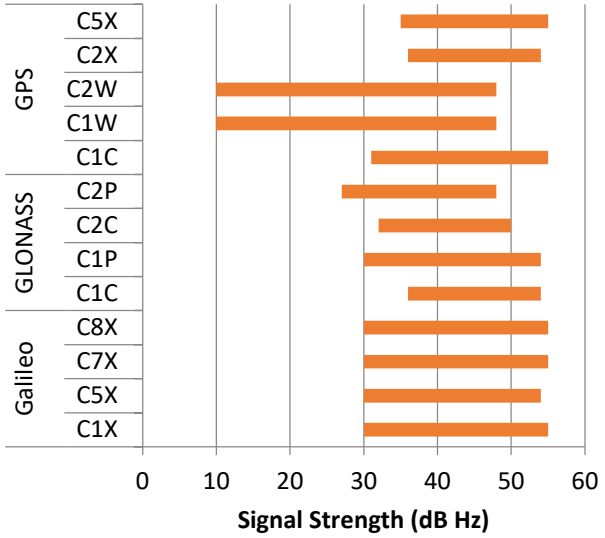
Novatel OEM6



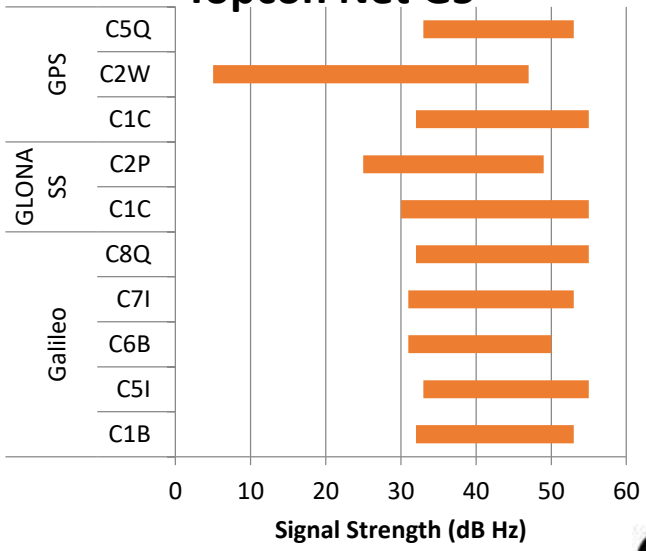
Trimble Net R9



Javad Delta 3N



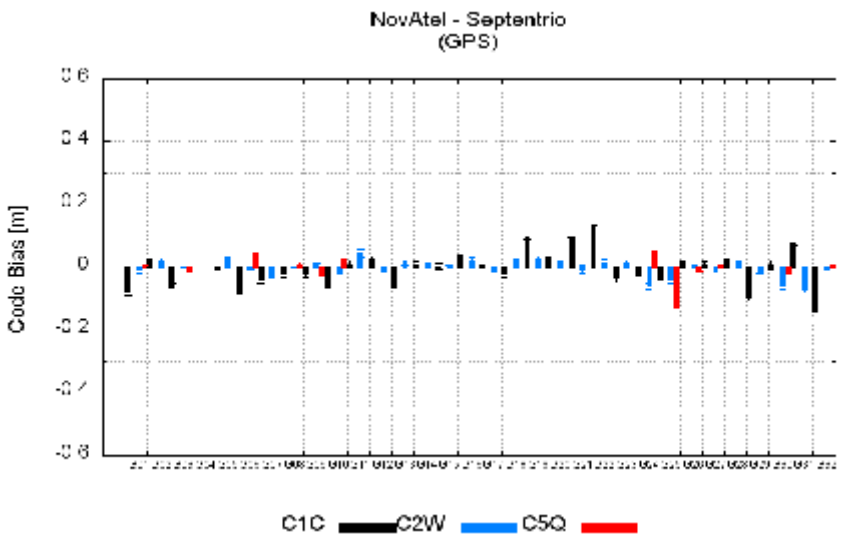
Topcon Net G5

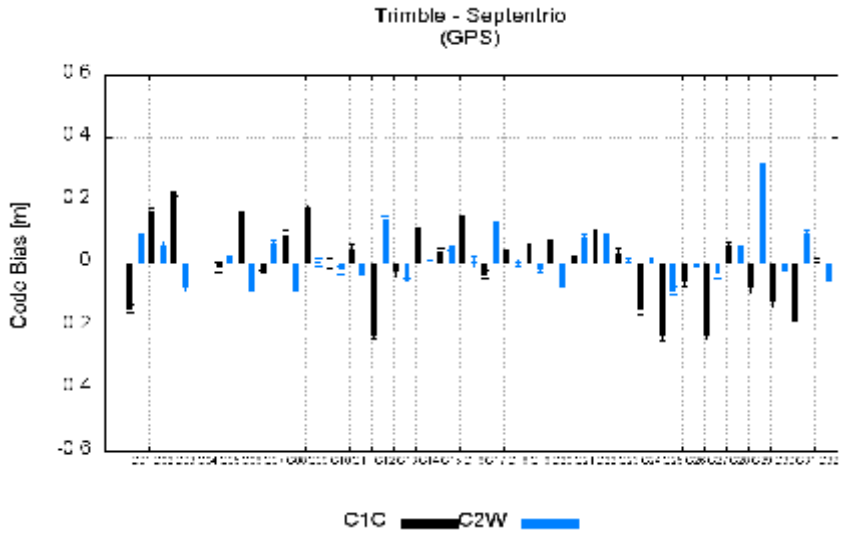


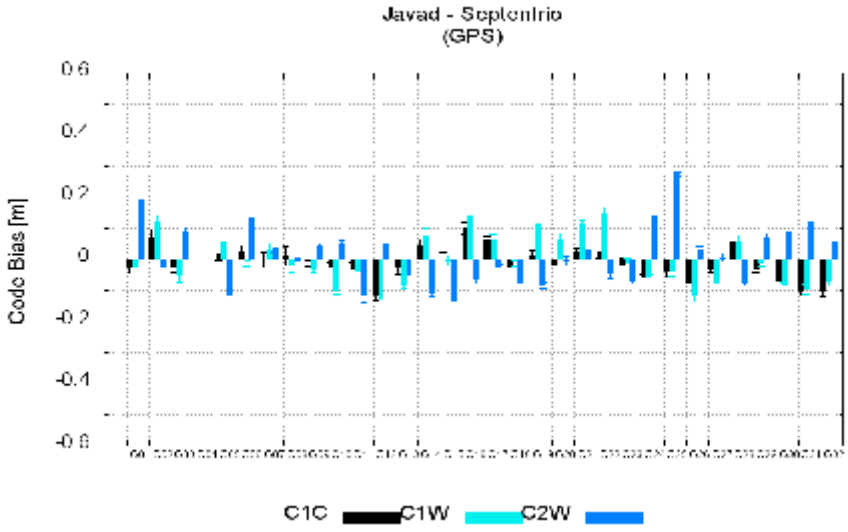
Inter-Receiver Code Bias Estimation Method

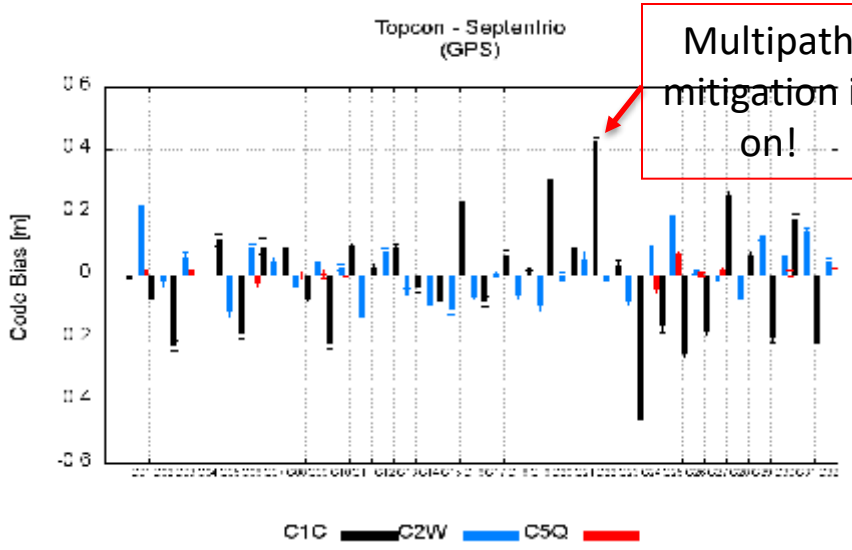
- Form single-differenced observations (phase and code) between receiver “X” and Septentrio (cancels satellite and atmospheric errors)
- Estimate the between-receiver clock offset and carrier-phase ambiguities (batch solution)
- Average code residuals per satellite over each day to obtain code biases
- Average code biases over 7 days and compute standard deviation (shown as error bars on plots very repeatable from day to day)

GPS Code Biases (7 day average)

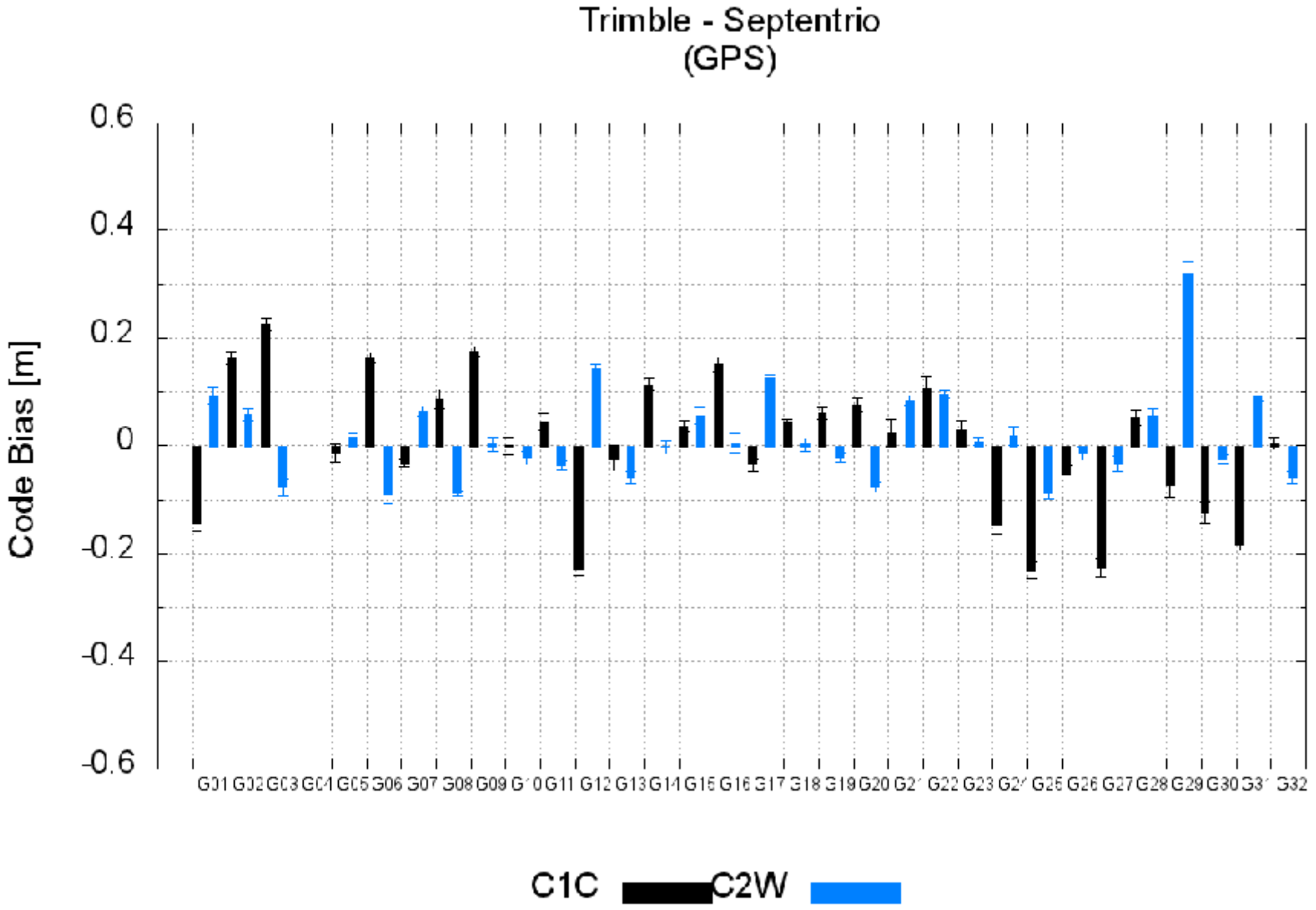


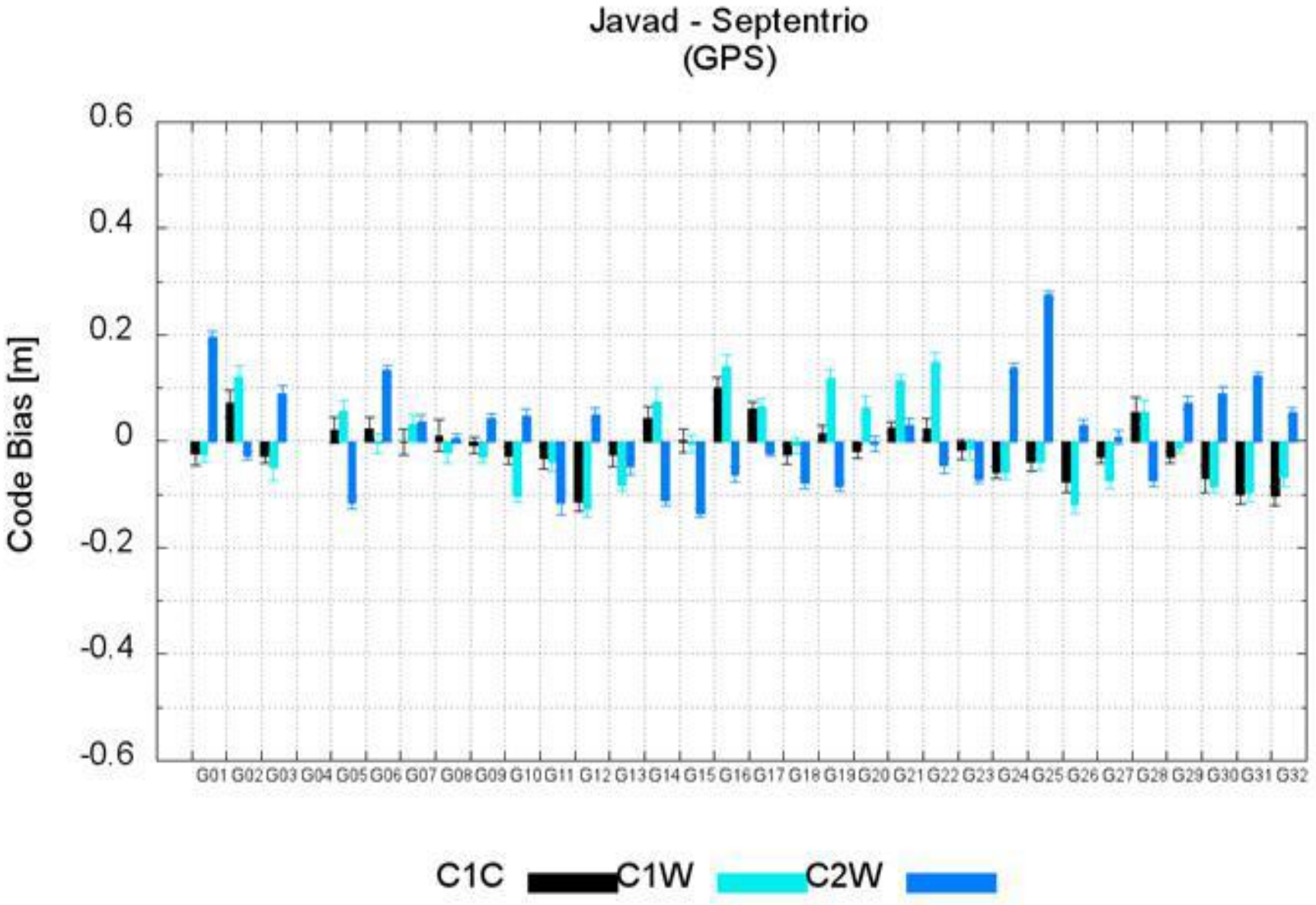




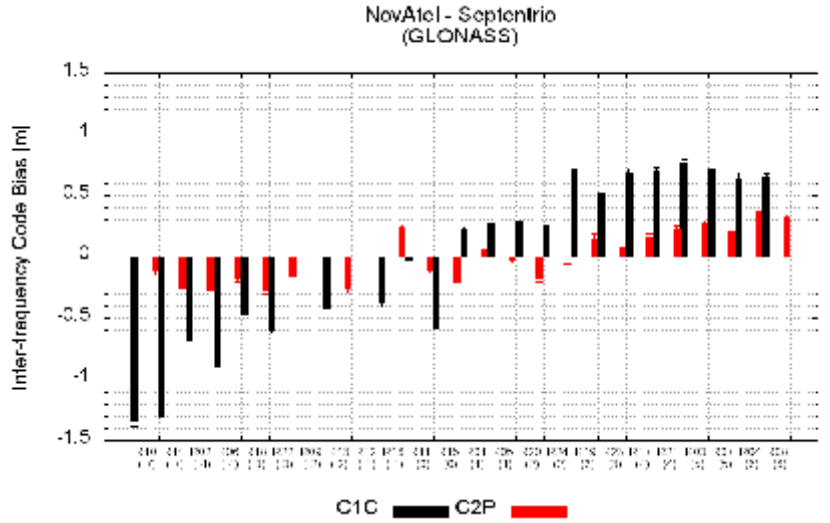


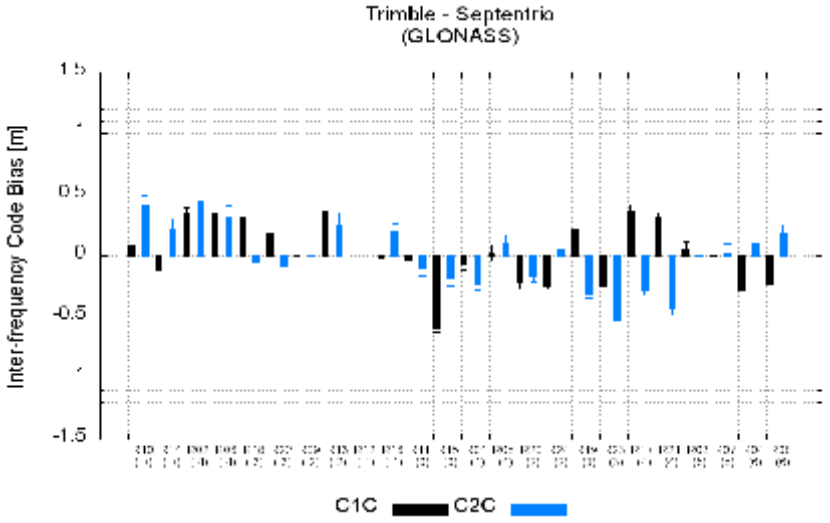
Multipath mitigation is on!

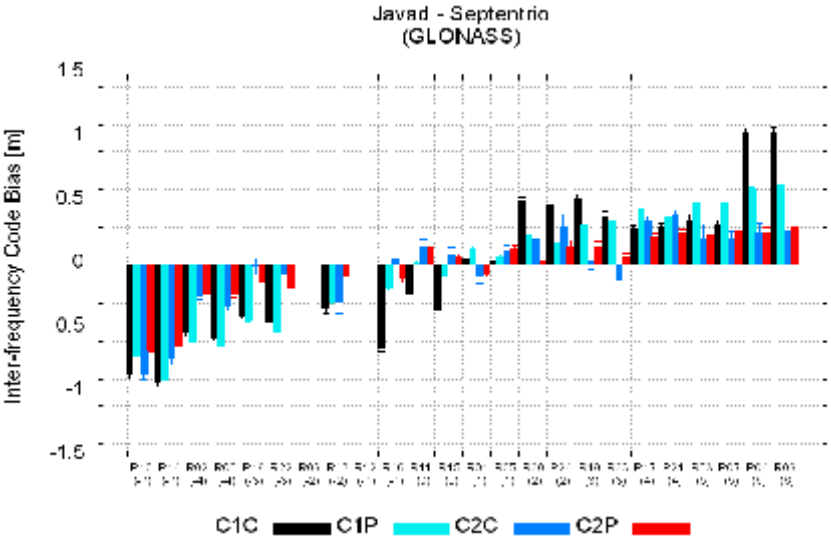

Trimble - Septentrio
(GPS)
Code Bias [m]
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15 G16 G17 G18 G19 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 G32
C1C
C2W

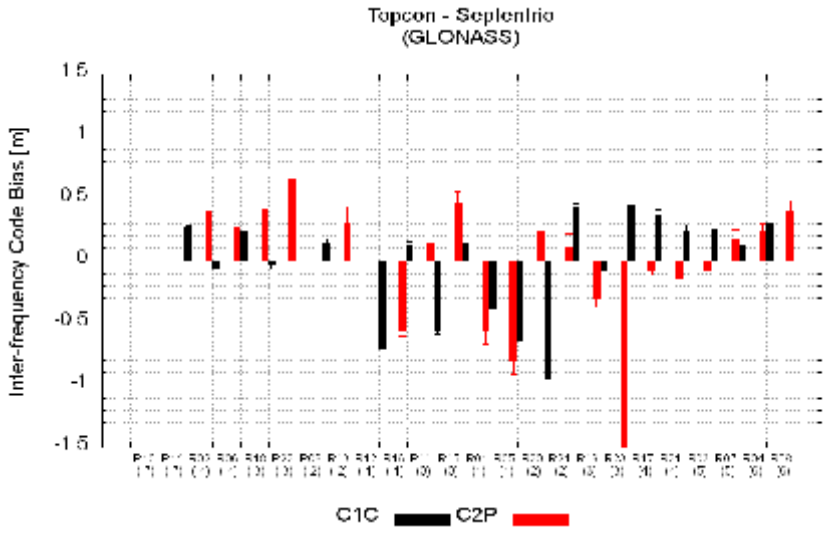

Javad - Septentrio
(GPS)
Code Bias [m]
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G12 G13 G14 G15 G16 G17 G18 G19 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 G32
C1C
C1W
C2W

GLONASS Code Biases









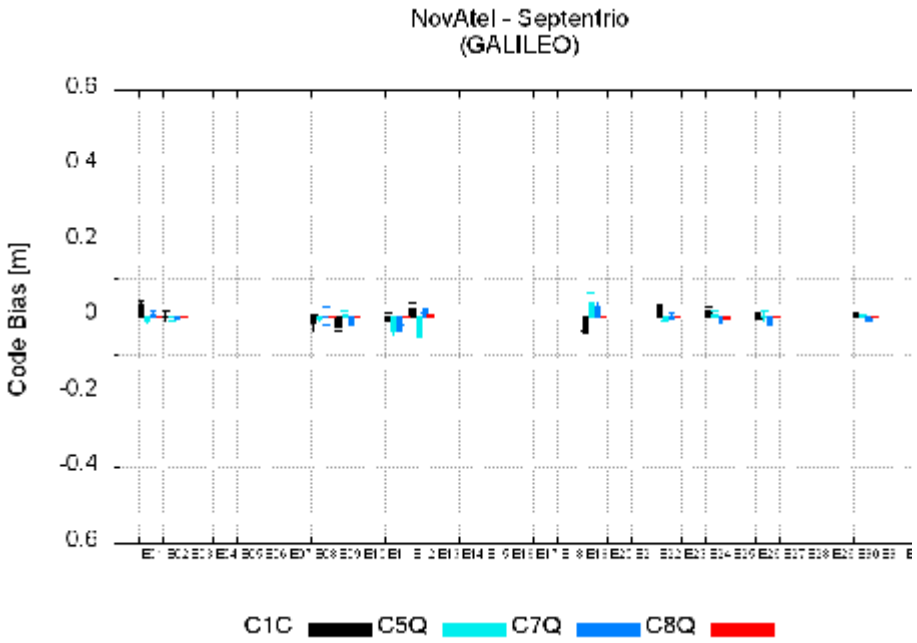
GLONASS Inter-Frequency Phase Biases

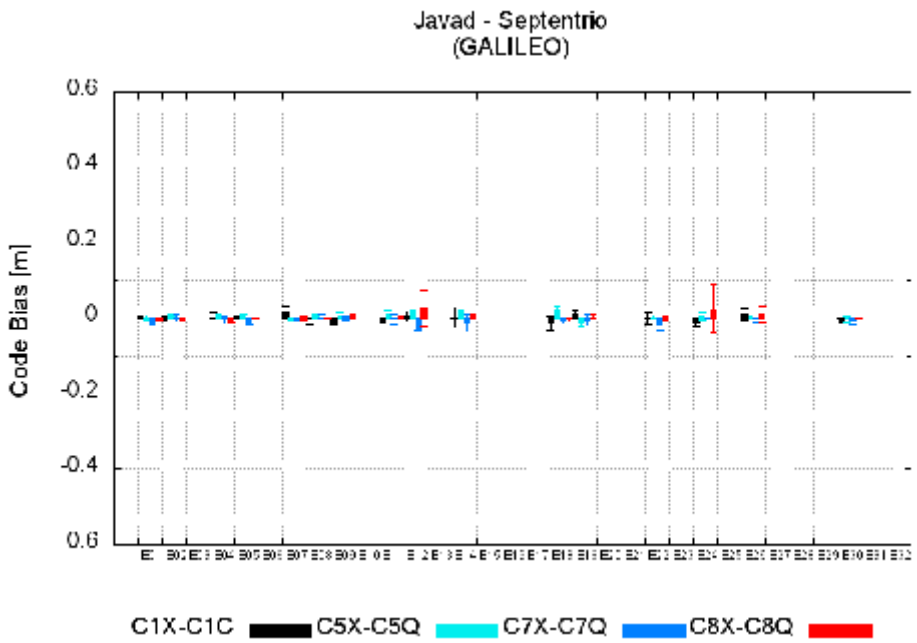
Receiver Make	Inter-frequency Phase Bias [mm/channel]
Septentrio	0.0
NovAtel	24.6
Trimble	-4.1
Javad	-0.1
Topcon	1.0

Estimated values are compatible with previous studies, e.g. Wanninger (2012)

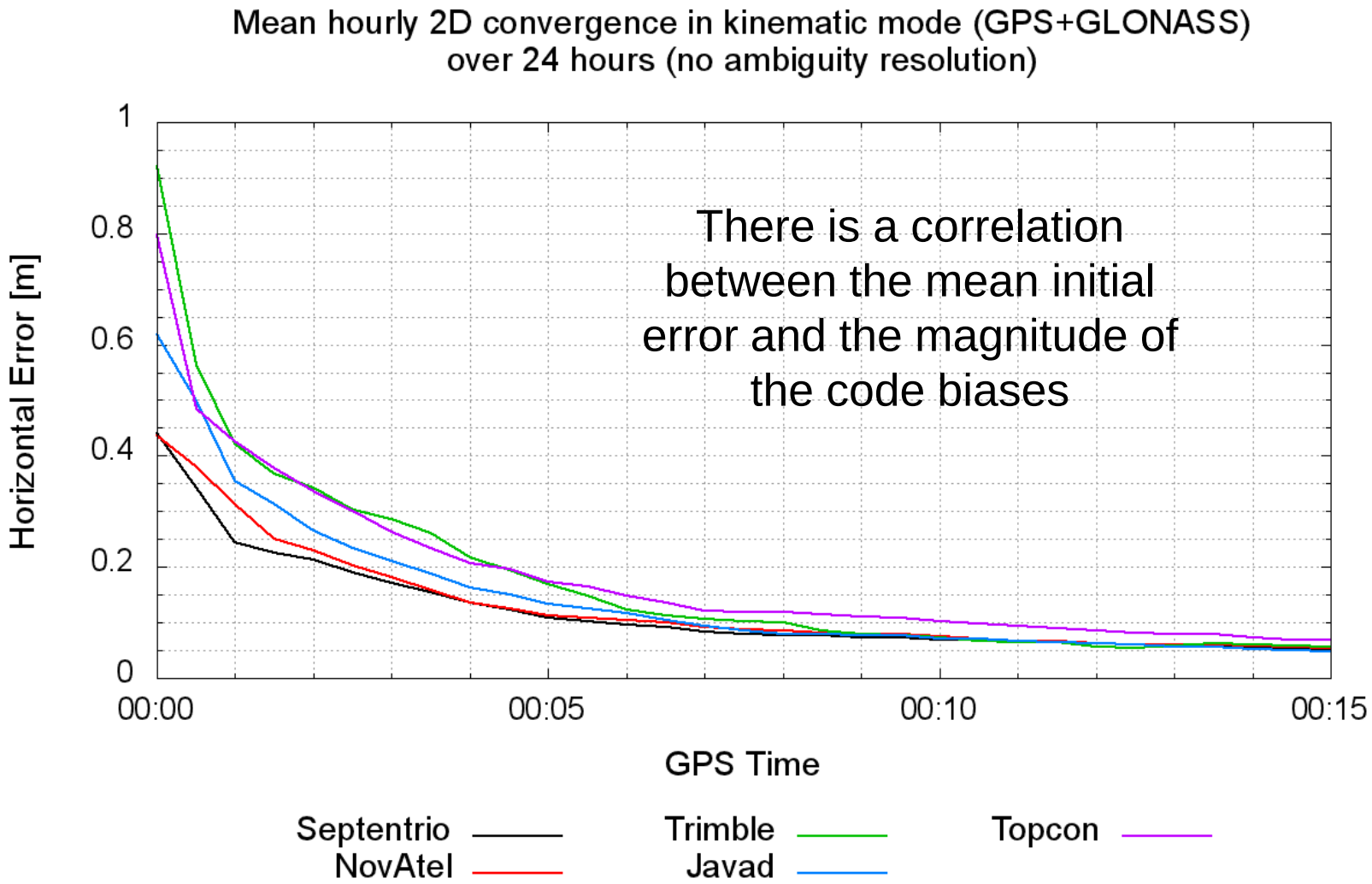
Galileo Code Biases

- Unexpected results: small intra-frequency biases, regardless of modulation (preliminary results)





Precise Point Positioning



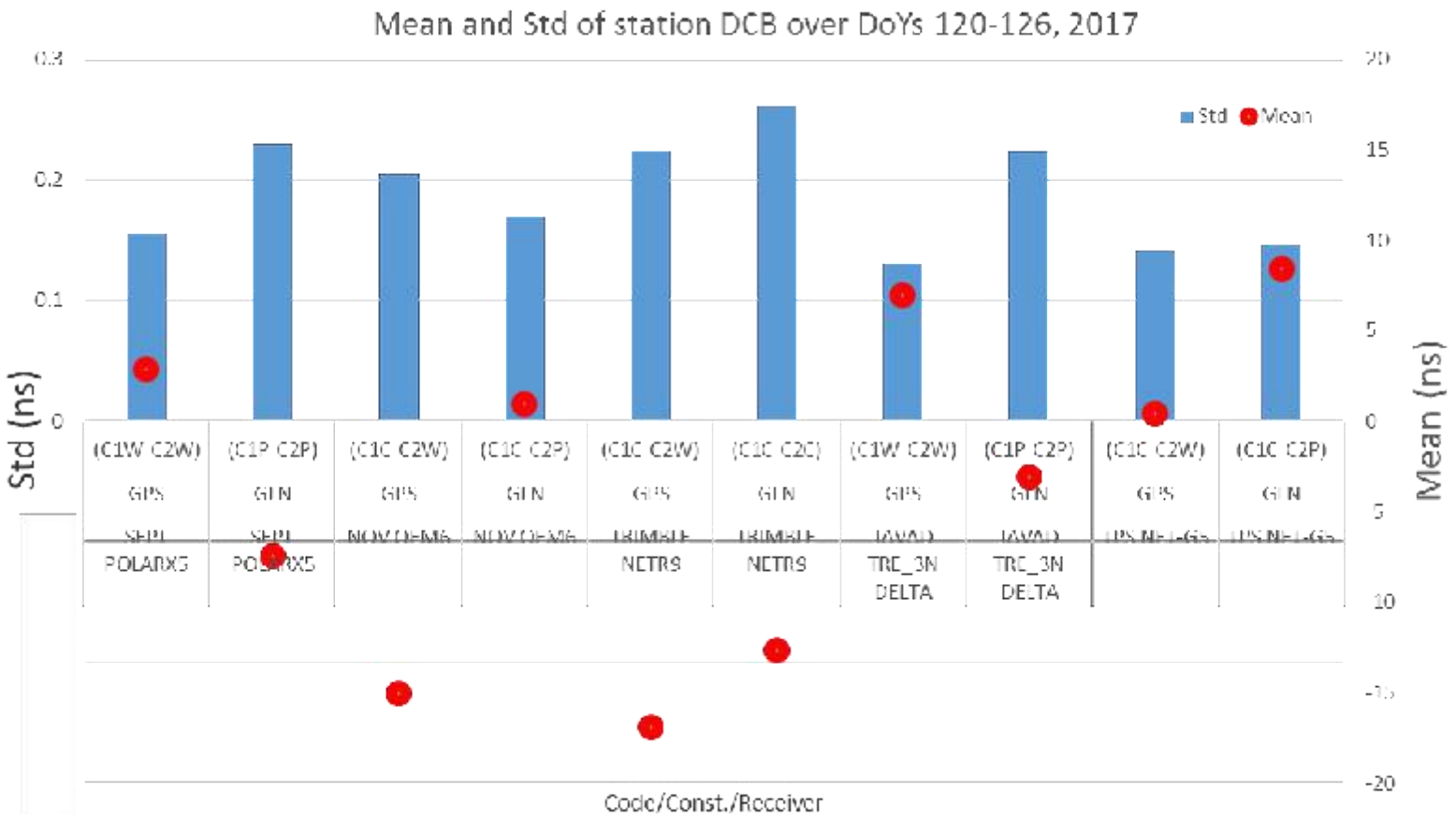
Phase alignment between Galileo and GPS signals on common frequencies(E1-L1)

Signals Differenced	Galileo E1 – GPS L1 (Zero baseline phase double difference fractional cycle offset)				Remarks
	Septentrio-Novatel	Septentrio-Trimble	Septentrio-Javad	Septentrio-Topcon	
E1-Gx	0.0	0.0	0.0	0.5	
E2-Gx	0.0	0.0	0.0	0.5	
E3-Gx	Not Tracked	Not Tracked	0.0	Not Tracked	Commissioning
E4-Gx	Not Tracked	Not Tracked	0.0	Not Tracked	Commissioning
E5-Gx	Not Tracked	Not Tracked	0.0	0.5	
E7-Gx	Not Tracked	Not Tracked	0.0	0.5	
E8-Gx	0.0	0.0	0.0	0.5	
E9-Gx	0.0	0.0	0.0	0.5	
E11-Gx	0.0	0.0	0.0	0.5	
E12-Gx	0.0	0.0	0.0	0.5	
E18-Gx	Not Tracked	0.0	0.0	0.5	Testing
E19-Gx	0.0	0.0	0.0	0.5	
E22-Gx	0.0	0.0	0.0	0.5	
E24-Gx	0.0	0.0	0.0	0.5	
E26-Gx	0.0		0.0	0.5	Not Usable
E30-Gx	0.0	0.0	0.0	0.5	

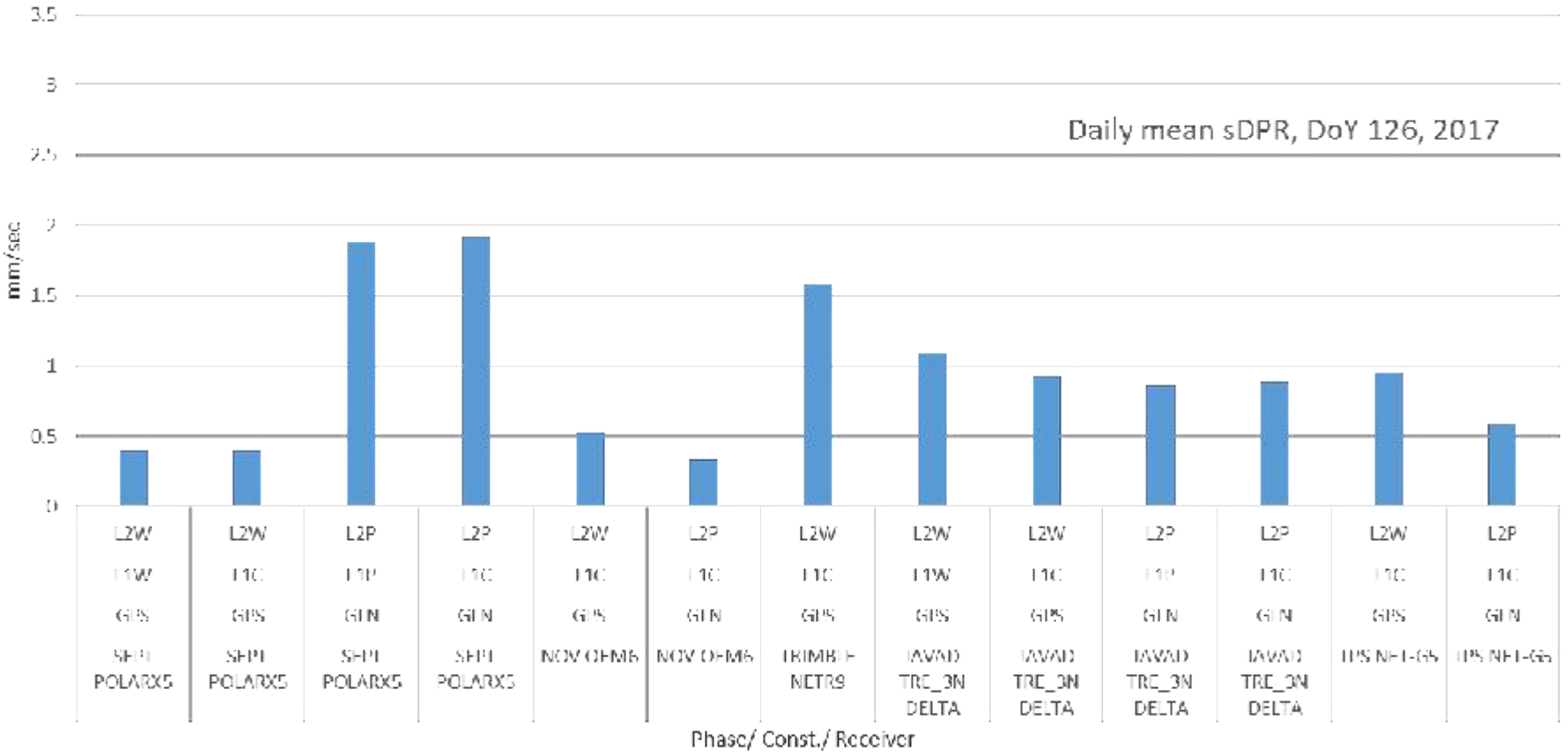
Phase alignment between Galileo and GPS signals on common frequencies(E5a-L5)

Signals Differenced	Galileo E5a – GPS L5 (Zero baseline phase double difference fractional cycle offset)			Remarks
	Septentrio-Novatel	Septentrio-Trimble	Septentrio- Javad	
E1-Gx	0.0	0.0	0.0	
E2-Gx	0.0	0.0	0.0	
E3-Gx	Not Tracked	Not Tracked	0.0	Commissioning
E4-Gx	Not Tracked	Not Tracked	0.0	Commissioning
E5-Gx	Not Tracked	Not Tracked	0.0	
E7-Gx	Not Tracked	Not Tracked	0.0	
E8-Gx	0.0	0.0	0.0	
E9-Gx	0.0	0.0	0.0	
E11-Gx	0.0	0.0	0.0	
E12-Gx	0.0	0.0	0.0	
E18-Gx	Not Tracked	0.0	0.0	Testing
E19-Gx	0.0	0.0	0.0	
E22-Gx	0.0	0.0	0.0	
E24-Gx	0.0	0.0	0.0	
E26-Gx	0.0	0.0	0.0	Not Usable
E30-Gx	0.0	0.0	0.0	

7 day GPS and GLONASS DCB: average and STD

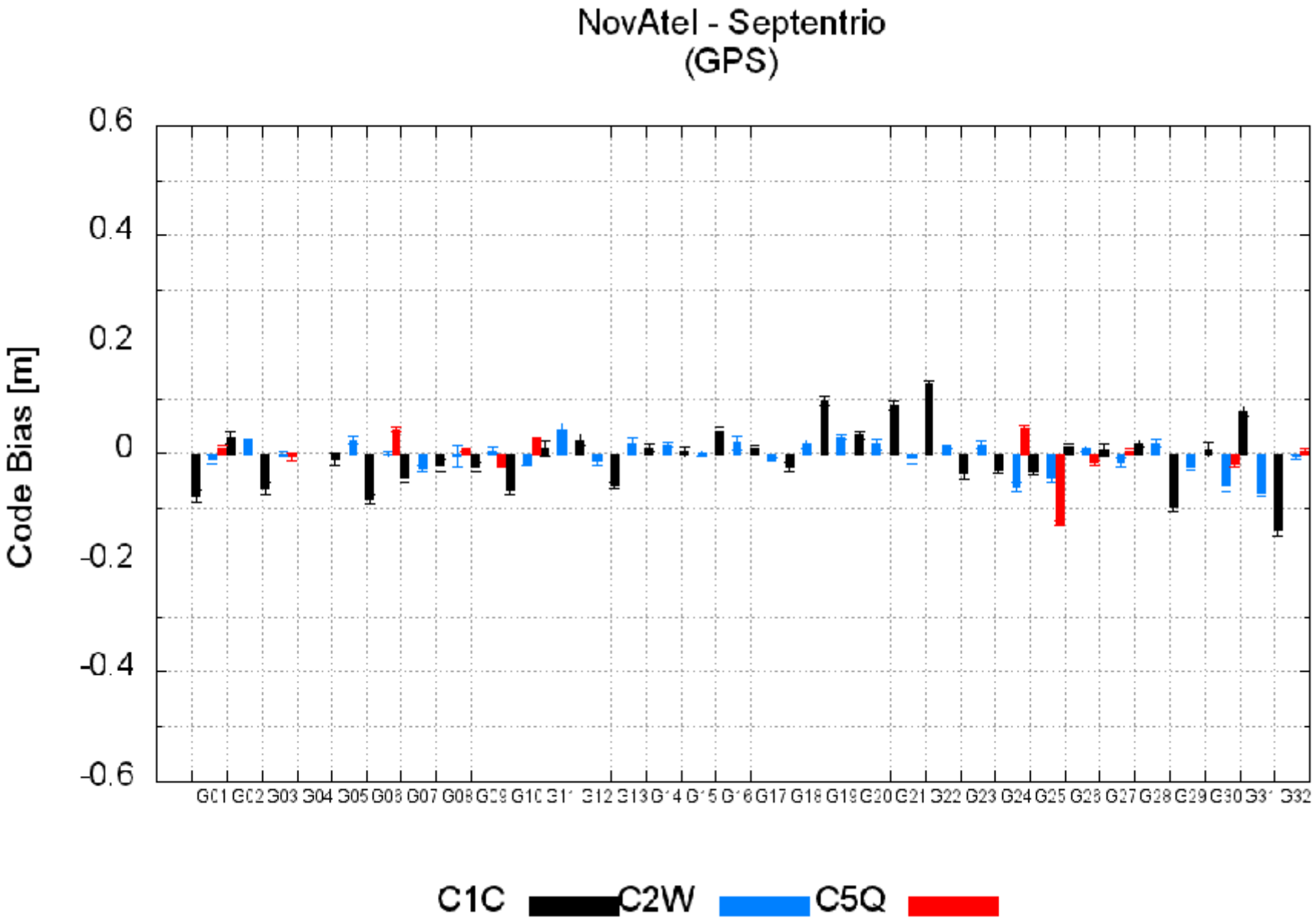


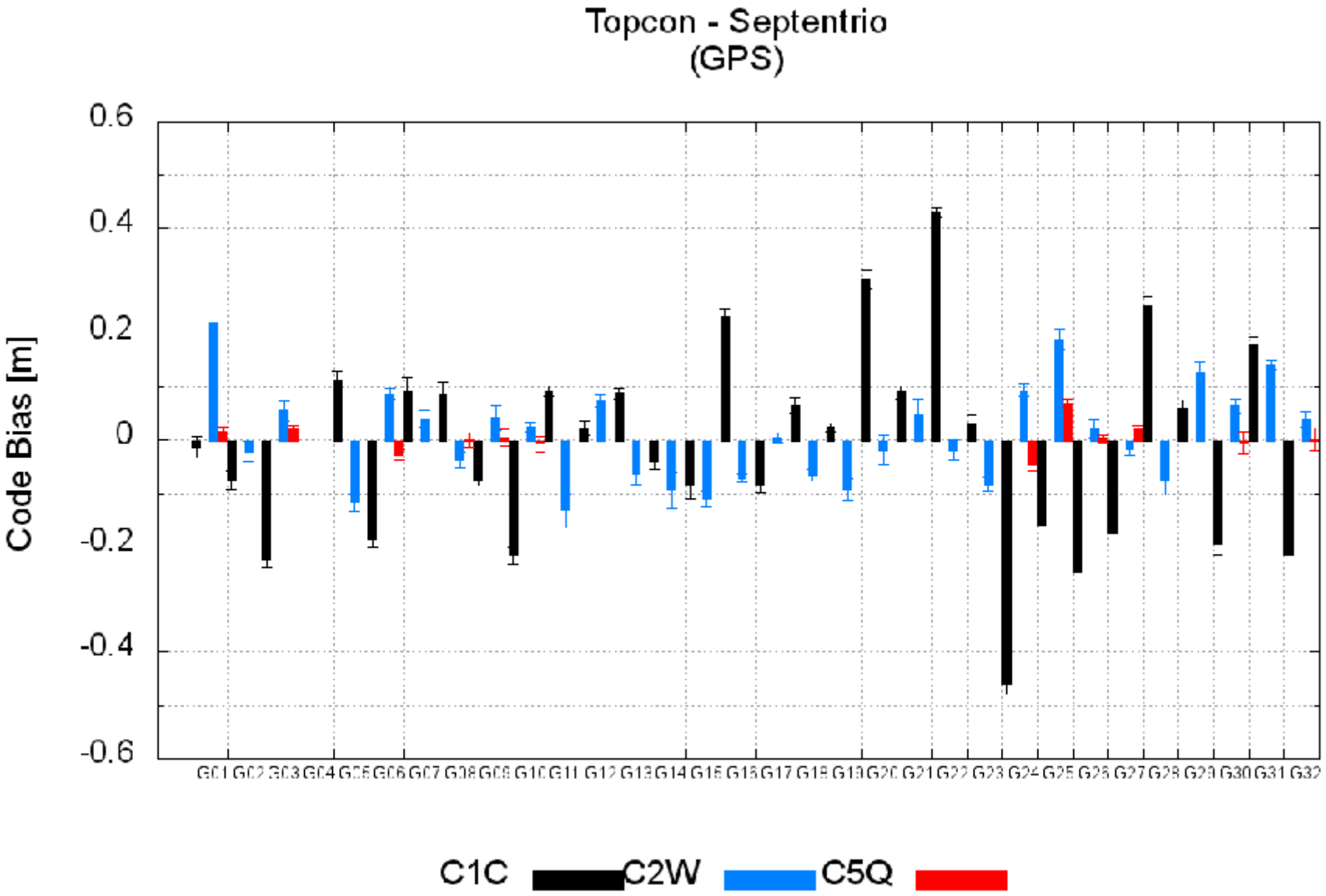
Dual-frequency background phase noise by means of daily mean STD of delta phase rate (sDPR) from 1 Hz data

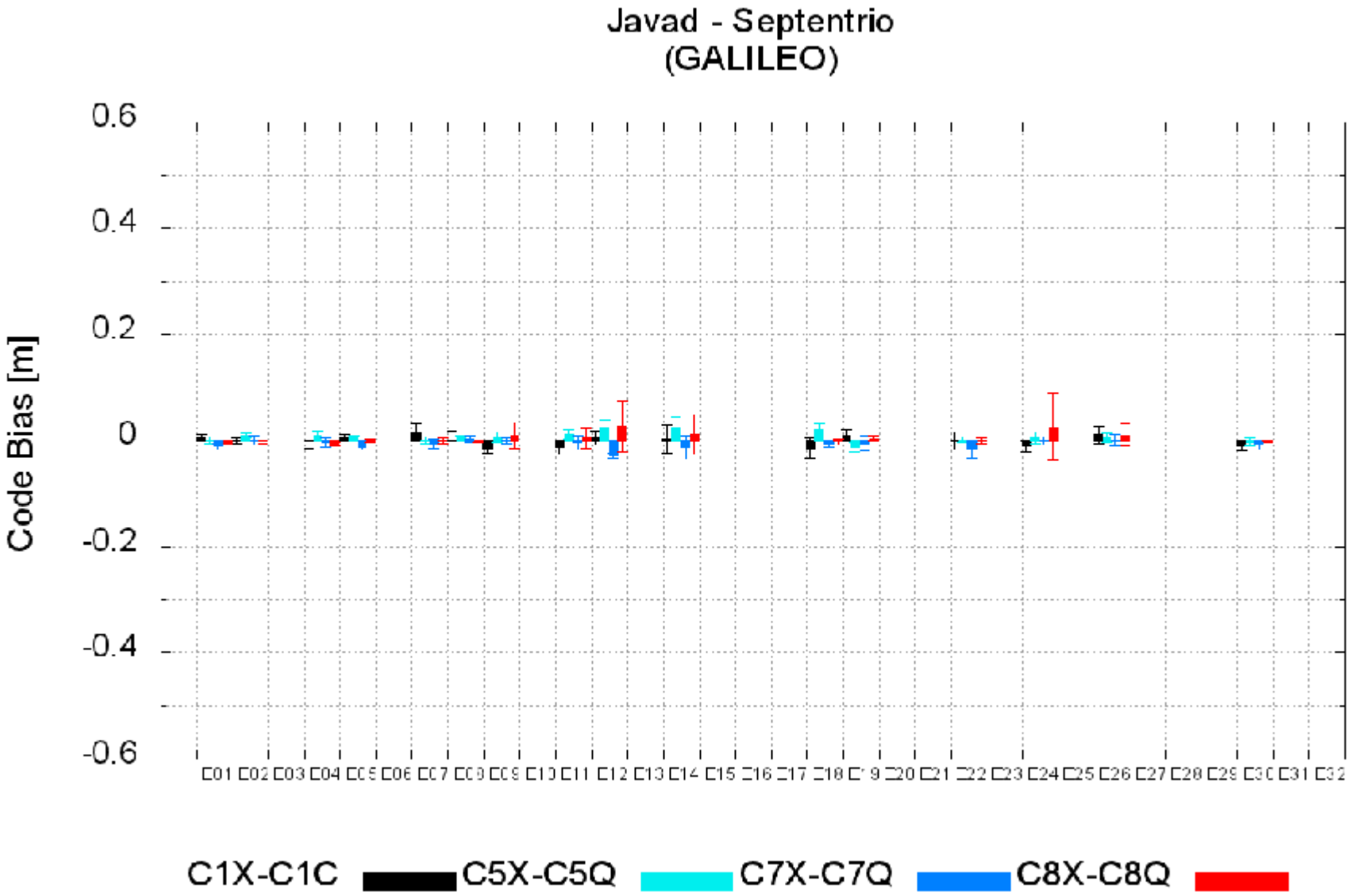


Summary

- Common signal tracking of Galileo satellites between all receiver types is not widely supported
  - Inter-signal DCB estimates required
- Effective SNR range between receivers varies significantly
- Inter-receiver code bias estimates:
  - GPS biases between receivers tracking the same signal can be ~ +/- 0.2m (Affects initial position and convergence time)
  - GLONASS biases are in line with previous reports
  - Initial Galileo bias estimates look very good
- GPS-Galileo E1-L1 and E5a-L5 phase signals are now aligned for many receiver types
- Interoperability of ionospheric measurements characterized
- Will repeat the test when new firmware is available
- RINEX 3.03 data will be shared with the IGS


NovAtel - Septentrio
(GPS)
Code Bias [m]
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
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
C1C
C2W
C5Q


Topcon - Septentrio
(GPS)
Code Bias [m]
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
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
C1C
C2W
C5Q


Javad - Septentrio
(GALILEO)
Code Bias [m]
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
C01 C02 C03 C04 C05 C06 C07 C08 C09 C10 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21 C22 C23 C24 C25 C26 C27 C28 C29 C30 C31 C32
C1X-C1C
C5X-C5Q
C7X-C7Q
C8X-C8Q

Phase Corrections to Raw Javad Data Types

- GPS
  - L1W(P1) -0.25
  - L2X(P3) 0.25
  - L5X(P5) 0.25
- Galileo
  - L1X(PC) 0.00
  - L5X(P5) 0.25
  - L7X(P2) 0.25
  - L8X(P1) 0.25

Shirley's Bay Antenna Cable

- SB18 Cable Heliax LDF4-50 1/2" ~175m
  - L5 Cable Loss 7.951*1.75 = 13.91
  - L1 Cable Loss 9.337*1.75 = 16.34
  - L2 Cable Loss 8.143*1.75 = 14.25
- GPS Networking Splitter: 14.5 dB Gain