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Biases in GNSS Analysis

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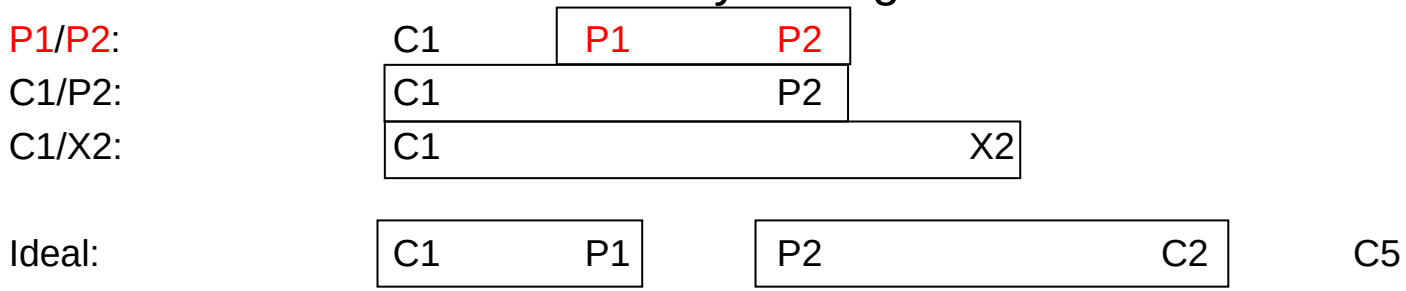
Outline

- Differential code biases (DCB) for GPS and GLONASS
- Biases relevant to multi-GNSS clock estimation
- Biases relevant to GLONASS ambiguity resolution
- Conclusions
- Remarks on:
  - use of GPS/GLONASS C2
  - use of GPS C5/L5
  - GPS quarter-cycle issue (as coped with at CODE)

Different GNSS Receiver Classes and Direct/Indirect DCB Determination

GPS receiver classes commonly distinguished:



Direct conversion (as done in cc2noncc with respect to (P1-C1)):

P1 = C1	+(P1-C1)
P2 = X2	+(P1-C1)
P2 = C2	+(P2-C2)

Ionosphere-free LC:

2.55·P1-1.55·P2	
2.55·C1-1.55·P2	+2.55·(P1-C1)
2.55·C1-1.55·X2	+1.00·(P1-C1)
2.55·C1-1.55·C2	+2.55·(P1-C1) -1.55·(P2-C2)

Melbourne-Wuebbena LC (for widelane ambiguity resolution):

4.53·L1-3.53·L2-0.56·P1-0.44·P2	
4.53·L1-3.53·L2-0.56·C1-0.44·P2	-0.56·(P1-C1)
4.53·L1-3.53·L2-0.56·C1-0.44·X2	-1.00·(P1-C1)
4.53·L1-3.53·L2-0.56·C1-0.44·C2	-0.56·(P1-C1) -044·(P2-C2)

Geometry-free LC (for ionosphere analysis):

P1-P2	+(P1-P2)
C1-P2	+(P1-P2) +(P1-C1)
C1-X2	+(P1-P2)
C1-C2	+(P1-P2) +(P1-C1) -(P2-C2)

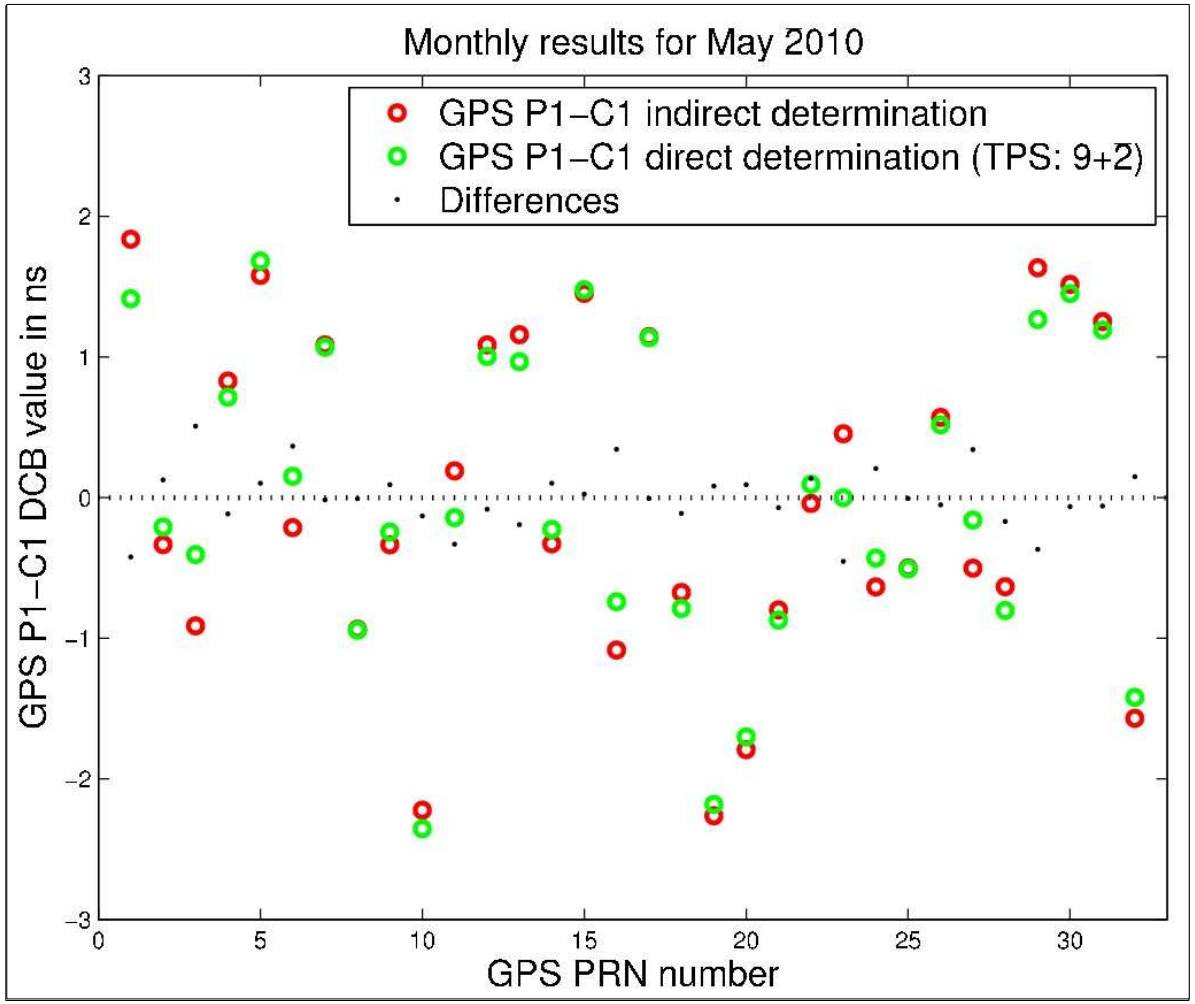
GPS/GLONASS Differential Code Bias (DCB) Products Regularly Generated at CODE (1/2)

Product	# G satellites Range (ns)	# R satellites Range (ns)	# G stations Range (ns)	# R stations Range (ns)	Generated in:
P1P2	31 12.3	21 25.7	278 60.8	125 53.1	GPS/GLONASS ionosphere analysis
P1C1 (Primary product)	31 4.0				GPS clock analysis
P1C1 (Extra product)	31 4.0				GPS Melbourne-Wübbena ambiguity resolution

GPS/GLONASS Differential Code Bias (DCB) Products Regularly Generated at CODE (2/2)

Product	# G satellites Range (ns)	# R satellites Range (ns)	# G stations Range (ns)	# R stations Range (ns)	Generated in:
P1P2	31 12.3	21 25.7	278 60.8	125 53.1	GPS/GLONASS ionosphere analysis
P1C1 (Primary product)	31 4.0				GPS clock analysis
P1C1 (Extra product)	31 4.0				GPS Melbourne-Wübbena ambiguity resolution
P2C2	8 0.9	19 14.0	26 3.1	9 3.5	GNSS direct determination
P1C1 (Complementary product)	31 4.0	22 5.1	11 (214) 4.5	22 (95) 3.8	GNSS direct determination

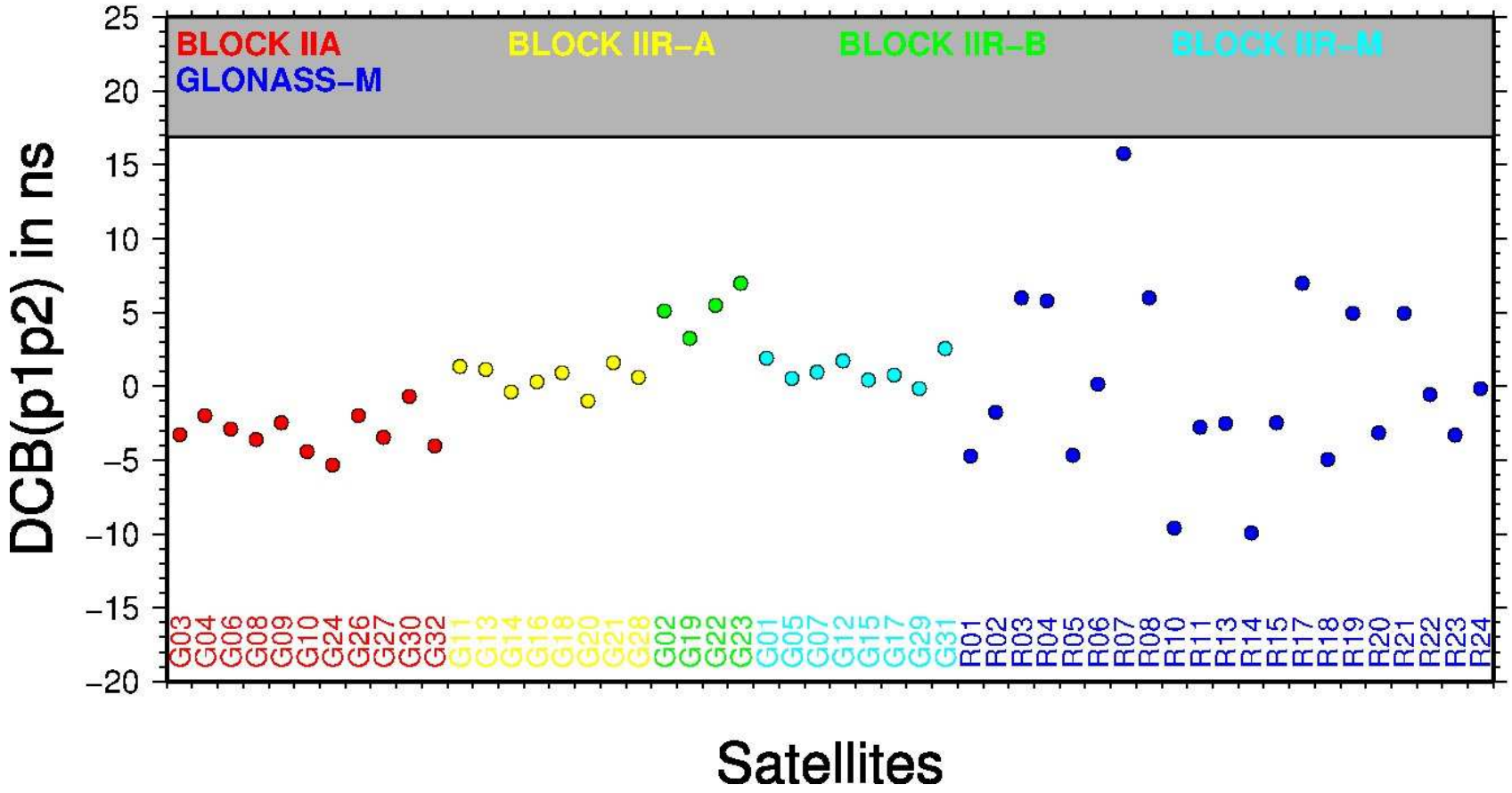
Comparison of GPS P1-C1 DCB Results From Indirect and Direct Determination



Stations Observing P2&C2 for GPS/GLONASS (and L5&C5 for GPS)

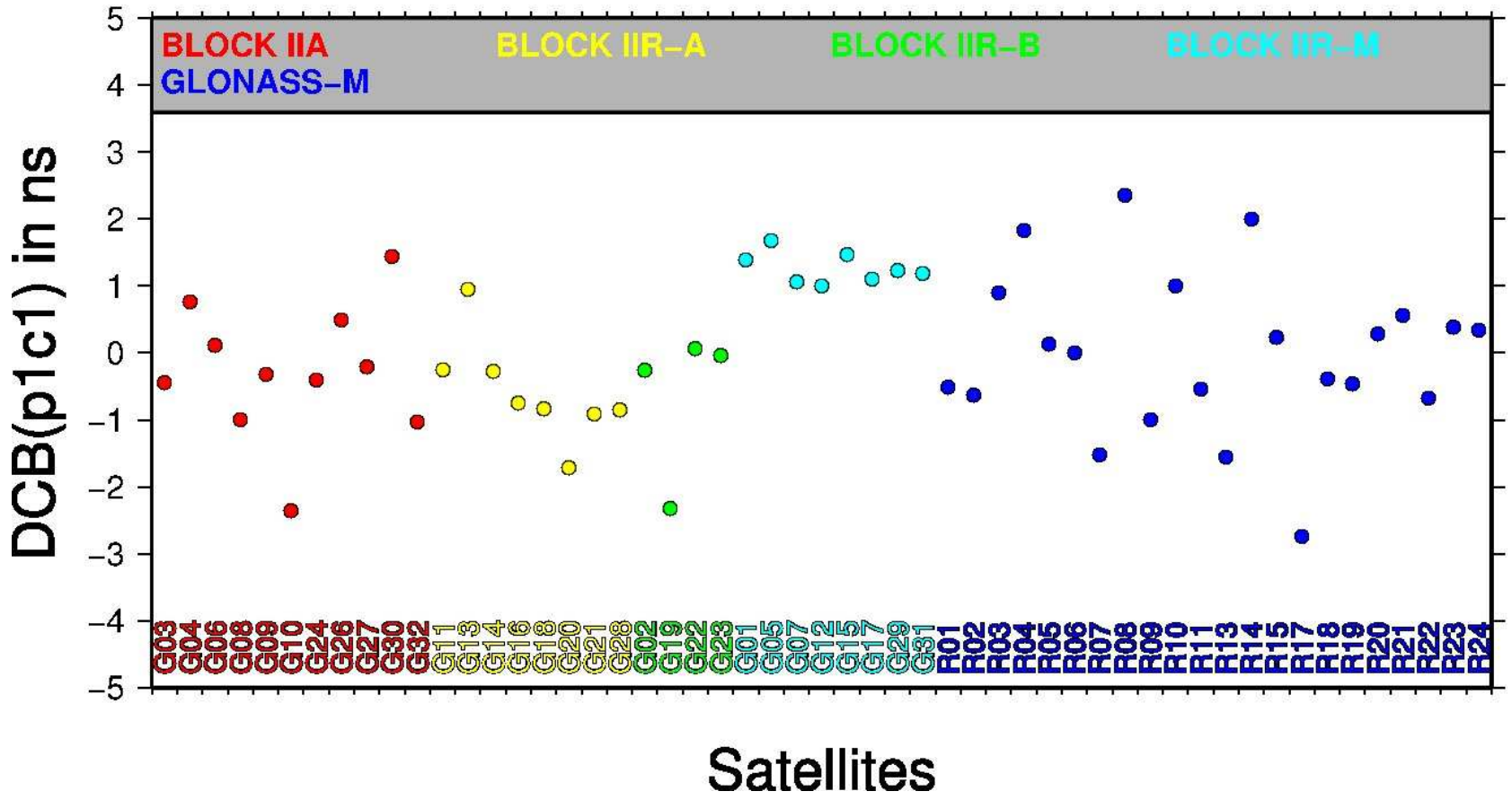
Station name	Receiver type	P1&C1	P2&C2	L5/C5
ABMF 97103M001	TRIMBLE NETR5	-/R	G/-	
AZGB	TRIMBLE NETR5	-/R	G/-	
BAKE 40152M001	TPS NETG3	G/R	G/R	
COCO 50127M001	TRIMBLE NETR5	-/R	G/-	
DUBO 40137M001	TPS NETG3	G/R	G/R	
ETAD	TRIMBLE NETR5	-/R	G/-	
ETDD	TRIMBLE NETR5	-/R	G/-	
ETJI	TRIMBLE NETR5	-/R	G/-	
FRDN 40146M001	TPS NETG3	G/R	G/R	
GANP 11515M001	TRIMBLE NETR8	-/R	G/-	X X
GOPE 11502M002	TPS NETG3	G/R	G/R	
GRAS 10002M006	TRIMBLE NETR5	G/R	G/-	
IQAL 40194M001	TPS NETG3	G/R	G/R	
KARR 50139M001	TRIMBLE NETR8	G/R	G/-	X X
LMMF 97205M001	TRIMBLE NETR5	-/R	G/-	
PGC5 40129M007	TRIMBLE NETRS	-/-	G/-	
REUN 97401M003	TRIMBLE NETR5	-/R	G/-	
ROSA	TRIMBLE NETR5	-/R	G/-	
SCH2 40133M002	TPS NETG3	G/R	G/R	
TID1 50103M108	TRIMBLE NETR8	-/R	G/-	
TLSE 10003M009	TRIMBLE NETR5	-/R	G/-	
TORI 12724M002	LEICA GRX1200+GNSS	-/-	G/-	
UCLU 40140M001	TRIMBLE NETRS	-/-	G/-	
UNB3 40146M002	TRIMBLE NETR5	-/R	G/-	
UNBT	TPS NETG3	G/R	G/R	
VALA 13463M002	LEICA GRX1200+GNSS	-/-	G/-	
VALD 40156M001	TPS NETG3	G/R	G/R	
WHIT 40136M001	TPS NETG3	G/R	G/R	
ZIM2 14001M008	TRIMBLE NETR5	-/R	G/-	

GPS/GLONASS P1-P2 DCB Values, Computed at CODE



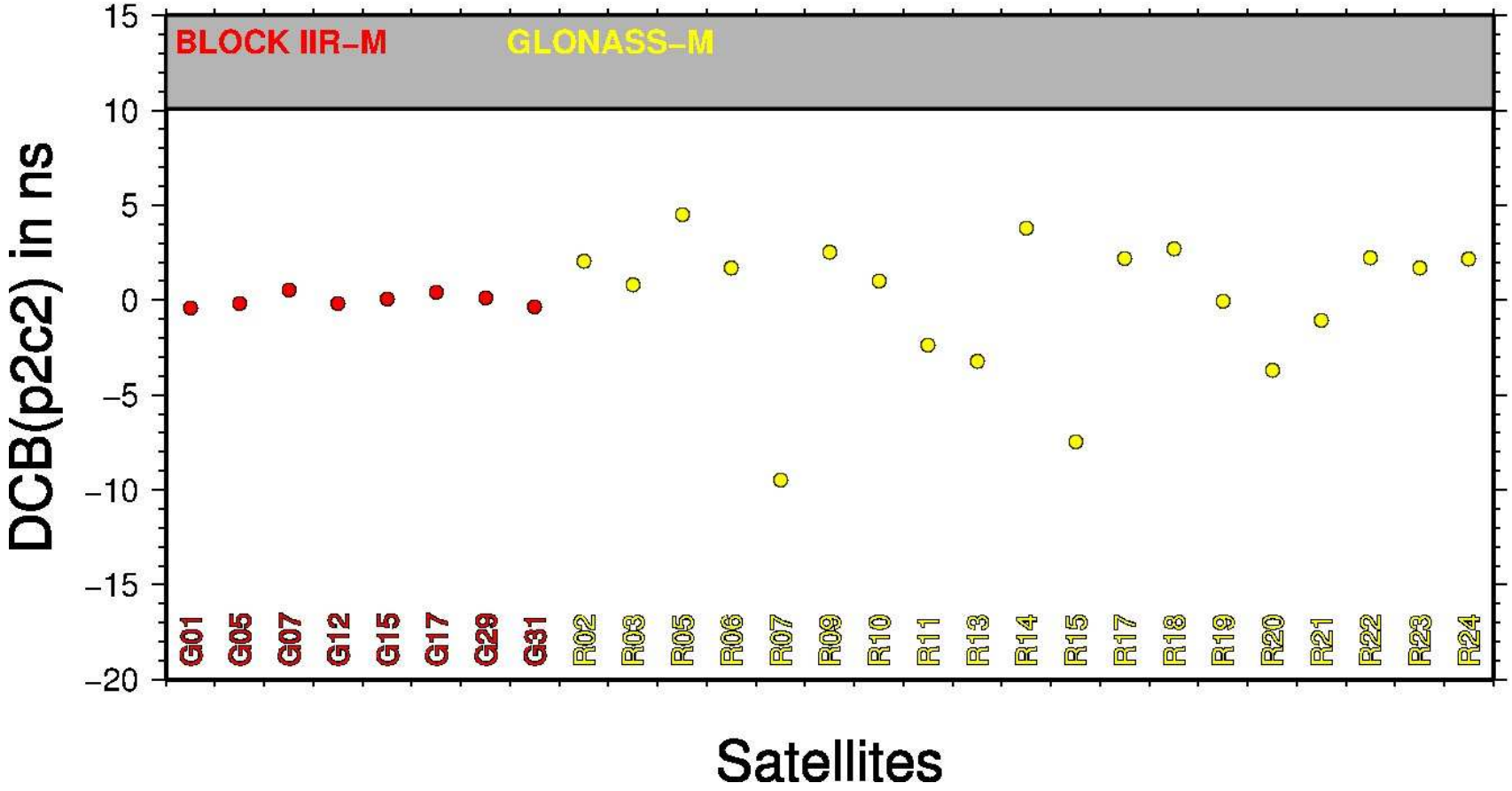
Monthly values for May 2010

GNSS P1-C1 DCB Values, Computed at CODE



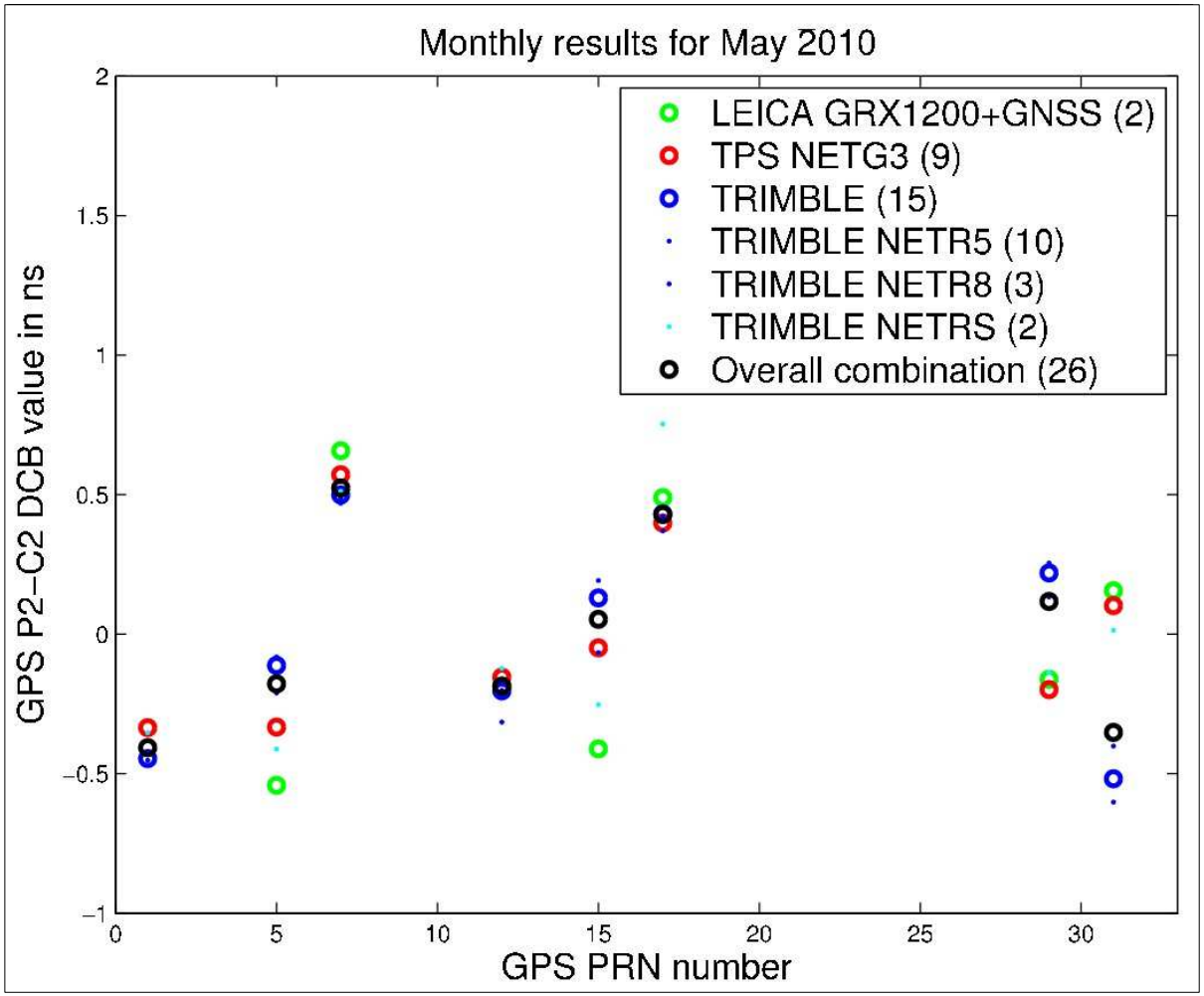
Monthly values for May 2010

GNSS P2-C2 DCB Values, Computed at CODE

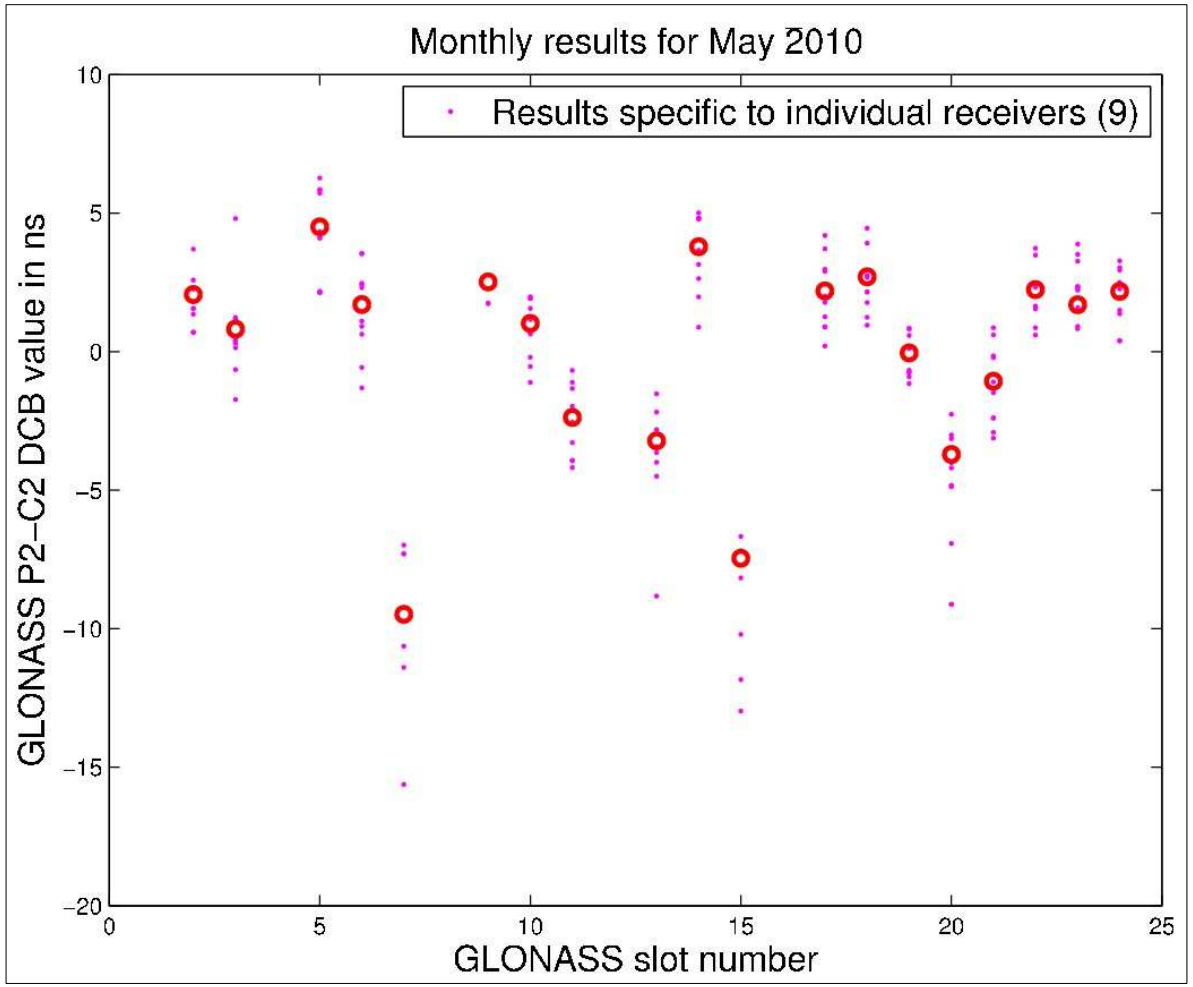


Monthly values for May 2010

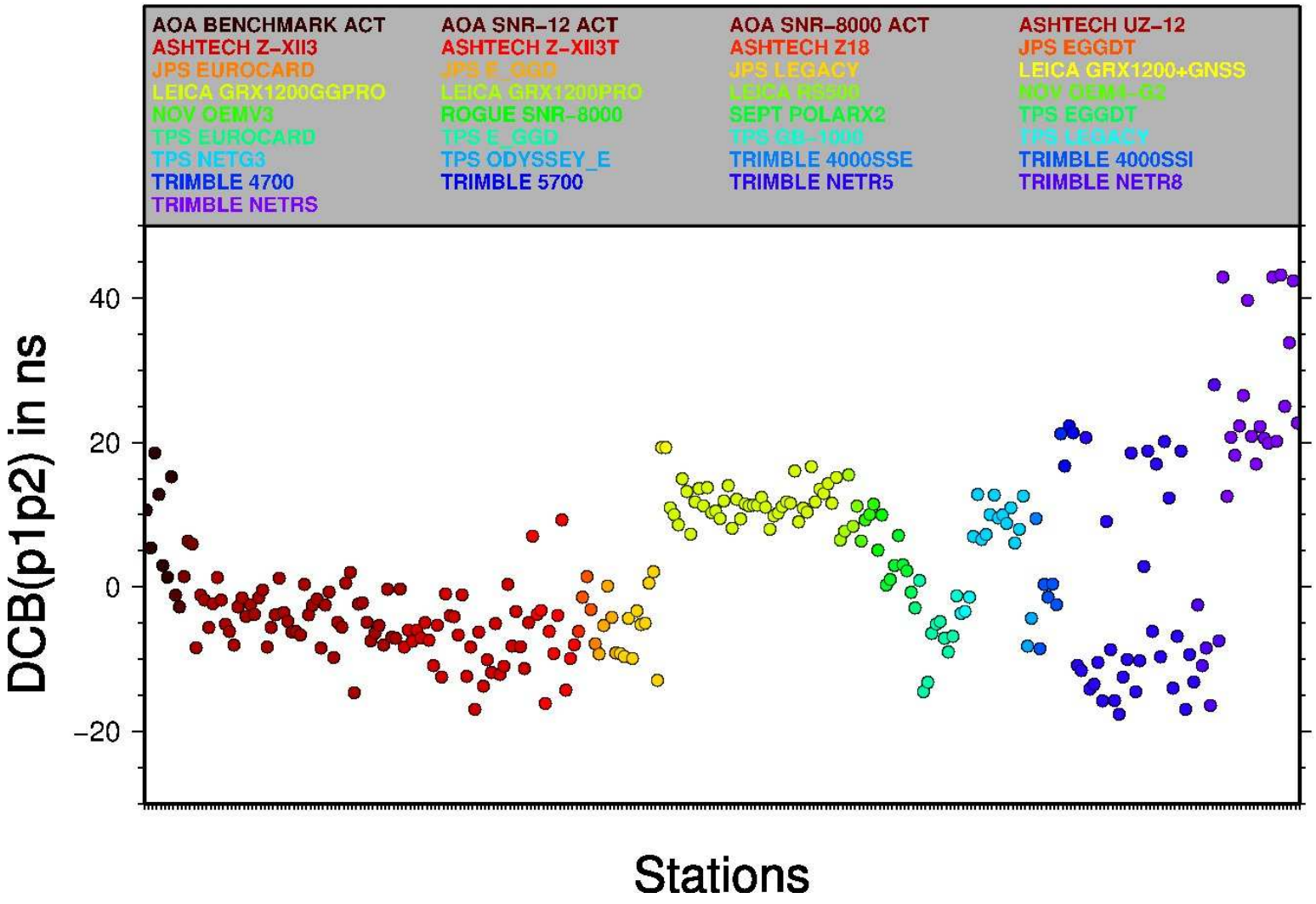
Comparison of P2-C2 DCB Results for the GPS Block IIR-M Satellites



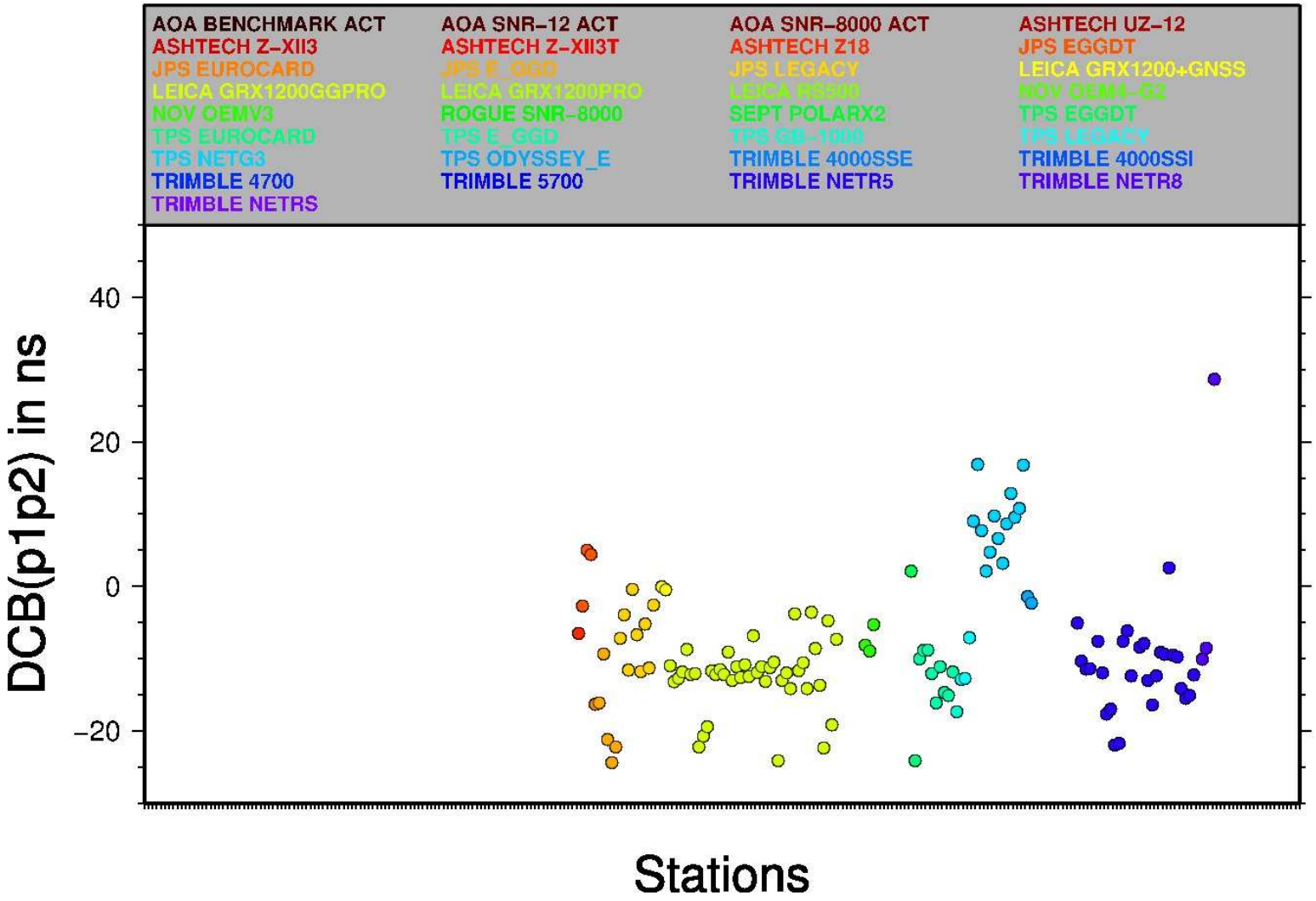
Comparison of P2-C2 DCB Results for the GLONASS-M Satellites



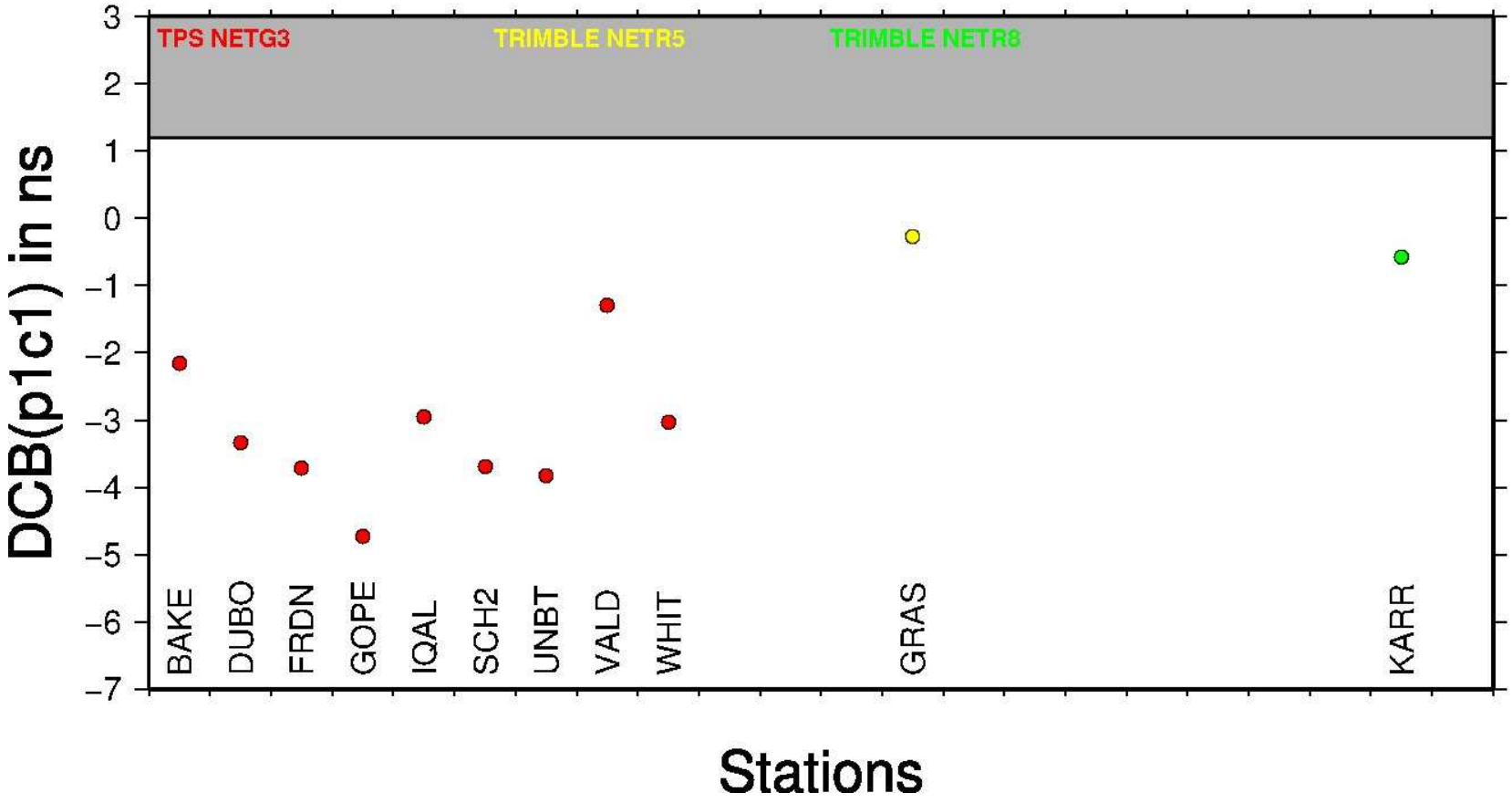
Receiver Code Biases for: GPS P1-P2 (1/6)



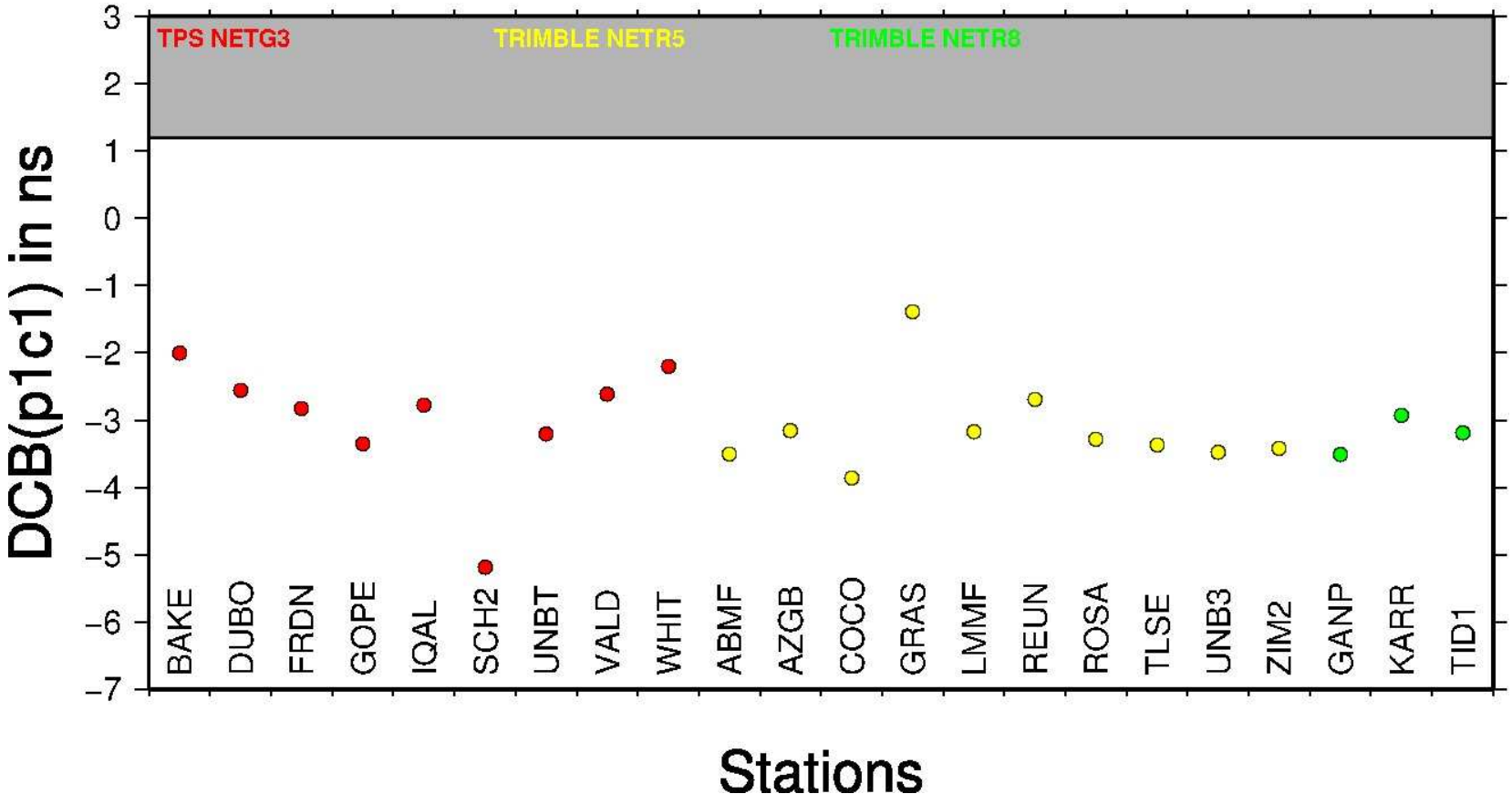
Receiver Code Biases for: GLONASS P1-P2 (2/6)



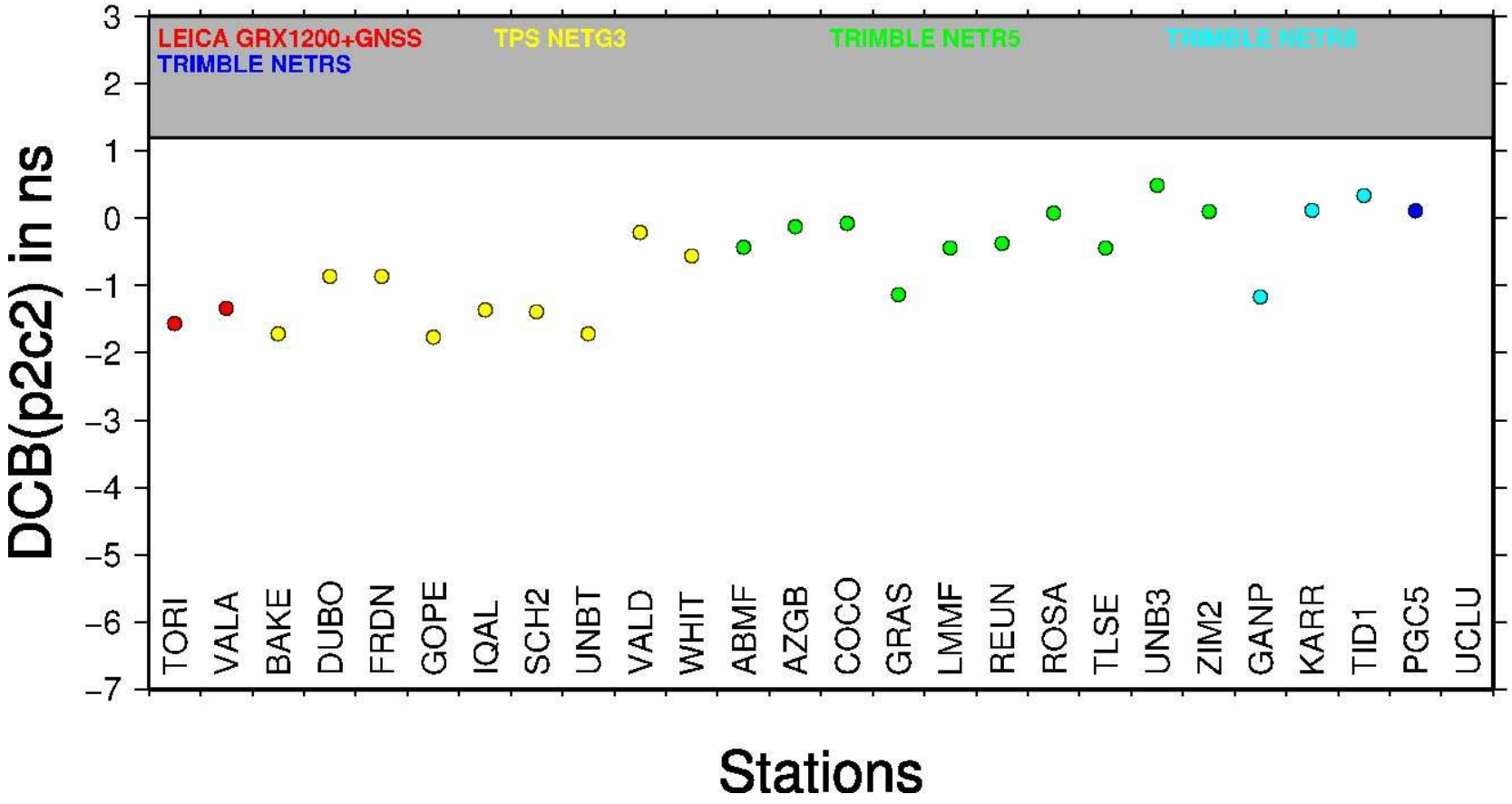
Receiver Code Biases for: GPS P1-C1 (3/6)



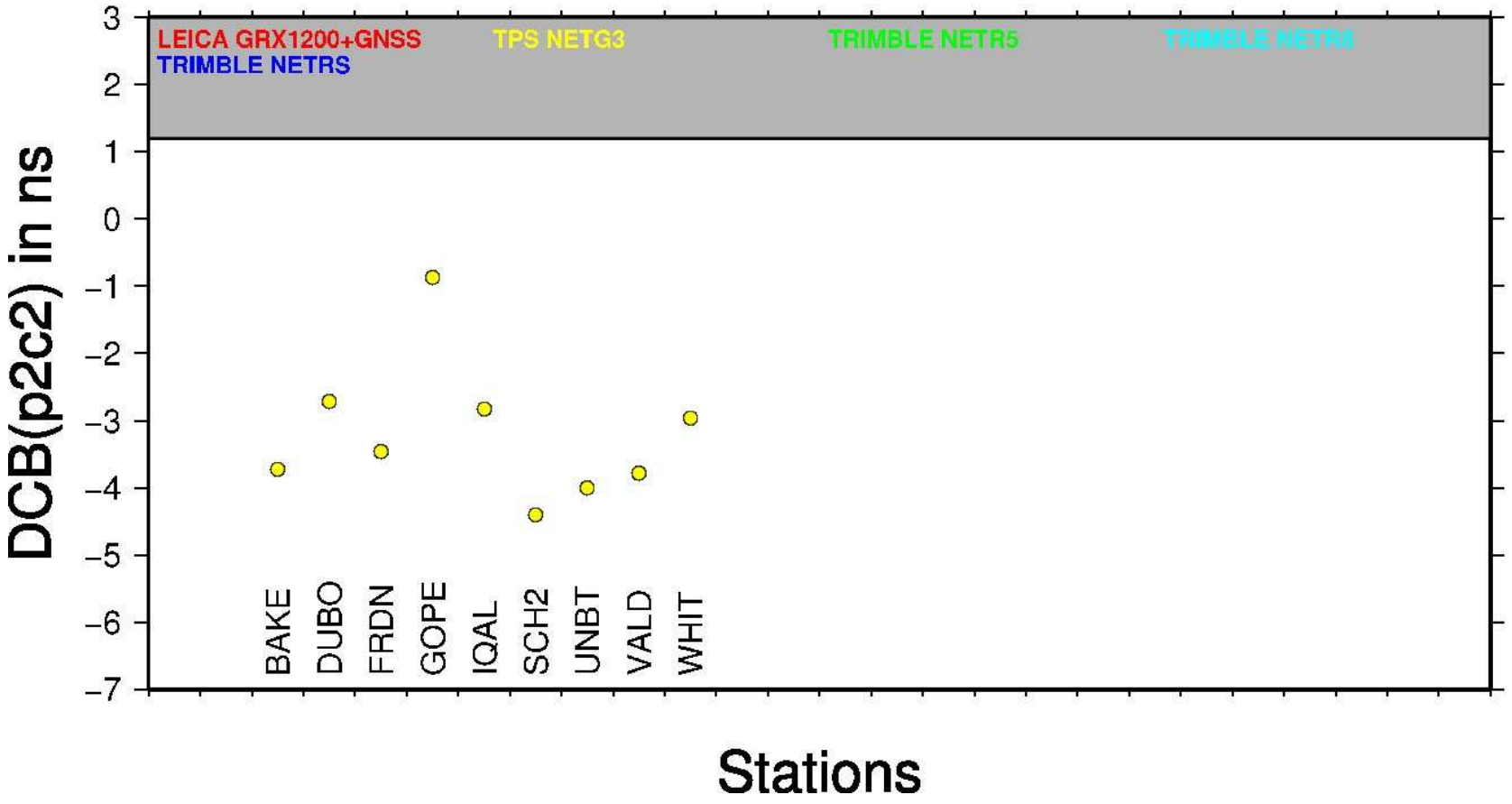
Receiver Code Biases for: GLONASS P1-C1 (4/6)



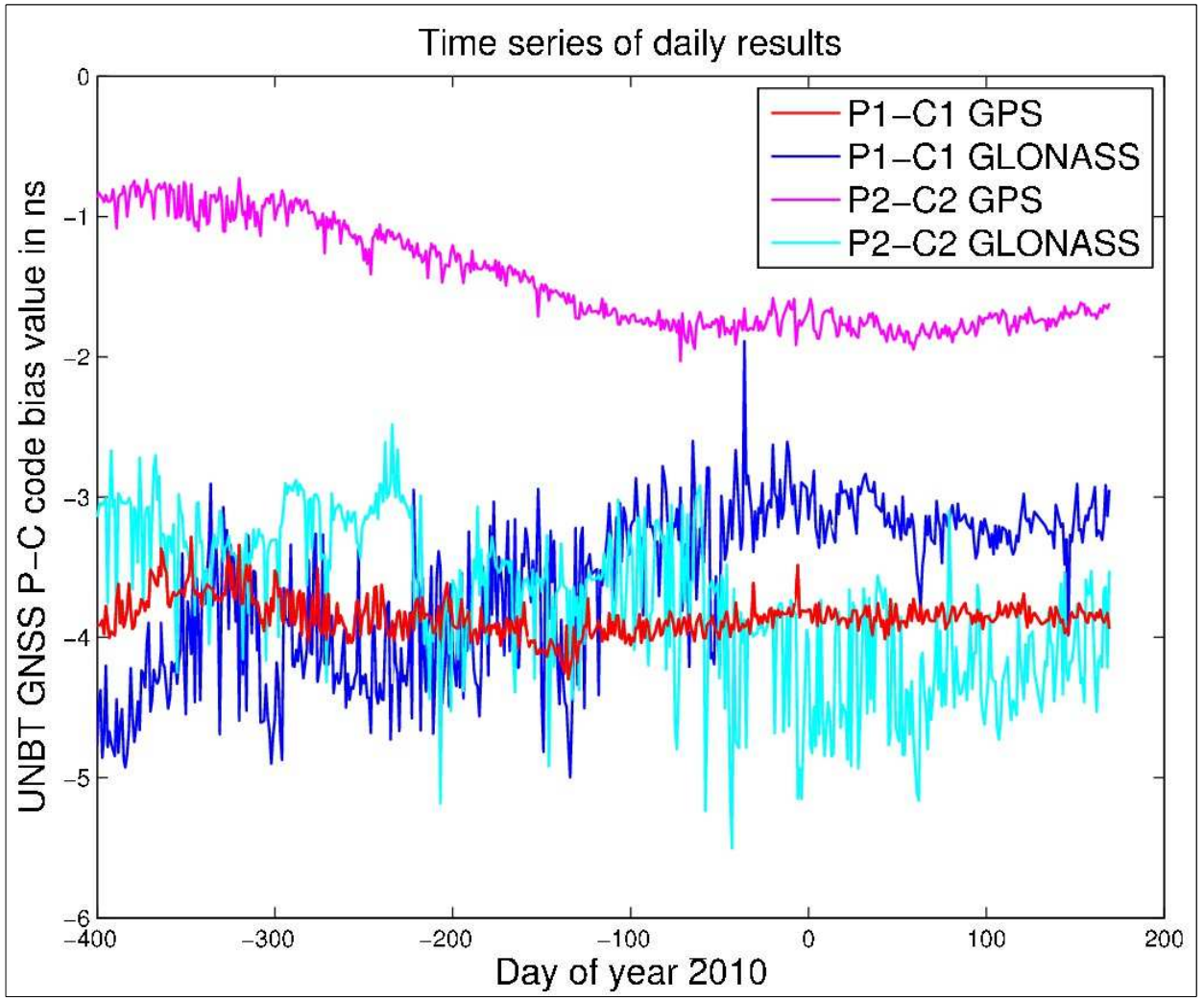
Receiver Code Biases for: GPS P2-C2 (5/6)



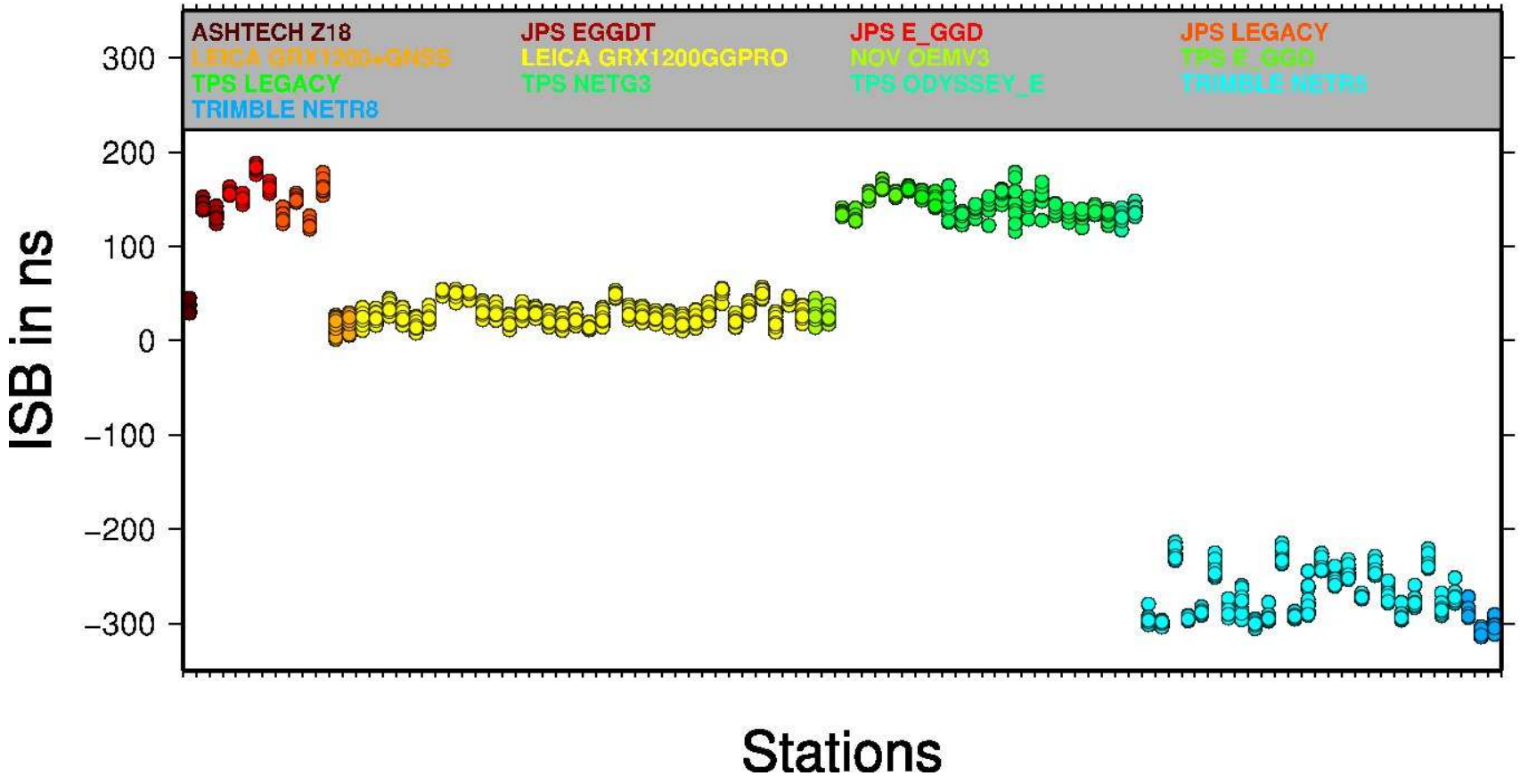
Receiver Code Biases for: GLONASS P2-C2 (6/6)



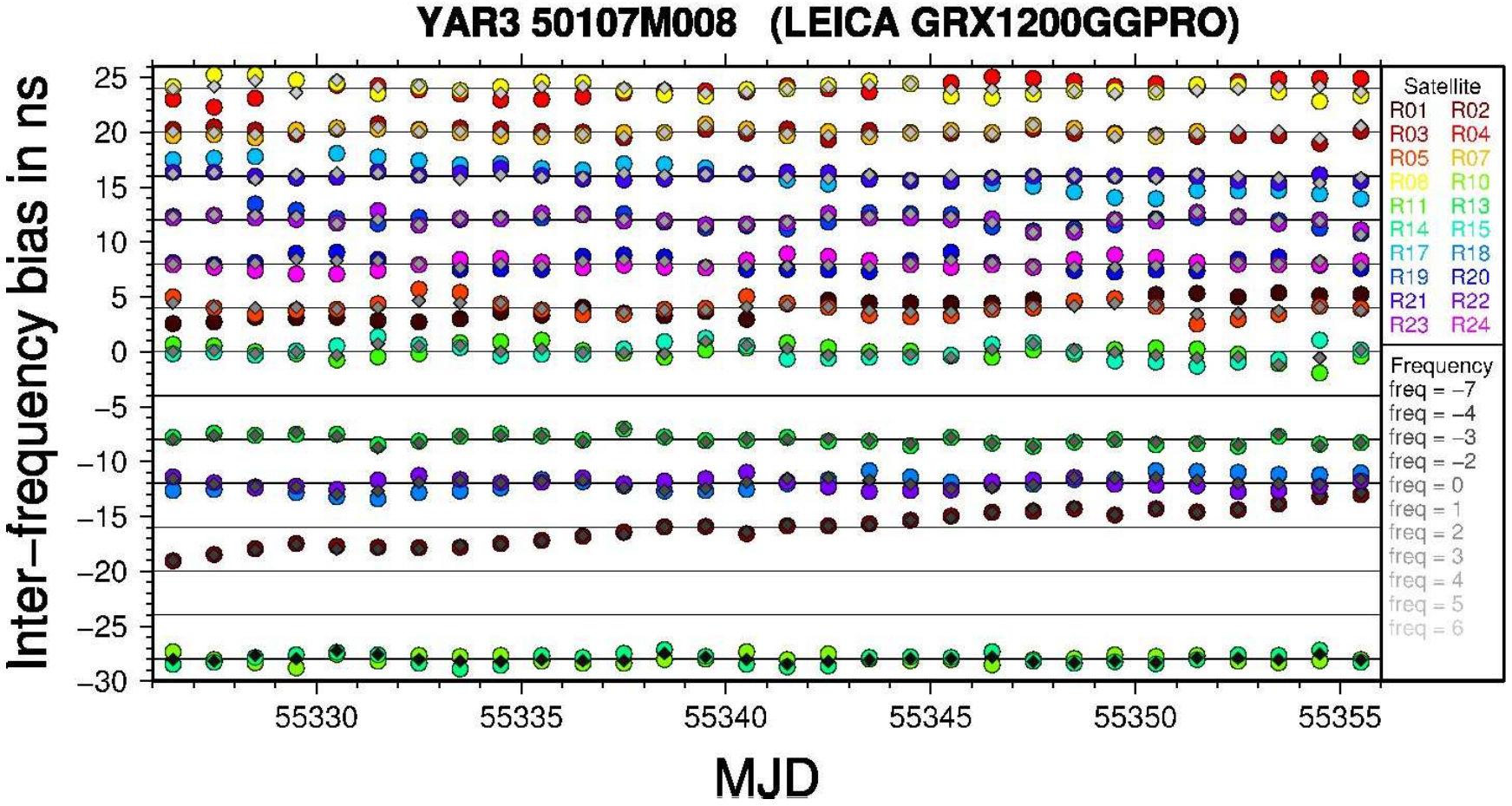
Time Series of Daily P-C Code Receiver Bias Retrievals, Computed for TPS NETG3 @ UNBT



GPS/GLONASS-Combined Clock Estimation: Inter-System Biases (ISB) Varying From Receiver to Receiver (Group)



GPS/GLONASS-Combined Clock Estimation: Inter-Frequency Biases (IFB) With Respect to Each Satellite or Each Frequency



GLONASS Inter-Frequency Code Biases (IFB) With Respect to Each Receiver Involved and Frequency Channel Observed

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DIFFERENTIAL (INTER-FREQ) CODE BIASES FOR SATELLITES AND RECEIVERS:

PRN / STATION NAME         VALUE (NS)  RMS (NS)     VALID   FROM                 TO
***   ****************     *****.***   *****.***    **** ** ** ** ** **  **** ** ** ** ** **
.
.
.
G     WTZR 14201M010           0.000       0.000
R01   WTZR 14201M010          10.663       0.078    2010 06 21 00 00 00  2010 06 21 23 59 30
R03   WTZR 14201M010           1.985       0.122    2010 06 21 00 00 00  2010 06 21 23 59 30
R04   WTZR 14201M010           4.101       0.084    2010 06 21 00 00 00  2010 06 21 23 59 30
R05   WTZR 14201M010          10.663       0.078    2010 06 21 00 00 00  2010 06 21 23 59 30
R07   WTZR 14201M010           1.985       0.122    2010 06 21 00 00 00  2010 06 21 23 59 30
R08   WTZR 14201M010           4.101       0.084    2010 06 21 00 00 00  2010 06 21 23 59 30
R09   WTZR 14201M010          16.184       0.111    2010 06 21 00 00 00  2010 06 21 23 59 30
R10   WTZR 14201M010          20.710       0.079    2010 06 21 00 00 00  2010 06 21 23 59 30
R11   WTZR 14201M010          12.918       0.078    2010 06 21 00 00 00  2010 06 21 23 59 30
R13   WTZR 14201M010          16.184       0.111    2010 06 21 00 00 00  2010 06 21 23 59 30
R14   WTZR 14201M010          20.710       0.079    2010 06 21 00 00 00  2010 06 21 23 59 30
R15   WTZR 14201M010          12.918       0.078    2010 06 21 00 00 00  2010 06 21 23 59 30
R17   WTZR 14201M010           5.316       0.073    2010 06 21 00 00 00  2010 06 21 23 59 30
R18   WTZR 14201M010          20.602       0.108    2010 06 21 00 00 00  2010 06 21 23 59 30
R19   WTZR 14201M010           6.623       0.084    2010 06 21 00 00 00  2010 06 21 23 59 30
R20   WTZR 14201M010           8.113       0.079    2010 06 21 00 00 00  2010 06 21 23 59 30
R21   WTZR 14201M010           5.316       0.073    2010 06 21 00 00 00  2010 06 21 23 59 30
R22   WTZR 14201M010          20.602       0.108    2010 06 21 00 00 00  2010 06 21 23 59 30
R23   WTZR 14201M010           6.623       0.084    2010 06 21 00 00 00  2010 06 21 23 59 30
R24   WTZR 14201M010           8.113       0.079    2010 06 21 00 00 00  2010 06 21 23 59 30
.
.
.
```

Receivers not Providing P1&C1 for GLONASS

Receiver type	P1&C1	Remark
ASHTECH Z18	0%	P1=C1
JAVAD TRE_G3T DELTA	100%	
JPS EGGDT	100%	
JPS EUROCARD	100%	
JPS E_GGD	100%	
JPS LEGACY	100%	
LEICA GRX1200+GNSS	0%	C1
LEICA GRX1200GGPRO	0%	C1
NOV OEMV3	0%	C1
TPS EGGDT	100%	
TPS EUROCARD	100%	
TPS E_GGD	100%	
TPS GB-1000	100%	
TPS LEGACY	100%	
TPS NETG3	100%	
TPS ODYSSEY_E	100%	
TRIMBLE NETR5	31%	C1 or P1&C1 (C1&C2 for BNDY!)
TRIMBLE NETR8	100%	

GLONASS Ambiguity Resolution

- GPS/GLONASS-combined ambiguity resolution is performed at CODE and at swisstopo for EPN/AGNES regional analysis (not yet activated for global analysis at CODE)
- The following strategies are applicable:
  - Direct L1/L2 ambiguity resolution (without any restriction)
  - Phase-based widelane/narrowlane resolution (currently just for receiver pairs belonging to the same receiver model, disregarding GLONASS ZD ambiguity initialization biases, see table below)
  - Quasi-Ionosphere-Free (QIF) strategy (for GLONASS satellites with the same frequency channel number)
  - New: GNSS-capable LAMBDA method (for rapid static positioning) was developed (paper by Schaer et al. in BGG)

Receiver model	GLONASS ZD ambiguity initialization bias in ns (when using GPS for receiver clock sync)
ASHTECH Z18	0
JPS	+100
LEICA	-250
NOV	-250
TPS	+80
TPS NETG3	+130
TRIMBLE NETR5	-320/-280
TRIMBLE NETR8	-300/-250

Conclusions

- Steadily increasing number of GNSS biases to be dealt with (due to new satellite generations and further satellite systems to be considered). A generalization may be expected for the handling of DCB information: from “DCB” towards “CB” values.
- An AC ready for GPS/GLONASS clock estimation should be well prepared for consideration of C2 and C5 observations.
- Proper referencing all analysis results to a well defined set of observable types is absolutely indispensable.
- We consider inclusion of ISB (and IFB) information in the clock RINEX format as a must. Note: This is actually not mandatory for a first GNSS clock combination.
- GPS quarter-cycle issue: At CODE, we do **not** resolve ambiguities between Block IIR-M and other GPS satellites if a *Leica* or a *NovAtel* receiver model is involved.
- Many anomalies found: no C2 for R01, R04, R08; and so on.
- Availability of IGS observation data with respect to new signals is far from being optimal (in terms of the revealed inhomogeneity of the RINEX observable types collected by each station (currently from 4 up to 11 observable types) and in terms of AIV tracking).

P2C2 DCB product made available at:
ftp://ftp.unibe.ch/aiub/CODE/P2C2.DCB
Monthly P2C2 DCB combinations for year-month (YYMM):
ftp://ftp.unibe.ch/aiub/CODE/2010/P2C2YYMM.DCB.Z

Tracking Situation Concerning two Unhealthy GPS Satellites: PRN01/SVN49 and PRN25/SVN62

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Tracking Situation Concerning PRN01/SVN49 (G01)
================================================

AOA BENCHMARK ACT   :  91.7% AIV ( 11 of  12) +  1
AOA SNR-            : 100.0% AIV (  6 of   6)
ASHTECH UZ-12       :  36.2% AIV ( 21 of  58) + 37
ASHTECH Z-XII3      :  27.6% AIV ( 16 of  58) + 42
ASHTECH Z18         :  50.0% AIV (  1 of   2) +  1
BLACKJACK           : 100.0% AIV (  1 of   1)
JAVAD               : 100.0% AIV (  1 of   1)
JPS                 :  54.3% AIV ( 19 of  35) + 16
LEICA GRX1200       :   1.7%     (  1 of  59)
LEICA RS            :   0.0%     (  0 of   1)
NOV                 :   0.0%     (  0 of   5)
ROGUE SNR-          :  75.0% AIV (  3 of   4) +  1
SEPT                :  25.0% AIV (  2 of   8) +  6
TPS                 :  66.7% AIV ( 24 of  36) + 12
TRIMBLE 4000SSE     : 100.0% AIV (  1 of   1)
TRIMBLE 4000SSI     :   0.0%     (  0 of   7)
TRIMBLE 4700        :   0.0%     (  0 of   3)
TRIMBLE 5700        :   0.0%     (  0 of   4)
TRIMBLE NET         :  36.9% AIV ( 24 of  65) + 41
------------------------------------------------
Total               :  35.8% AIV (131 of 366)
------------------------------------------------
Total (possible)    :  78.4% AIV (287 of 366)
```

```
Tracking Situation Concerning PRN25/SVN62 (G25)
================================================

AOA BENCHMARK ACT   : 100.0% AIV ( 12 of  12)
AOA SNR-            : 100.0% AIV (  6 of   6)
ASHTECH UZ-12       :  36.2% AIV ( 21 of  58) + 37
ASHTECH Z-XII3      :  27.6% AIV ( 16 of  58) + 42
ASHTECH Z18         :   0.0%     (  0 of   2)
BLACKJACK           : 100.0% AIV (  1 of   1)
JAVAD               : 100.0% AIV (  1 of   1)
JPS                 :  48.6% AIV ( 17 of  35) + 18
LEICA GRX1200       :  37.3% AIV ( 22 of  59) + 37
LEICA RS            :   0.0%     (  0 of   1)
NOV                 :   0.0%     (  0 of   5)
ROGUE SNR-          : 100.0% AIV (  4 of   4)
SEPT                :  25.0% AIV (  2 of   8) +  6
TPS                 :  69.4% AIV ( 25 of  36) + 11
TRIMBLE 4000SSE     :   0.0%     (  0 of   1)
TRIMBLE 4000SSI     :   0.0%     (  0 of   7)
TRIMBLE 4700        :   0.0%     (  0 of   3)
TRIMBLE 5700        :   0.0%     (  0 of   4)
TRIMBLE NET         :  36.9% AIV ( 24 of  65) + 41
------------------------------------------------
Total               :  41.3% AIV (151 of 366)
------------------------------------------------
Total (possible)    :  93.7% AIV (343 of 366)
```

- PRN01 is no longer in the broadcast almanac (since around 21 May 2010).
- Some receivers (LEICA GRX1200) therefore refuse to track it even if instructed to track unhealthy satellites.

New DCB File Format

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Differential code biases for satellites and receivers
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Format version:   1.00

PRN / Station name           Typ1-Typ2   Value (ns)       RMS error (ns)   Flag          From               To               Remark
***   ********************   **** ****  *******.******   *******.******   ****  YYYY MM DD HH MM SS  YYYY MM DD HH MM SS  ********************
G                            LC              2.243000         0.003000   Rel                                             GNSS-specific
G01                          P1   C1         8.120000         0.003400   Rel                                             Satellite-specific
G01                          P1   P2        -3.342000         0.004000   Rel                        2008 02 13 23 59 59  Before event/jump
G01                          P1   P2        -2.432000         0.003100   Rel   2008 02 14 00 00 00                    After  event/jump
...                          ...  ...            ...              ...   ...                                             ...
#
      ZIM2 14001M008         P1   C1        -2.314000         0.002000   Rel                                             Station-specific
G     ZIM2 14001M008         P1   P2         9.681000         0.022000   Abs                                             Sta/GNSS-specific
G     ZIM2 14001M008         P1              19.293000         0.052000   Abs                                             Sta/GNSS-specific
R     ZIM2 14001M008         P1   P2        11.491000         0.034000   Rel                                             Sta/GNSS-specific
E12   ZIM2 14001M008         P1   P5        10.245000         0.027000   Rel                                             Sta/sat-specific
E12   ZIM2 14001M008         P1   P6         0.828000         0.012000   Rel                                             Sta/sat-specific
...   ...                    ...  ...            ...              ...   ...                                             ...
```

Figure 4: New DCB file format for the BSW.

See also: http://www.aiub.unibe.ch/download/bcwg/cc2noncc/