Bias and Calibration Working Group Technical Report 2017

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1 Introduction

The IGS Bias and Calibration Working Group (BCWG) coordinates research in the field of GNSS bias retrieval and monitoring. It defines rules for appropriate, consistent handling of biases which are crucial for a "model-mixed" GNSS receiver network and satellite constellation, respectively. At present, we consider: GPS C1W–C1C, C2W-C2C, and C1W–C2W differential code biases (DCB). Potential quarter-cycle biases between different GPS phase observables (specifically L2P and L2C) are another issue to be dealt with. In the face of GPS and GLONASS modernization programs and upcoming GNSS, like the European Galileo and the Chinese BeiDou, careful treatment of measurement biases in legacy and new signals becomes more and more crucial for combined analysis of multiple GNSS.

The IGS BCWG was established in 2008. More helpful information and related Internet links may be found at http://www.igs.org/wg. For an overview of relevant GNSS biases, the interested reader is referred to (Schaer 2012).

2 Activities in 2017

- Regular generation of C1W–C1C (P1–C1) bias values for the GPS constellation (based on *indirect* estimation) and maintenance of receiver class tables was continued at CODE/AIUB.
- The final approval of the new **Bias-SINEX Format Version 1.00** by the IGS was a key achievement in 2017 (see also Section 6).

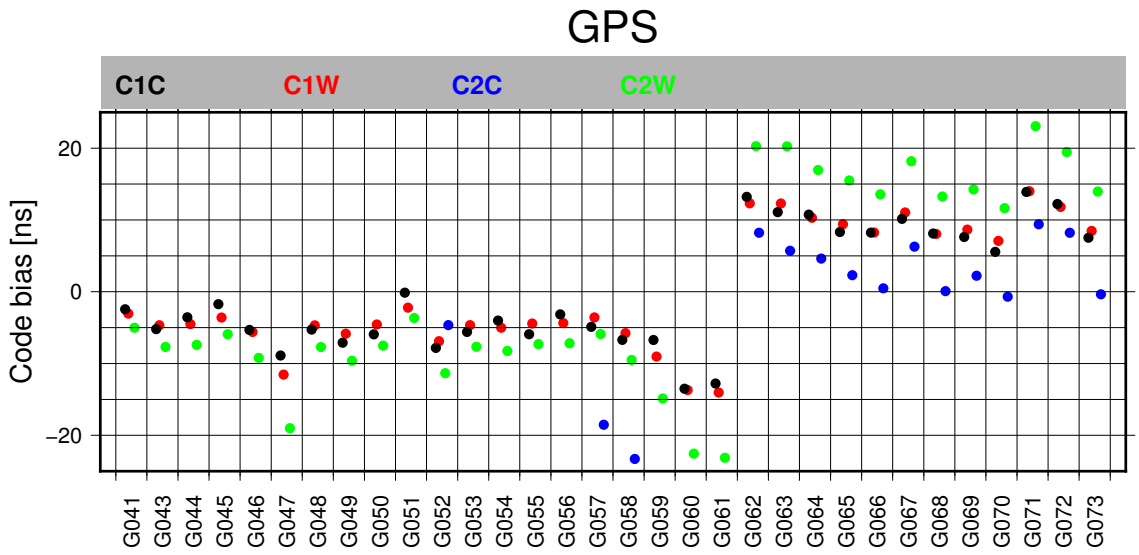

Figure 1: Observable-specific code bias (OSB) estimates for GPS code observable types (using the RINEX3 nomenclature) and GPS SV numbers, computed at CODE, for January 2018. Note that G041–G061 correspond to Block IIR, IIR-M; G062–G073 correspond to Block IIF satellite generations.

- At CODE, a refined GNSS bias handling to cope with all available GNSS systems and signals has been implemented and activated (in May 2016) in all IGS analysis lines. As part of this major revision, processing steps relevant to bias handling and retrieval were reviewed and completely redesigned. In 2017, further refinements could be achieved concerning bias processing and combination of the daily bias results at NEQ level. A daily updated 30-day sliding average for GPS and GLONASS code bias (OSB) values coming from a rigorous combination of ionosphere and clock analysis is made available in Bias-SINEX V1.00 at: `ftp://ftp.aiub.unibe.ch/CODE/CODE.BIA`

- It should be mentioned that the current GPS C1W-C1C DSB (P1-C1 DCB) product provided by CODE (specifically in the Bernese DCB and in a CC2NONCC-compatible format) corresponds to a converted extract from our new OSB final/rapid product line.

- Our new bias implementation allows to combine bias results at normal-equation (NEQ) level. We are thus able to combine bias results obtained from both clock and ionosphere analysis, and, moreover, to compute coherent long-term OSB solutions. This could be already achieved for the period starting with epoch 2016:136:00000 up to now. Corresponding long-term OSB solutions are updated daily (see GPS/GLONASS bias results shown in Figures 1 and 2).

- The tool developed for *direct* estimation of GNSS P1–C1 and P2–C2 DCB values is

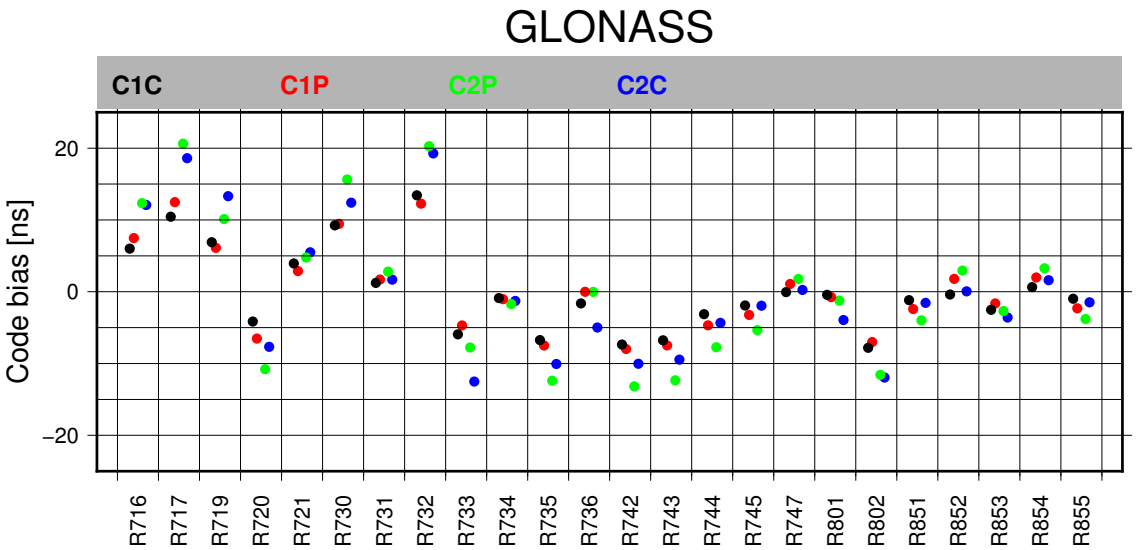

Figure 2: Observable-specific code bias (OSB) estimates for GLONASS code observable types (using the RINEX3 nomenclature) and GLONASS SV numbers, computed at CODE, for January 2018.

(still) used to generate corresponding GPS and GLONASS bias results on a daily basis.

- The ambiguity resolution scheme at CODE was extended (in 2011) to GLONASS for three resolution strategies. It is essential that *self-calibrating* ambiguity resolution procedures are used. Resulting GLONASS DCPB(differential code-phase bias) results are collected and archived daily.
- More experience could be gained concerning station-specific GLONASS-GPS inter-system translation parameters, which are estimated and accumulated as part of CODE's IGS analysis (but completely ignored for all submissions to IGS).
- CODE's enhanced RINEX observation data monitoring was continued. Examples may be found at:
  `ftp://ftp.aiub.unibe.ch/igsdata/odata2_day.txt`
  `ftp://ftp.aiub.unibe.ch/igsdata/odata2_receiver.txt`
  `ftp://ftp.aiub.unibe.ch/igsdata/y2017/odata2_d335.txt`
  `ftp://ftp.aiub.unibe.ch/igsdata/y2017/odata2_d335_sat.txt`
  Internally, the corresponding information is extracted and produced using metadata stored in an xml database (established in December 2014).
- This RINEX monitoring service is provided in addition for MGEX observation data (available in RINEX3 format). See: `ftp://ftp.aiub.unibe.ch/mgex/y2017`

3 Last Reprocessing Activities

In 2012: A complete GPS/GLONASS DCB reprocessing was carried out at CODE on the basis of 1990–2011 RINEX data. The outcome of this P1–C1 and P2–C2 DCB reprocessing effort is: daily sets, a multitude of daily subsets, and in addition monthly sets.

In 2016/2017: A GNSS bias reprocessing (for GPS/GLONASS) using the recently implemented observable-specific code bias (OSB) parameterization was initiated at CODE for 1994-2016 RINEX data. The outcome of this reprocessing effort are daily NEQs for GPS and GLONASS OSB parameters from both global ionosphere and clock estimation. A consistent time series of global ionosphere maps (GIMs) with a time resolution of 1 hour is an essential by-product of this bias reprocessing effort.

In 2017: 3-day combined ionosphere solutions were computed for the entire reprocessing period (back to 1994). The ionosphere (IONEX) results (for the middle day) of this computation effort were not yet made available to the public.

4 Computation of Coherent Long-Term GPS/GLONASS Code Bias Solution

The accumulated "bias-NEQs" from our 1994–2016 bias reprocessing in conjunction with those from our operational IGS processing allow us to compute a coherent long-term GPS/GLONASS code bias solution. Such a computation procedure could be successfully implemented. The bias combination procedure is executed on a daily basis thus yielding daily updates for our long-term GPS/GLONASS code bias solution. This NEQ-combined bias solution covers more than 24 years and provides one common datum over the entire period. This particular property is of great interest for those applications where long-term stability is crucial (e.g. for timing, or time transfer applications using GNSS).

The daily bias-NEQ results are re-aligned relying on the unique bias datum provided by our long-term bias solution. This re-alignment of all daily bias retrievals is done once a week. Examples of thus re-aligned time series are shown in Figure 3 for one selected GPS satellite (SVN G046).

A list of instantaneous discontinuities that could be collected as part of the implementation of the long-term code bias combination was an essential outcome. The epochs of this discontinuity list are then used to decide to which combination time window the daily NEQ contributions have to be referred to. Many of these epochs may be associated with a maintenance event as they were announced in GPS NANU messages. The first discontinuity in 2001 in Figure 3 may be attributed to such an event: NANU 2001120: SVN46 (PRN11) UNUSABLE JDAY 256/0030 - JDAY 256/0530.

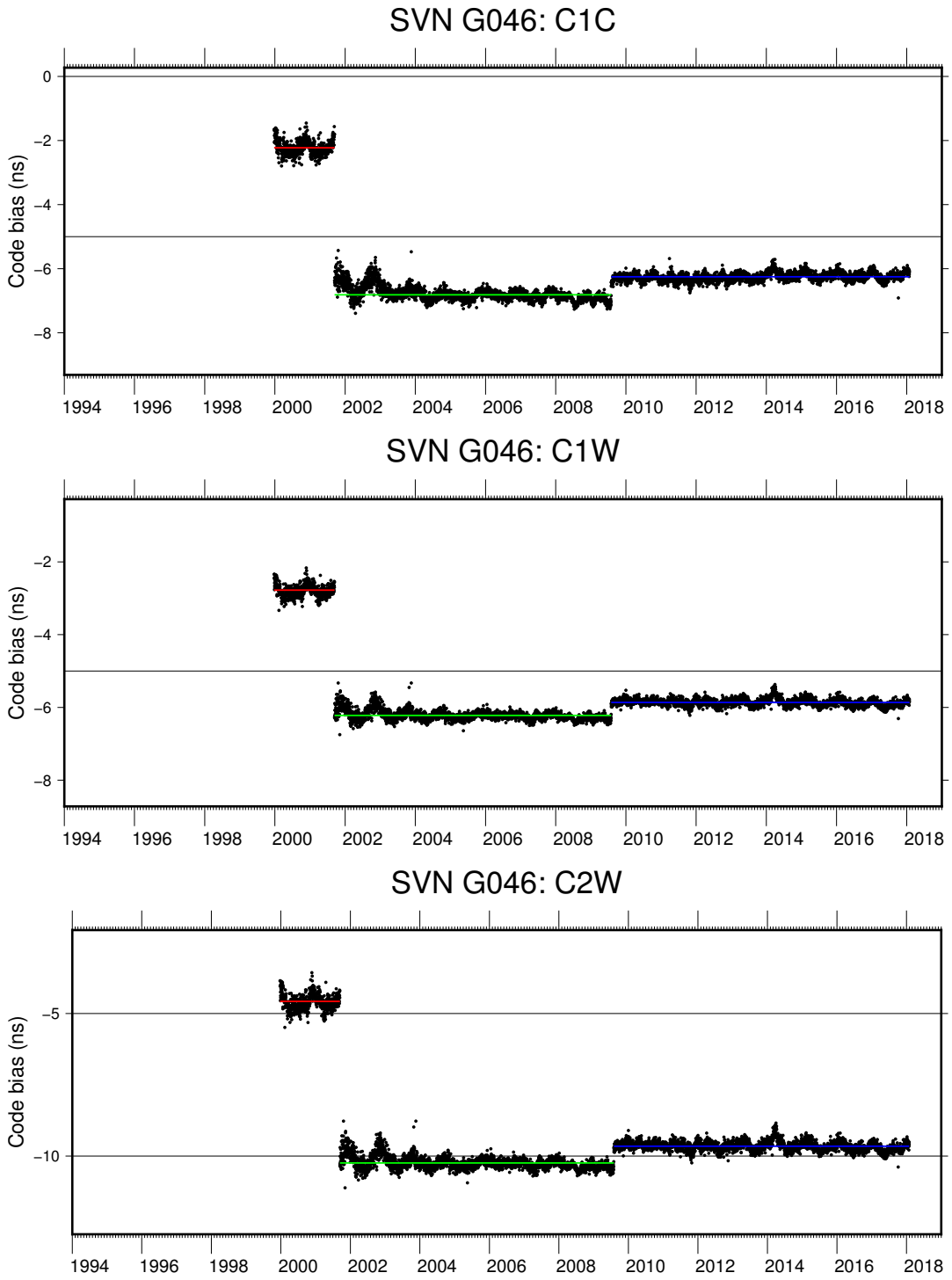

Figure 3: Time series of daily code bias (OSB) estimates for a selected GPS satellite (SVN G046) and various code observable types (C1C, C1W, C2W), computed at CODE on the basis of "bias-NEQs" from a dedicated reprocessing. Note that the daily results were realigned with respect to the combined bias solution (indicated with colored lines).

```
*-------------------------------------------------------------------------------
+BIAS/SOLUTION
*BIAS SVN_ PRN STATION__ OBS1 OBS2 BIAS_START____ BIAS_END______ UNIT __ESTIMATED_VALUE____ _STD_DEV___
 OSB  G063 G01           C1C       2018:030:00000 2018:031:00000 ns                -1.60616     0.00603
 OSB  G063 G01           C2C       2018:030:00000 2018:031:00000 ns                -3.65842     0.20465
 OSB  G063 G01           C1W       2018:030:00000 2018:031:00000 ns                -0.01049     0.00108
 OSB  G063 G01           C2W       2018:030:00000 2018:031:00000 ns                 0.01160     0.00109
 OSB  G063 G01           L1C       2018:030:00000 2018:031:00000 ns                -0.17676     0.00000
 OSB  G063 G01           L1W       2018:030:00000 2018:031:00000 ns                -0.17676     0.00000
 OSB  G063 G01           L2C       2018:030:00000 2018:031:00000 ns                -0.36450     0.00000
 OSB  G063 G01           L2W       2018:030:00000 2018:031:00000 ns                -0.36450     0.00000
 ...
-BIAS/SOLUTION
*-------------------------------------------------------------------------------
```

Figure 4: Example for a set of code and phase bias values for a GPS satellite (G063/G01) as included in a Bias-SINEX file.

5 Determination of Fractional Phase Biases for Undifferenced Ambiguity Resolution

First developments were made towards determination of fractional phase biases for *undifferenced* ambiguity resolution (AR) as they may be used for PPP-AR or simply Integer-PPP (IPPP), where between-satellite single differencing is commonly applied for AR.

A new software components in this working field is PHABIA, a dedicated program that is able to extract widelane (WL) or narrowlane (NL) fractional phase biases from PPP analysis results of a significant sample of IGS station data.

Following our pseudo-absolute (OSB) bias treatment, the retrieved WL and NL fractional phase biases may be finally mapped to a set of L1 and L2 phase biases that is consistent to the two particular linear combinations (LC): WL and NL.

Figure 4 illustrates how such a consistent set of code and phase bias values may be provided in a Bias-SINEX file. A user may just consider the given set of biases (in combination with a bias-consistent GPS clock product) for all involved code and phase observations (and accordingly derived LCs, such as Melbourne-Wübbena or ionosphere-free LC).

6 Bias-SINEX Format Version 1.00

A finalized draft version for the new Bias-SINEX Format (Version 1.00) was announced in (Schaer 2016b):

ftp://ftp.aiub.unibe.ch/bcwg/format/draft/sinex_bias_100_dec07.pdf

This format version has been developed on the basis of

- a first draft proposed and discussed at the IGS Bias Workshop 2015 in Bern, Switzerland,
- an updated draft prepared for the IGS Workshop 2016 in Sydney,
- substantial inputs from the IGS MGEX community (in particular from Oliver Montenbruck, DLR, Germany), and
- our experiences gained as part of the GNSS bias implementation performed at CODE.

The latest essential updates since the IGS Workshop 2016 included:

- Bias-SINEX was completely decoupled from the SINEX format and corresponding format descriptions.
- The previously used 2-digit year tag (YY) was generally replaced by a 4-digit year tag (YYYY) for all time tags (YYYY:DDD:SSSSS).
- Numerous bias (.BIA) example files could be prepared based on the new GNSS bias products generated at CODE.

The latest format document (and the entire format document history) may be found at:

http://www.biasws2015.unibe.ch/documents.html

References

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