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sapere dove
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Bias-SINEX Format and Implications for IGS Bias Products

Stefan Schaer

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IGS Workshop on GNSS Biases

IGS INTERNATIONAL GNSS SERVICE

- Main
- Program
- Registration
- List of participants
- Supporting documents
- Travel and accommodation
- Presentations etc.
- Email contact

The next IGS Workshop on GNSS Biases will be organized from **5 to 6 November 2015**. It will be hosted by AIUB, the Astronomical Institute, at the University of Bern, Switzerland.

This workshop is foreseen as a roundtable conference with a limited number of participants (about 40). We will consider this mostly an invitation-only meeting. Issues concerning handling/determination/calibration/consideration of (observable) biases of current GNSS and their signals shall be discussed.

It is our intention to open the IGS-BCWG discussion forum to a broader focused group of experts with experience and strong interests (including the RTCM/RINEX community and key experts from GNSS receiver manufacturers). Therefore, we propose that all interested persons (particularly interested in the "Bias Workshop 2015") are invited to register in addition to

http://igscb.jpl.nasa.gov/mailman/listinfo/igs-bcwg

in order to follow the technical discussions (and further general announcements concerning the workshop).

Please be also referred to the webpage from the first IGS Workshop on GNSS Biases (held in 2012):

http://www.biasws2012.unibe.ch

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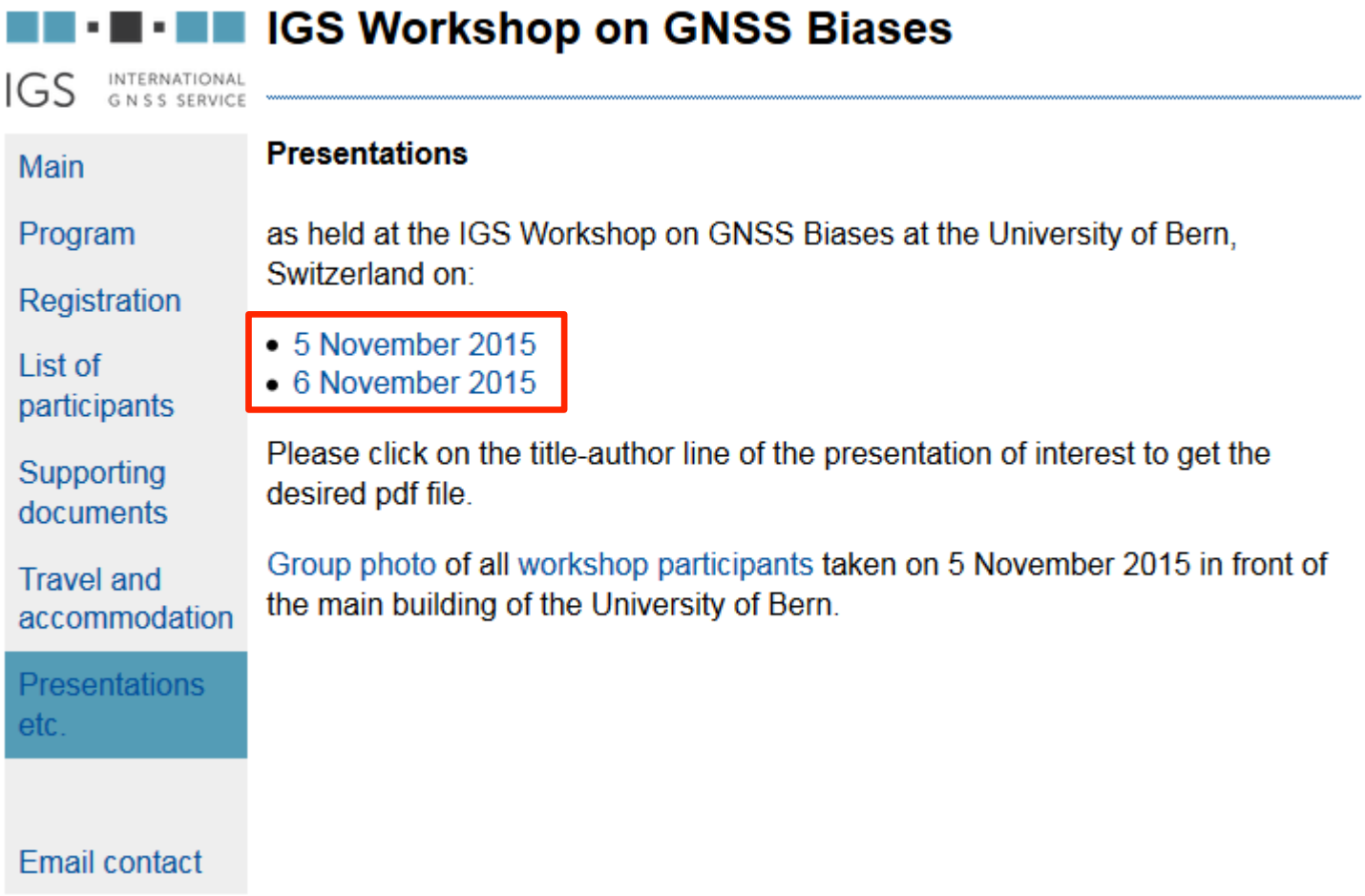
IGS Workshop on GNSS Biases 2015 (5 November 2015, with 31 participants)

IGS Bias WS 2016 Presentations



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Presentations

as held at the IGS Workshop on GNSS Biases at the University of Bern, Switzerland on:

- 5 November 2015
- 6 November 2015

Please click on the title-author line of the presentation of interest to get the desired pdf file.

Group photo of all workshop participants taken on 5 November 2015 in front of the main building of the University of Bern.

Bias-SINEX V1.00: Three Format Blocks

The proposed format is based on the SINEX Format [SINEX 2.02]. A number of format blocks may be taken directly from [SINEX 2.02], in particular:

```
FILE/REFERENCE
SITE/ID
SITE/RECEIVER
```

Some other format blocks are defined within this document:

```
BIAS/DESCRIPTION       (Mandatory)
BIAS/RECEIVER_GROUPS   (Optional)
BIAS/SOLUTION          (Mandatory)
```

Bias-SINEX V1.00: Main Features

2.2. Main Features of SINEX_BIAS

The `BIAS/SOLUTION` format structure of SINEX_BIAS V1.00 does allow the following main features:

- biases are specified for a give time interval of validity, defined by start and end time;
- biases may be augmented by their slope parameters;
- support of biases responding to: (i) *system*, (ii) *satellite*, (iii) *receiver*, (iv) *satellite-receiver*, and even (v) biases attributed to (user-defined) *receiver groups*;
- *differential* (relative) **or** *observable-specific* (pseudo-absolute) bias parameters;
- consideration of bias parameters with respect to *code* **and** *phase* observations;
- the possibility to define *GNSS observable groups* (to be treated with one common bias parameter).

Bias-SINEX V1.00: Representation in Time

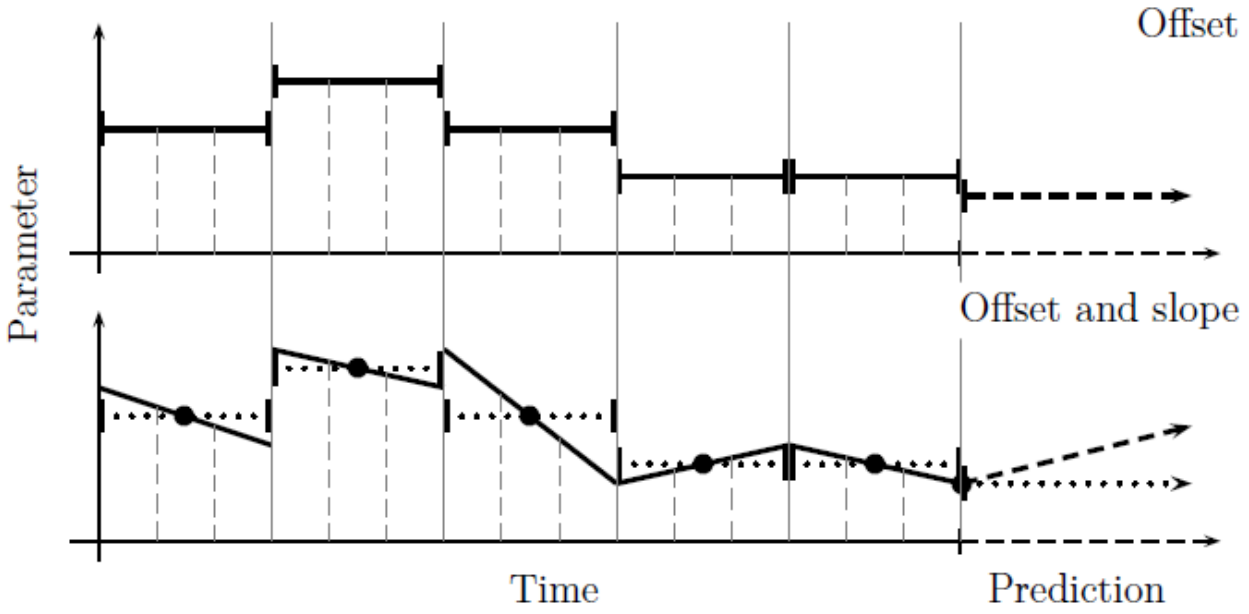

Figure 1: Bias parameter representation *without* (top) and *with* slopes (bottom), as supported by the Bias-SINEX V1.00.

Bias-SINEX V1.00: Three Types of Biases

6.3. Three Types of Signal Biases

We distinguish between three types of signal biases:

- **Observable-specific Signal Bias**, labeled with **OSB**, or $B_{\mathrm{O(constellation,observable)}}$;
- **Differential Signal Bias**, labeled with **DSB**, or $B_{\mathrm{D(constellation,observable1,observable2)}}$;
- **Ionosphere-free linear combination Signal Bias**, or simply **Ionosphere-free Signal Bias**, labeled with **ISB**, or $B_{\mathrm{I(constellation,observable1,observable2)}}$.

The terminology introduced here is based on the outcome of a dedicated e-mail discussion carried out after the Bias Workshop 2015. The (previously used) term "Code," was replaced by "Signal," as the SINEX_BIAS Format now also support biases with respect to GNSS phase observations.

Bias-SINEX V1.00: Bias Arithmetics

6.1. Sign Convention

The following sign convention is used for bias values:

$$\text{bias} = \text{observation} - \text{true (or unbiased) observation} \tag{3a}$$
$$\text{observation} = \text{true observation} + \text{bias} \tag{3b}$$
$$\text{true observation} = \text{observation} - \text{bias} \tag{3c}$$

Numerical example: ground truth 11, observed 7, bias (or error) −4.

6.2.2. Satellite and Receiver Bias Components (and Total Bias)

The **total bias** (or overall bias), if a separation into a satellite component, $B_{\text{satellite}}$, and into a receiver component, B_{receiver}, is assumed, is defined as follows:

$$B_{\text{total}} = B_{\text{satellite}} + B_{\text{receiver}} \tag{5}$$

6.3.2. Ionosphere-free Signal Bias (ISB)

The Ionosphere-free Signal Bias (ISB) has to be interpreted as

$$B_{\text{I(G,C1W,C2W)}} = \kappa_1 B_{\text{(G,C1W)}} + \kappa_2 B_{\text{(G,C2W)}}, \tag{11}$$

Bias SINEX Format Version 1.00

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Supporting documents for the workshop

- **Bias SINEX 0.01**: Proposal for a format to exchange information on GNSS biases
  Format description (draft only)
- **Bias SINEX 1.00**: Finalized draft version
  Format description (Proposed DRAFT Nov. 4, 2015)
  Format description (Finalized DRAFT Feb. 7, 2016, for **IGSWS2016**)
  Message concerning naming of biases (Dec. 4, 2015)
- **IONEX 1.0**: Format to exchange ionosphere maps
  Format description
- **IONEX 1.1**: Format update (concerning multi-GNSS DCBs)
  Format description (DRAFT)

www.biasws2015.unibe.ch

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Implications for IGS Bias Products (1/2)

- IGS ACs should start to consider the bias format standards of *Bias-SINEX Format Version 1.00*.
- *CC2NONCC RINEX2 conversion utility* should no longer be used.
- *Classic GPS P1-C1 DCB corrections* should be made directly by the analysis software.
- In case of MGEX multi-GNSS analysis or GLONASS analysis, there seems to be a necessity that an AC is capable to determine “ISB” bias parameters as such bias parameters become crucial in a **clock analysis of two or more GNSS systems**.

Implications for IGS Bias Products (2/2)

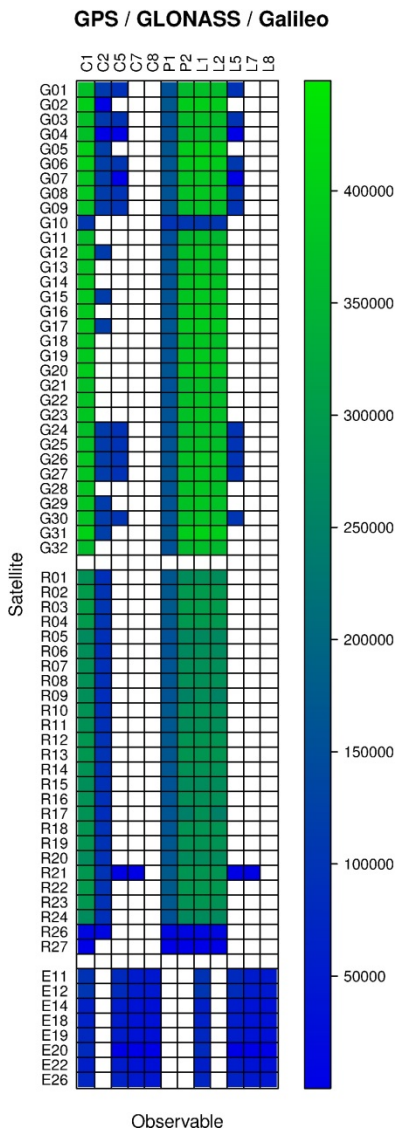
- GPS (and GLONASS) P1-P2 DCB satellite and receiver estimates shall no longer be included in IGS IONEX files.
- A minor update (to V1.1) is proposed for the IONEX Format.

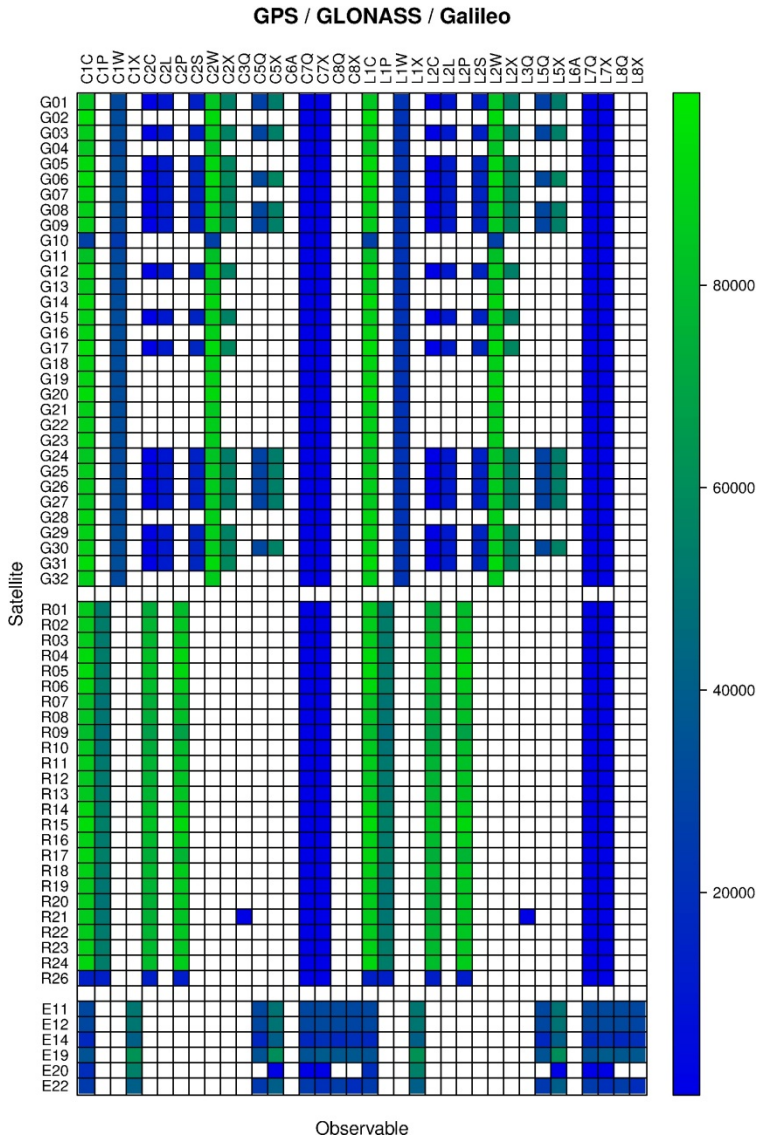
- At AIUB, implementation of (OCB) bias parameter handling into the development version of the Bernese GNSS Software (V5.3) is in progress:
  - multi-GNSS flexibility
  - GNSS observation selection according to given priority list
  - OSB-like bias parameter setup
  - with flexibility for parameter manipulations at NEQ level
- Content of current GPS/GLONASS DCB data archive will be converted into Bias-SINEX Format V1.00
- CODE ISB products are internally available for the IGS (GPS/ GLONASS) and the MGEX analysis product (covering 5 GNSS).

Bias and Calibration Splinter Meeting

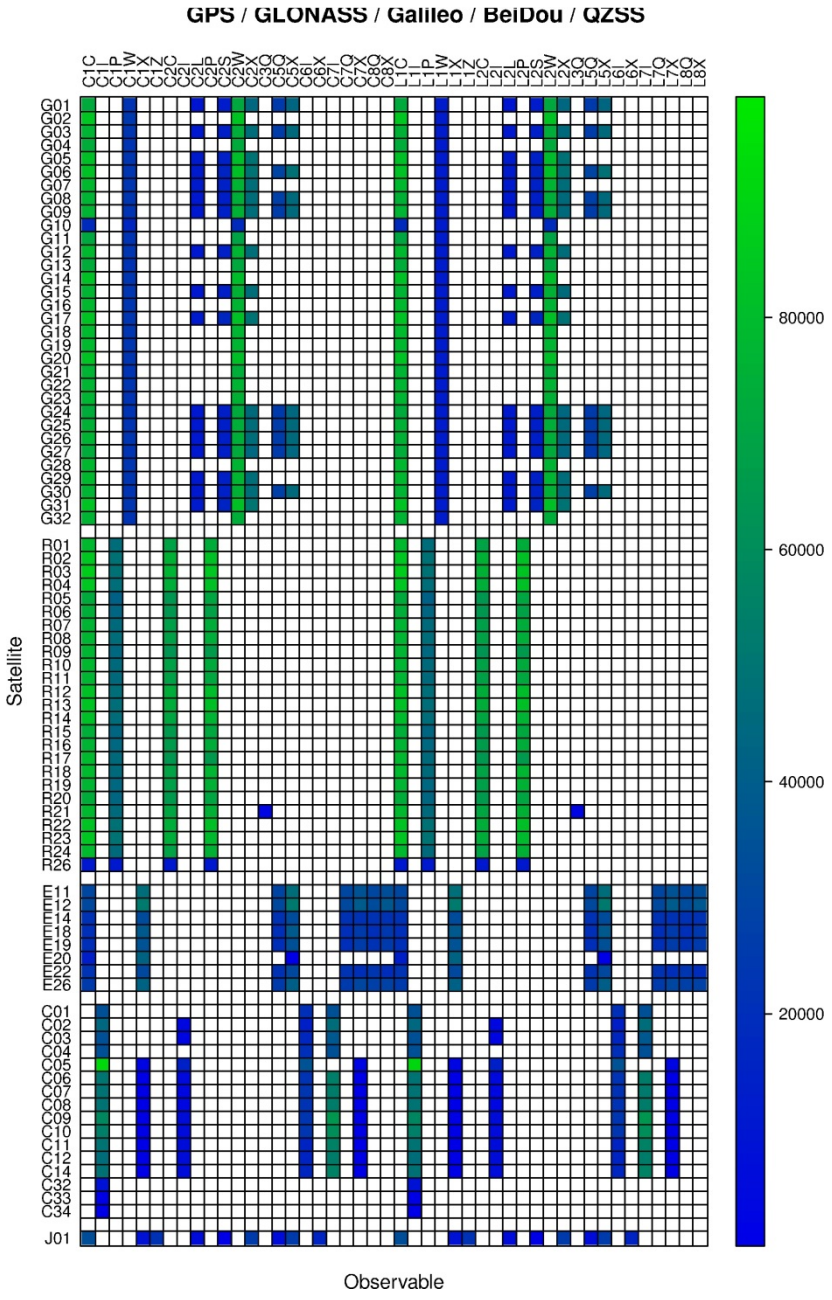
- Tuesday 9 February, 15:00-17:00
- Theatre A
- **Bias-SINEX Format** will be the primary topic for discussion.
- The format description is available at: www.biasws2015.unibe.ch
- Any input, or feedback is welcome.

GNSS Observables in IGS RINEX2 & RINEX3

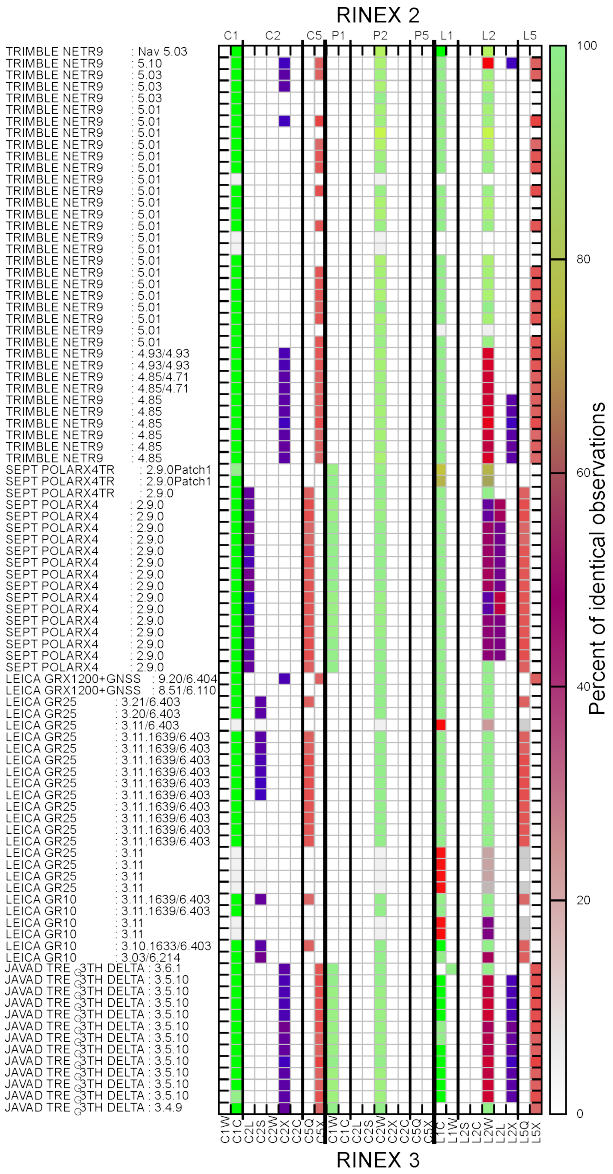




RINEX3 (for 5 GNSS)



Comparison of RINEX2/RINEX3 GPS Observations



SINEX_BIAS: Update from V0.01 to V1.00 …

```
%=BIA 1.00 PF2 11:180:59736 PF2 11:113:86385 11:114:86385 P 04774 2 SINEX_BIA
*-------------------------------------------------------------------------------
* Bias Solution INdependent EXchange Format (Bias-SINEX)
*-------------------------------------------------------------------------------
+FILE/REFERENCE
 REFERENCE FRAME     IGS08
 DESCRIPTION         European Space Operation Center (ESOC)
 INPUT               ESOC solutions in normal equation format
 OUTPUT              ESOC solutions in Bias-SINEX format
 CONTACT             Tim.Springer@esa.int.nospam
 HARDWARE            Linux dgnl2 2.6.27.19-5-default #1 SMP 2009-02-28 04:40:21
 SOFTWARE            Napeos 3.6 TAS 07/06/2011
-FILE/REFERENCE
*-------------------------------------------------------------------------------
+BIAS/DESCRIPTION
*KEYWORD_________________________________ VALUE(S)_____________________________
 OBSERVATION SAMPLING                          300
 PARAMETER SPACING                           86400
 DETERMINATION METHOD                    CLOCK ANALYSIS
 BIAS MODE                               DIFFERENTIAL
 TIME SYSTEM                             G
 REFERENCE SYSTEM                        G
 REFERENCE OBSERVABLES                   E  C1C  C7Q
 REFERENCE OBSERVABLES                   G  C1W  C2W
 ZERO-MEAN CONDITIONS                    G    0    0    0    0    0    0    0
 ZERO-MEAN CONDITIONS                    E    1    0    0    1    0    0    0
-BIAS/DESCRIPTION
*-------------------------------------------------------------------------------
+BIAS/SOLUTION
*BIAS SVN_ PRN STATION__ OBS1 OBS2 BIAS_START__ BIAS_END____ UNIT __ESTIMATED_VALUE____ _STD_DEV___ __ESTIMATED_SI
 ISB  G    G   GIEN      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GKIR      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GKOU      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GLPG      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GMAL      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GMIZ      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GNNO      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GNOR      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GOUS      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GTHT      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GUSN      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  G    G   GVES      C1W  C2W  11:113:86385 11:115:00285 ns   0.000000000000000E+00 .000000E+00
 ISB  E    E   GIEN      C1C  C7Q  11:113:86385 11:115:00285 ns   -.157174143960592E+03 .259286E+02
 ISB  E    E   GKIR      C1C  C7Q  11:113:86385 11:115:00285 ns   -.153942459345551E+03 .259286E+02
 ISB  E    E   GKOU      C1C  C7Q  11:113:86385 11:115:00285 ns   -.163243805130824E+03 .259285E+02
 ISB  E    E   GLPG      C1C  C7Q  11:113:86385 11:115:00285 ns   -.151698143836368E+03 .259290E+02
 ISB  E    E   GMAL      C1C  C7Q  11:113:86385 11:115:00285 ns   -.156472089904428E+03 .259285E+02
 ISB  E    E   GMIZ      C1C  C7Q  11:113:86385 11:115:00285 ns   -.167156432084244E+03 .259321E+02
 ISB  E    E   GNNO      C1C  C7Q  11:113:86385 11:115:00285 ns   -.156922861008147E+03 .259665E+02
 ISB  E    E   GNOR      C1C  C7Q  11:113:86385 11:115:00285 ns   -.153679440866705E+03 .259285E+02
 ISB  E    E   GOUS      C1C  C7Q  11:113:86385 11:115:00285 ns   -.101593337222667E+03 .259439E+02
 ISB  E    E   GTHT      C1C  C7Q  11:113:86385 11:115:00285 ns   -.159918985571303E+03 .259356E+02
 ISB  E    E   GUSN      C1C  C7Q  11:113:86385 11:115:00285 ns   -.149146613879327E+03 .259279E+02
 ISB  E    E   GVES      C1C  C7Q  11:113:86385 11:115:00285 ns   -.156221372596643E+03 .259288E+02
-BIAS/SOLUTION
*-------------------------------------------------------------------------------
%=ENDBIA
```

Bias-SINEX V1.00: SVN/PRN/STATION Usage

5.2. Notes on SVN/PRN and STATION Usage in BIAS/SOLUTION Block

The fields SVN/PRN and STATION may used for coding of biases with four different characteristics:

- **Satellite bias:** If a bias depends only on a satellite, SVN/PRN should be filled, STATION may be left empty.
- **Station bias:** If a bias depends only on a station and a particular GNSS, STATION should be filled and SVN/PRN should have the system code only (e.g. "G", "R", "E" for GPS, GLONASS, Galileo).
- **Satellite-station (satellite-receiver) bias:** If a bias depends on both satellite and station, all three fields, SVN/PRN/STATION, should be used.
- **System bias:** If a bias depends only on a particular GNSS, SVN/PRN should have the system code only (e.g. "G", "R", "E" for GPS, GLONASS, Galileo).

Bias-SINEX V1.00: Examples for Four Cases

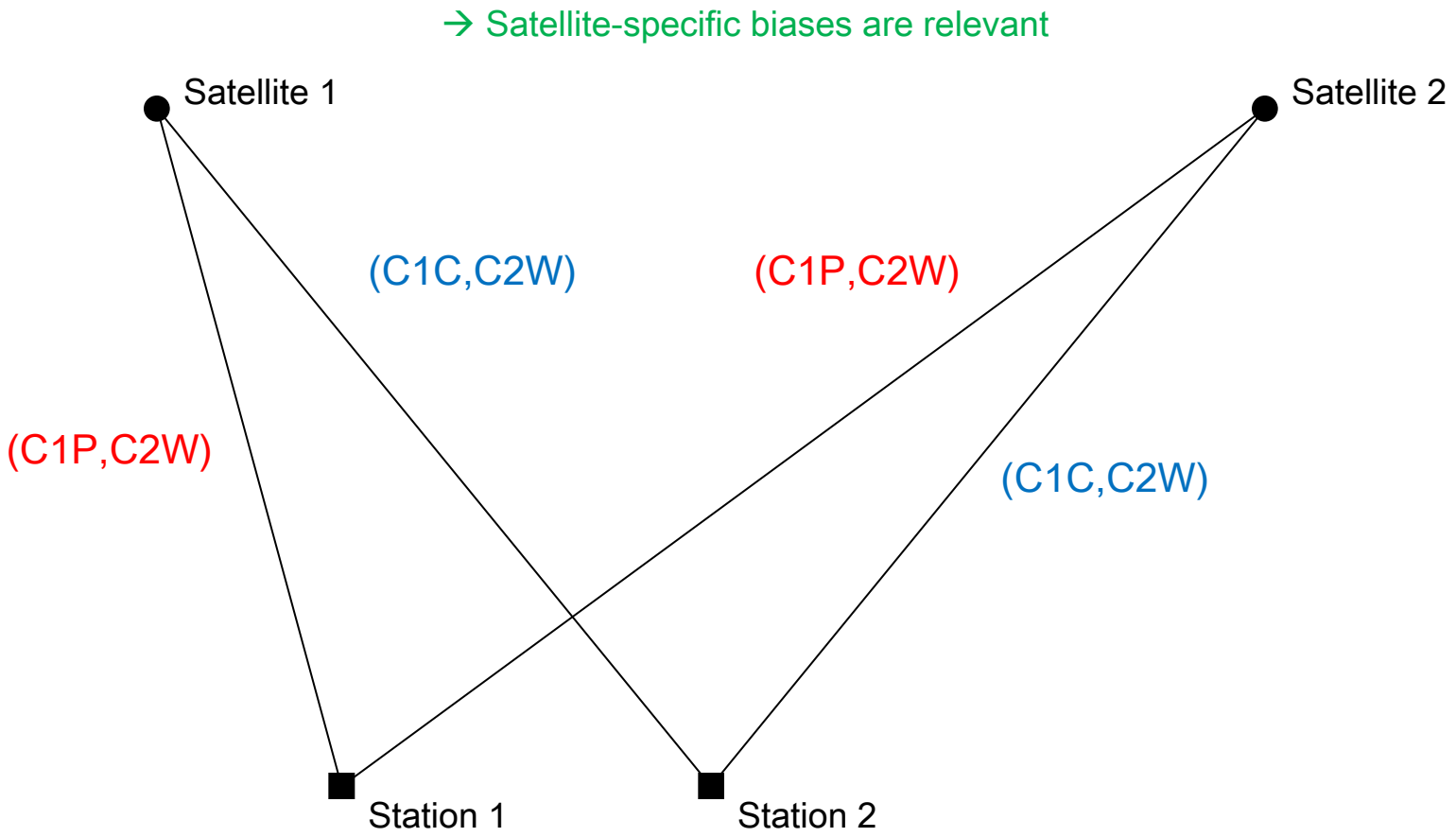
Examples for the four cases (listed above) may look like:

```
*-------------------------------------------------------------------------------
+BIAS/SOLUTION
*BIAS  SVN_  PRN  STATION__  OBS1  OBS2  BIAS_START__  BIAS_END____  UNIT  __ESTIMATED_VALUE____  _STD_DEV___  __EST
 DSB   G063  G01              C1W   C1C   15:276:00000  15:276:86399  ns    0.148022937908458E+01  .398201E-01
 ISB   C     C    ABMF        C1I   C7I   15:276:00000  15:276:86399  ns    0.240909461328850E+02  .835246E+00
 ISB   R730  R01  AUCK        C1P   C2P   15:276:00000  15:276:86399  ns    0.104868834341878E+02  .101419E+01
 ISB   G     G                C1W   C2W   15:276:00000  15:276:86399  ns    0.000000000000000E+00  .000000E+00
-BIAS/SOLUTION
*-------------------------------------------------------------------------------
```

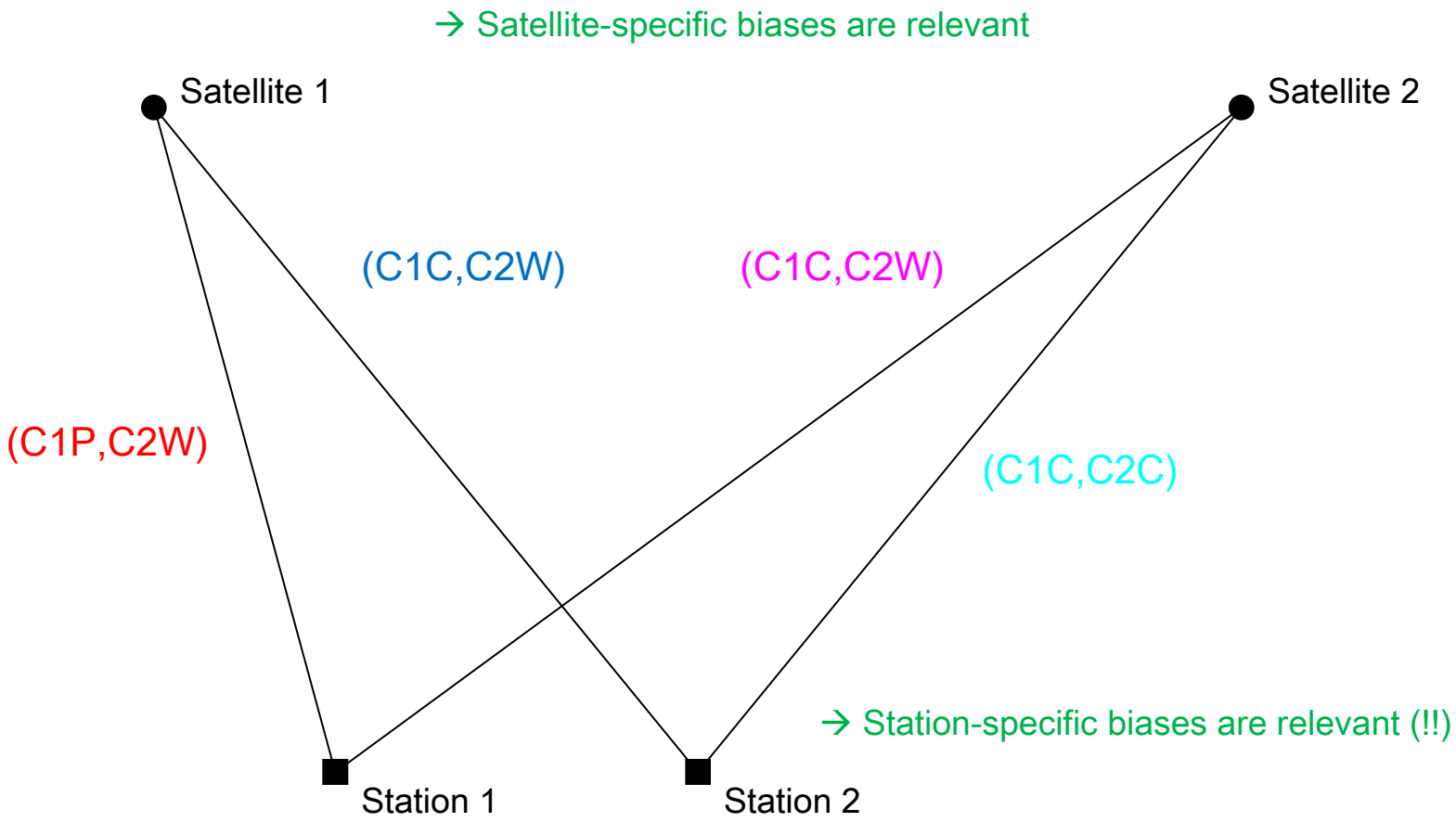
Bias-SINEX V1.00: Receiver Groups

```
+BIAS/RECEIVER_GROUPS
*STATION__ C GROUP____ DATA_START__ DATA_END____ RECEIVER_TYPE_______ RECEIVER_FIRMWARE___
 MAOO      G @MP0      15:276:00000 15:276:86399 JAVAD TRE-G3TH DELTA 3.6.4
 SIN0      G @MP0      15:276:00000 15:276:86399 JAVAD TRE-G3TH DELTA 3.6.4
 SIN1      G @MP1TRI   15:276:00000 15:276:86399 TRIMBLE NETR9        5.10
 STFU      G @MP1JAV-1 15:276:00000 15:276:86399 JAVAD TRE-G3TH DELTA 3.6.4
 TEST      G @MP1JAV-2 15:276:00000 15:276:86399 JAVAD TR_VS          3.6.4
 XYYX      G @MP1TRI   15:276:00000 15:276:86399 TRIMBLE NETR5        4.93
 WTZZ      G @MP_      15:276:00000 15:276:86399 JAVAD TRE-G3TH DELTA 3.6.4
 MAOO      E @ALL      15:276:00000 15:276:86399 JAVAD TRE-G3TH DELTA 3.6.4
 SIN0      E @ALL      15:276:00000 15:276:86399 JAVAD TRE-G3TH DELTA 3.6.4
 SIN1      E @ALL      15:276:00000 15:276:86399 TRIMBLE NETR9        5.10
 STFU      E @ALL      15:276:00000 15:276:86399 JAVAD TRE-G3TH DELTA 3.6.4
 TEST      E @ALL      15:276:00000 15:276:86399 JAVAD TR_VS          3.6.4
 WTZZ      E @ALL      15:276:00000 15:276:86399 JAVAD TRE-G3TH DELTA 3.6.4
*-------------------------------------------------------------------------
*LEGEND:   G @MP0      Receivers with disabled multipath (MP) mitigation.
*LEGEND:   G @MP1JAV-1 JAVAD TRE-G3TH receivers with MPNEW   MP mitigation enabled.
*LEGEND:   G @MP1JAV-2 JAVAD TRIUMPH  receivers with MPNEW   MP mitigation enabled.
*LEGEND:   G @MP1TRI   TRIMBLE        receivers with Everest MP mitigation enabled.
*LEGEND:   G @MP_      Extra group with unknown MP mitigation mode.
*LEGEND:   E @ALL      No grouping for the indicated system.
*-------------------------------------------------------------------------
-BIAS/RECEIVER_GROUPS
*-------------------------------------------------------------------------
+BIAS/SOLUTION
*BIAS SVN_ PRN STATION__ OBS1 OBS2 BIAS_START__ BIAS_END____ UNIT __ESTIMATED_VALUE____ _STD_DEV___ __EST
 DSB  G001 G01 @MP0      C1W  C2W  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  G001 G01 @MP1TRI   C1W  C2W  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  G001 G01 @MP1JAV-1 C1W  C2W  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  G001 G01 @MP1JAV-2 C1W  C2W  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  G001 G01 @MP_      C1W  C2W  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  G002 G02 @MP0      C1W  C2W  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  G002 G02 @MP1TRI   C1W  C2W  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  G002 G02 @MP1JAV-1 C1W  C2W  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  G002 G02 @MP1JAV-2 C1W  C2W  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  G002 G02 @MP_      C1W  C2W  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  E001 E01 @ALL      C1X  C5X  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
 DSB  E002 E02 @ALL      C1X  C5X  15:276:00000 15:276:86399 ns   0.000000000000000E+00 .000000E+00
-BIAS/SOLUTION
*-------------------------------------------------------------------------
```

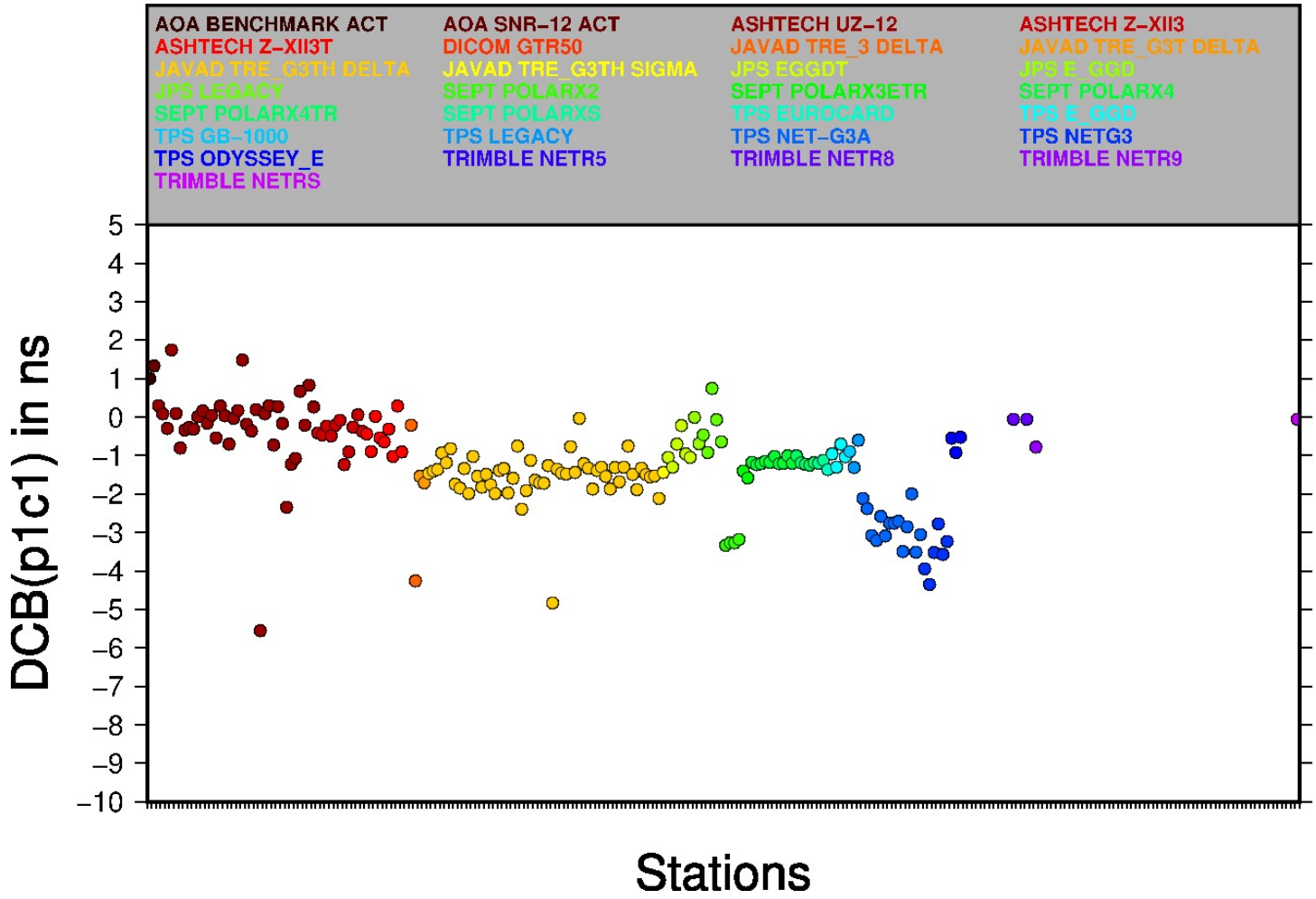
Mixture of different code observables (and biases!) is crucial for code-based widelane ambiguity resolution (1/2)



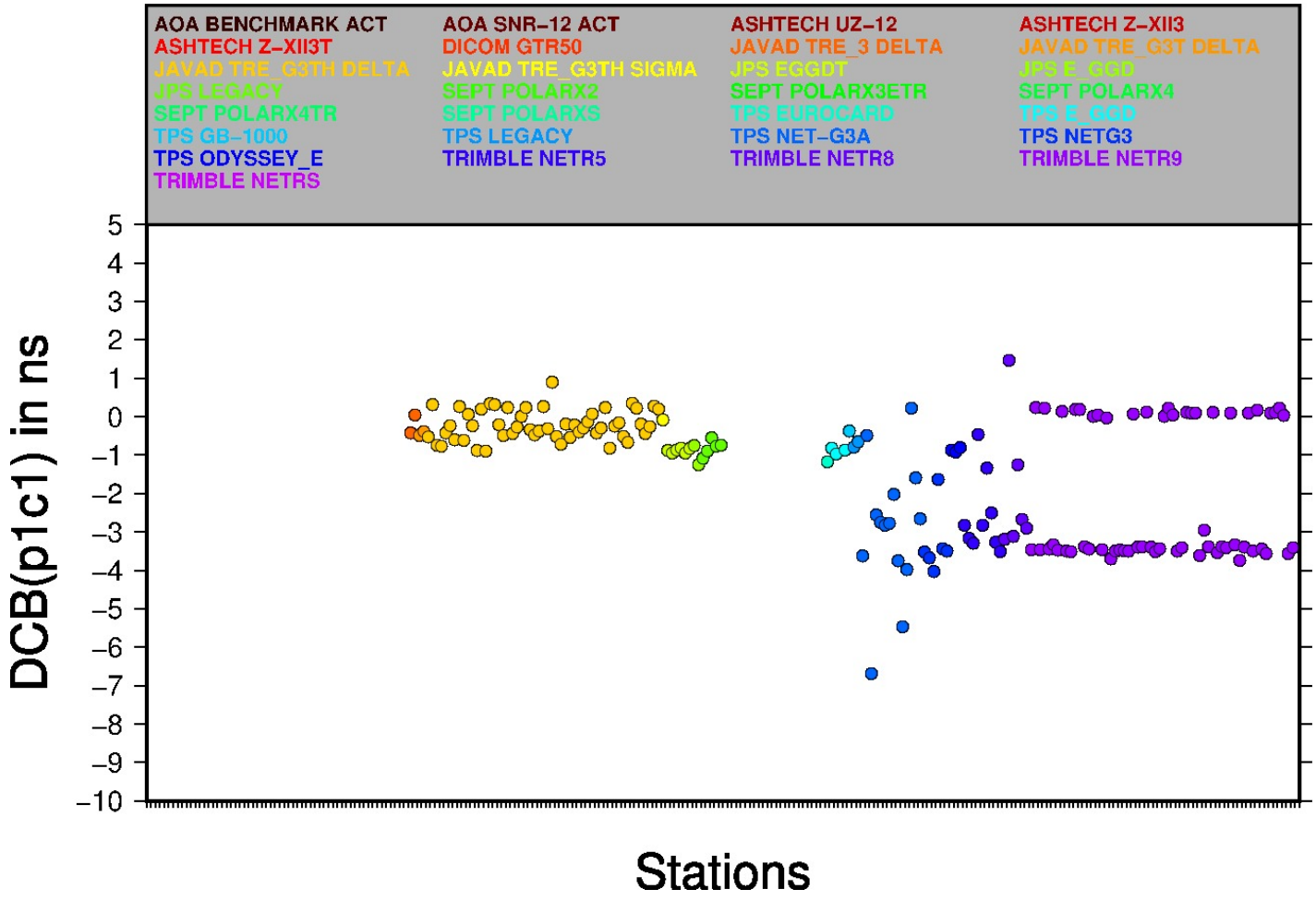
Mixture of different code observables (and biases!) is crucial for code-based widelane ambiguity resolution (2/2)



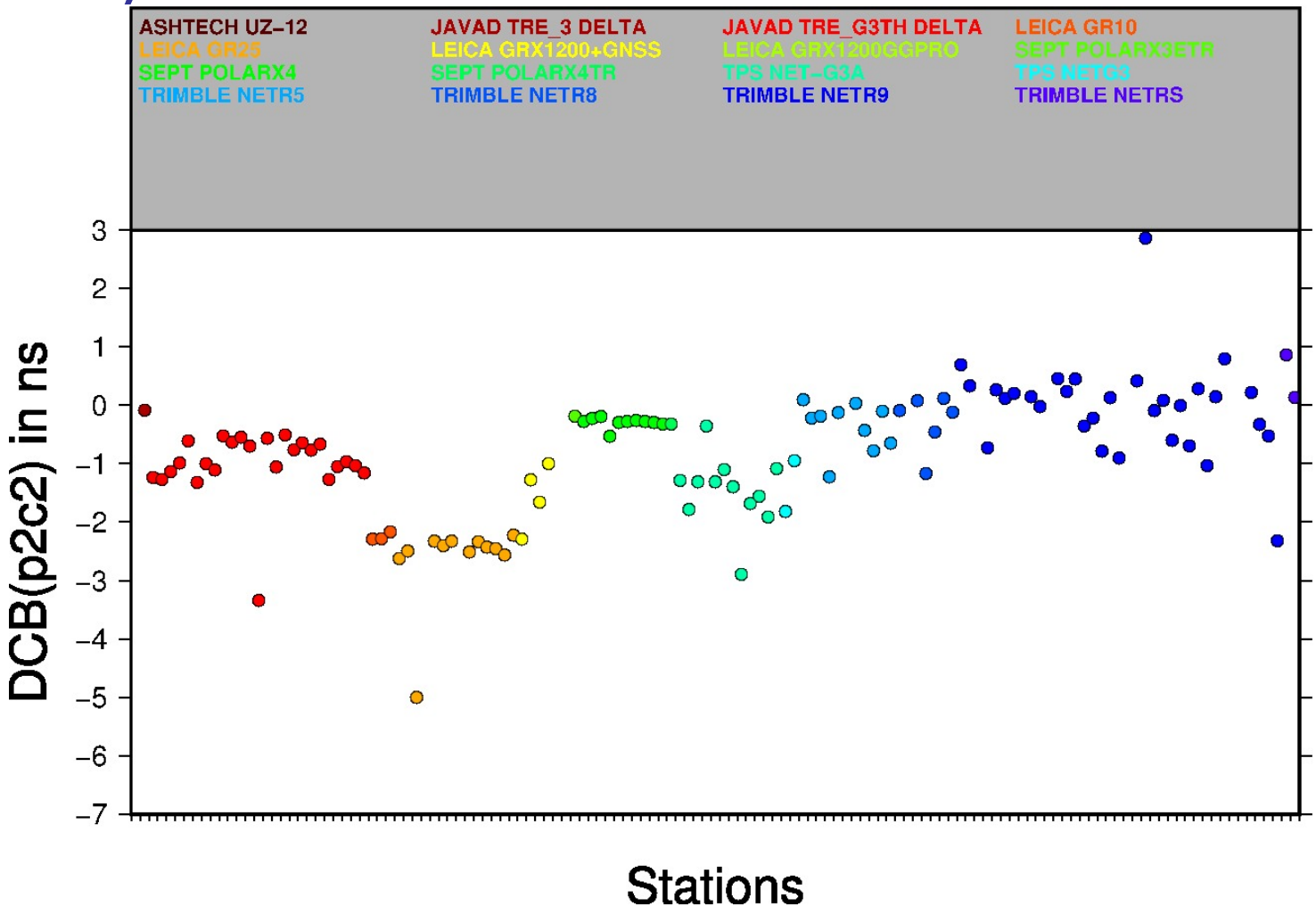
CODE's GPS P1-C1 DCB monthly solution, computed for September 2015 (directly from RINEX)



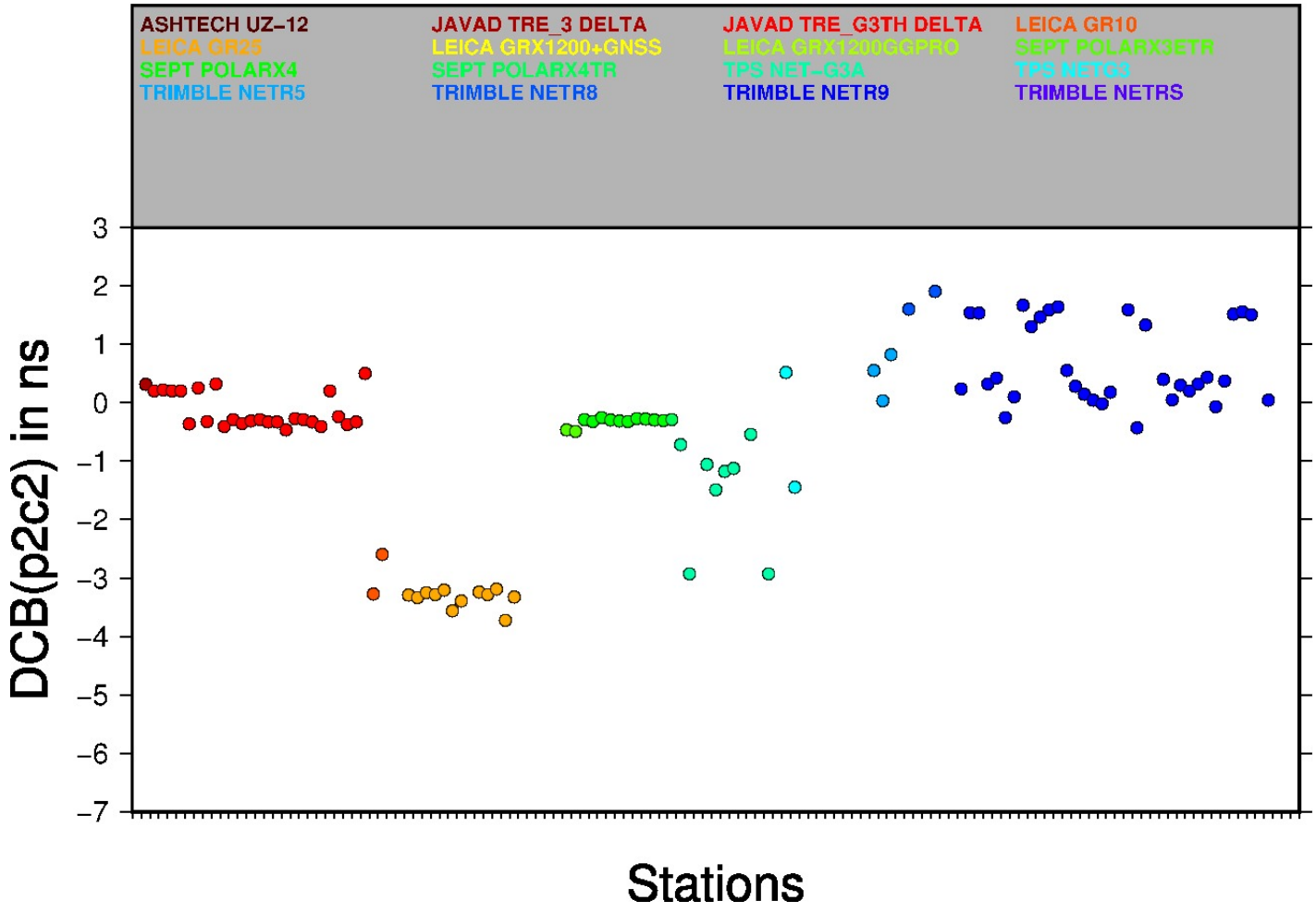
CODE's GLONASS P1-C1 DCB monthly solution, computed for September 2015 (directly from RINEX)



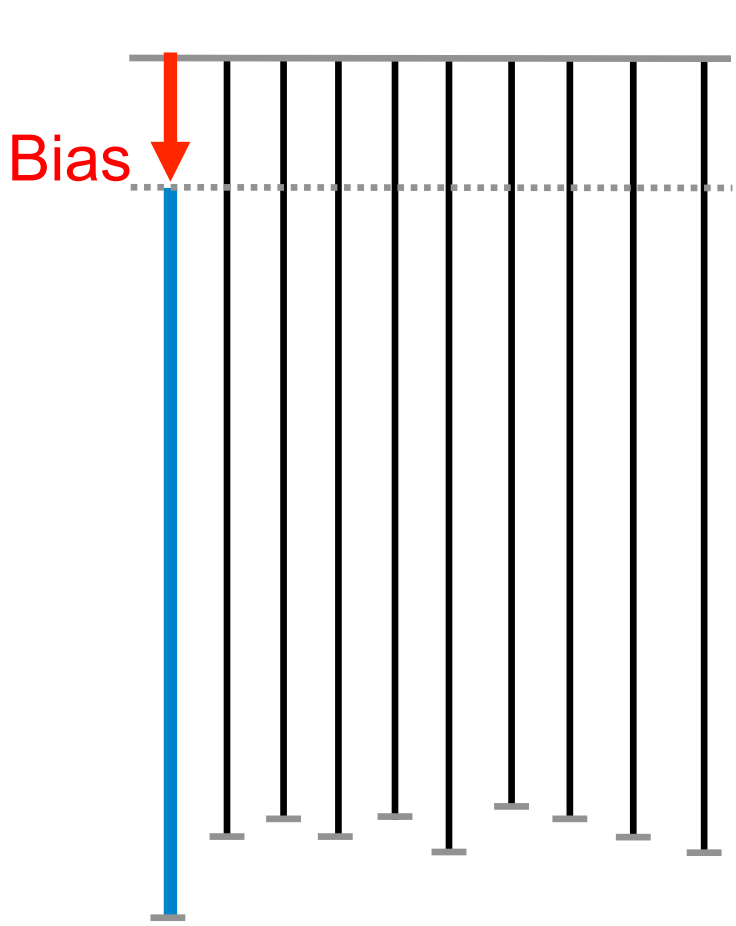
CODE's GPS P2-C2 DCB monthly solution, computed for September 2015 (directly from RINEX)



CODE's GLONASS P2-C2 DCB monthly solution, computed for September 2015 (directly from RINEX)



Illustrated impact of changed reference observable selection on clock and bias products (1/2)



Referenced satellite clock

Corrected satellite clock

Receiver clocks

Illustrated impact of changed reference observable selection on clock and bias products (2/2)