Multi-GNSS code bias handling: an observation specific perspective

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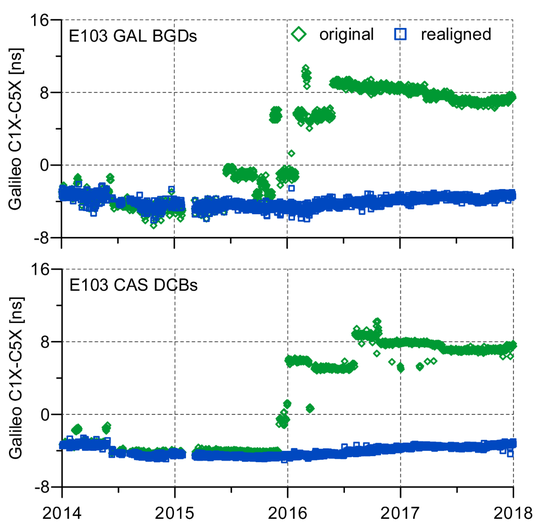
1. CAS's multi-GNSS bias analysis activities within IGS-MGEX

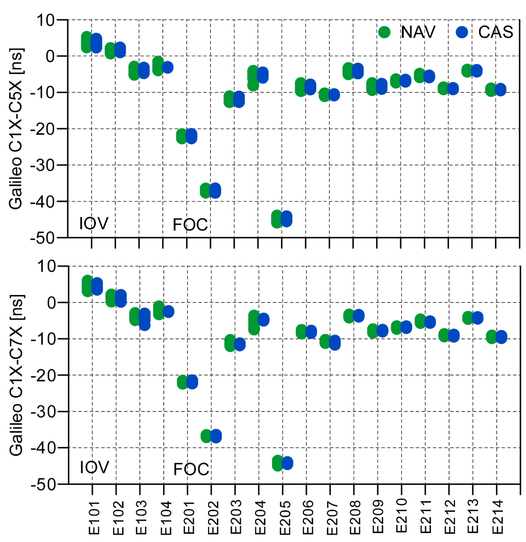
- Routine estimation of daily GPS, GLONASS, BeiDou and Galileo differential code biases (DCBs) since 10/2015
- CAS's multi-GNSS DCBs delivered to IGN & CDDIS archives since 12/2015
- A new alignment procedure added for the automatic generation of weekly and monthly multi-GNSS DCBs since mid-2017
- Analysis of Galileo E6 and QZSS signals added since 05/2018
- Supporting all trackable multi-GNSS signals within MGEX network

  GPS(9) + GLONASS(5) + BeiDou(2) + Galileo(7) + QZSS(6)
- Daily multi-GNSS DCB solutions available at CAS, IGN and CDDIS archives, weekly and monthly solutions available at CAS archive

  Daily DCB solution ftp://ftp.gipp.org.cn/product/dcb/mgex/
  Weekly DCB solution ftp://ftp.gipp.org.cn/product/dcb/weekbias/
  Monthly DCB solution ftp://ftp.gipp.org.cn/product/dcb/monthbias/



Original and aligned BGD (top) and DCB (bottom, CAS-estimated) for Galileo sat E103



Comparison of Galileo broadcast BGDs and precise DCBs during 2014-2017

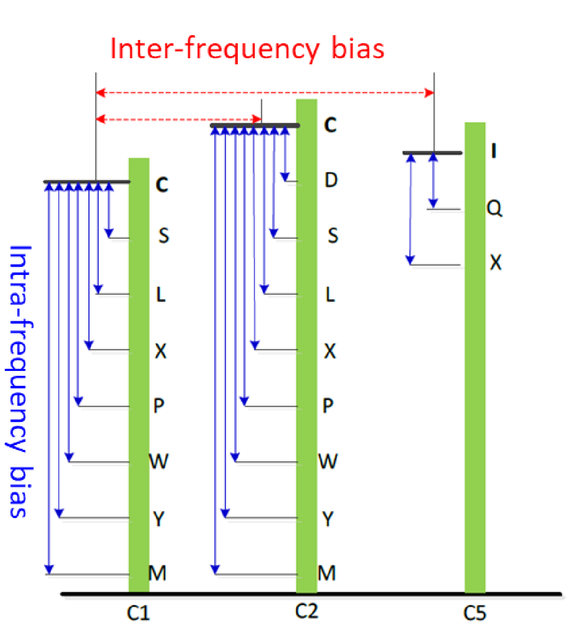
2. GNSS Observation-Specific Bias (OSB) concept

- OSB concept first proposed by the Center for Orbit Determination in Europe (CODE) Analysis Center (AC) team
- Defined in Bias-SINEX V1.00 in addition to differential signal bias (DSB)

GNSS pseudo range measurement equations

$$P_{L_{i,x}} = \rho_{los} + c\cdot\delta t_r - c\cdot\delta t^s + \tau^S_{L_{i,x}} + \tau_{r,L_{i,x}} + \alpha_i \cdot I + T + \varepsilon\left(P_{L_{i,x}}\right)$$
$$P_{L_{j,z}} = \rho_{los} + c\cdot\delta t_r - c\cdot\delta t^s + \tau^S_{L_{j,z}} + \tau_{r,L_{j,z}} + \alpha_j \cdot I + T + \varepsilon\left(P_{L_{j,z}}\right)$$

where, i/j denotes the signal frequency, and x/z denotes the signal type



Satellite DCB: $DCB^s\left(L_{i,x}, L_{j,z}\right) = \tau^S_{L_{i,x}} - \tau^S_{L_{j,z}}$

Receiver DCB: $DCB_r\left(L_{i,x}, L_{j,z}\right) = \tau_{r,L_{i,x}} - \tau_{r,L_{j,z}}$

OSB of CDMA signals

$$\tau^S_{L_{i,x}},\ \tau^S_{L_{j,z}},\ \tau_{r,L_{i,x}},\ \tau_{r,L_{j,z}}$$

OSB of FDMA signals

$$\left(\tau^S_{L_{i,x}} + \tau_{r,L_{i,x}}\right),\ \left(\tau^S_{L_{j,z}} + \tau_{r,L_{j,z}}\right)$$

3. Estimation of multi-GNSS OSBs at CAS

- Estimation of GNSS satellite and receiver OSB parameters in our ionosphere analysis (geometry-free combination)
- OSB parameter set: One bias set for each individual observable
- Bias reference: Satellite clock convention (ionosphere-free combination)
- Reference observation selection: Predefined priority list
- Datum definition: Zero-mean condition/constraint

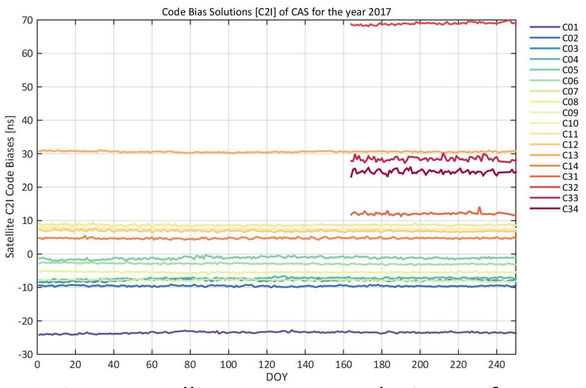
- For global TEC modeling (like SH function), different OSB parameterization applied for CDMA and FDMA (GLONASS, affected by *inter-channel bias*) signals:

  CDMA signals: Sat_{osb}, Rec_{osb} FDMA signals: SPR_{osb}
- For local TEC modeling, the satellite-plus-receiver (SPR) SPRdcb are first parameterized for both CDMA and FDMA signals at each individual contributing site:

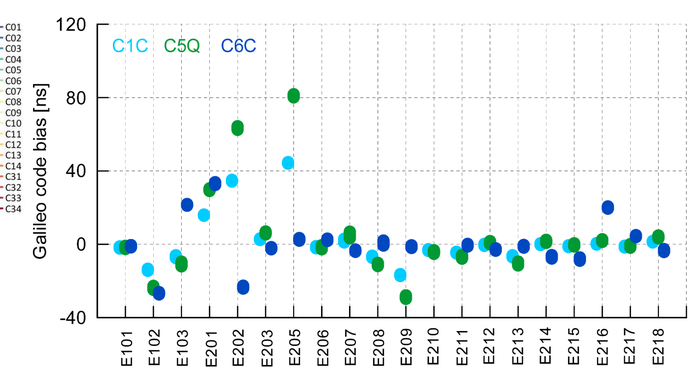
  OSB estimation: SPR_{osb} -> Sat_{osb}, Rec_{osb}
- A modified Generalized Triangular Series (mGTS, Polynomial + Fourier Series) function is now applied at CAS for local ionospheric TEC modeling

4. Results and analysis

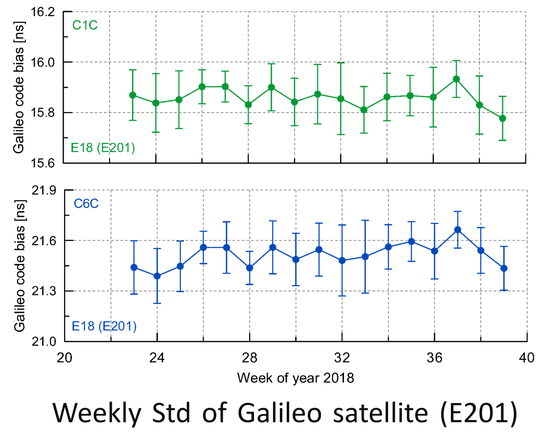
- Examples of CAS's multi-GNSS satellite OSB solutions



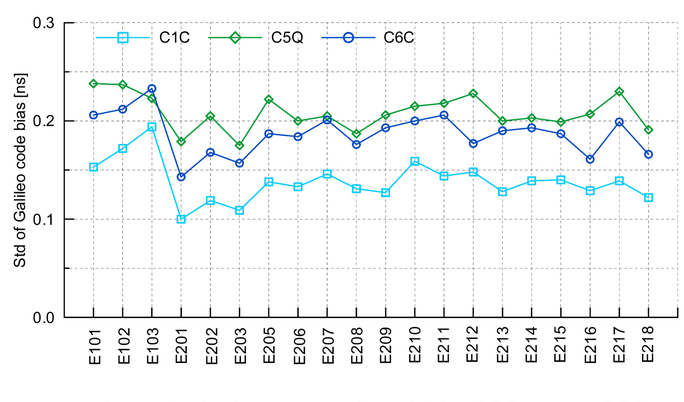
BeiDou satellite C2I OSB solutions of BDS-2 and BDS3-IOV (C31-C34)



Galileo satellite C1C, C5Q and C6C OSB solutions (doy 152-273, 2018)



Weekly Std of Galileo satellite (E201) C1C and C6C OSB solutions



Std of Galileo satellite C1C, C5Q and C6C OSB solutions (doy 152-273, 2018)

- Multi-GNSS bias handling in the concept of observation-specific biases since the 3rd quarter of 2017
- Local and global ionospheric modeling SW updated in supporting OSB estimation at CAS
- Independent OSB solutions from EPN, IGS & MGEX networks available
- Multi-GNSS OSB files in Bias-SINEX format available at CAS's ftp archive

  CAS's OSB solutions ftp://ftp.gipp.org.cn/product/dcb/
- Real-time satellite OSBs routinely broadcasted via CAS01 mount point

  CAS's Mount point (account required): products.gipp.org.cn/CAS01

References

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2. Arturo Villiger, Generalized Bias Handling in the Bernese GNSS Software and First Examples. IGS Workshop on GNSS Biases 2015.
3. Arturo Villiger et al., Determination of multi-GNSS pseudo-absolute code biases and varication of receivers tracking technology. EGU 2017.

Acknowledgments

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