# IGS-MGEX: Multi-GNSS Biases

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# Biases – Topics

- Clock reference signals
- Differential Code Biases (DCBs)
- Inter-System Biases (ISBs)
- BeiDou Inter-Satellite-Type Biases (ISTBs)
- Raw/uncombined processing


http://cliffordgarstang.com/wp-content/uploads/2013/01/Work_in_progress.png

# Clock Reference Signal

- For each constellation a conventional signal pair needs to be defined that provides the reference for satellite clock offset determination
- When using other signals than the reference signals, appropriate biases need to be applied
- Only part of these biases are provided through TGDs and ISCs transmitted in the GNSS navigation messages
- In a multi-GNSS scenario a comprehensive set of differential code biases is required to allow seamless use of all signals with a conventional clock product

# Conventional Clock Offsets

- Conventional clock offset

$$\mathrm{IF}(P_{S_{C1}}, P_{S_{C2}}) = \rho + \left[c\delta t^{\mathrm{rcv}} + \mathrm{IF}(B^{\mathrm{rcv}}_{S_{C1}}, B^{\mathrm{rcv}}_{S_{C2}})\right] - \left[c\delta t^{\mathrm{sat}} - \mathrm{IF}(B^{\mathrm{sat}}_{S_{C1}}, B^{\mathrm{sat}}_{S_{C2}})\right] + T$$

$c\overline{\delta t}^{\mathrm{rcv}}$ $c\overline{\delta t}^{\mathrm{sat}}$

Biases lumped into clock offsets

GPS: All clock offsets based on P(Y)-code ($S_{C1}$=C1W, $S_{C2}$=C2W)

- Same in terms of DCBs

$$P_S = \rho + c\overline{\delta t}^{\mathrm{rcv}} - c\overline{\delta t}^{\mathrm{sat}} + T + I\left(-\frac{f^2_{S_{C2}}}{f^2_{S_{C1}} - f^2_{S_{C2}}} \cdot \mathrm{DCB}_{S_{C1}-S_{C2}} + \mathrm{DCB}_{S-S_{C1}}\right)$$

TGD

Scaled DCB of conventional clock signals

DCB relative to 1st conventional clock signal

ISC

# MGEX DCB Product

- Differential Code Biases from ionosphere corrected pseudorange differences[(1)]
- Prototype Bias SINEX format
- Daily satellite and station DCBs; weekly satellite DCBs
- Supported constellations: GPS, GLO, BDS, GAL
- Available at

  ftp://cddis.gsfc.nasa.gov/pub/gps/products/mgex/dcb

- See presentation PY08-5

[(1)] Montenbruck et al., ION-ITM 2014

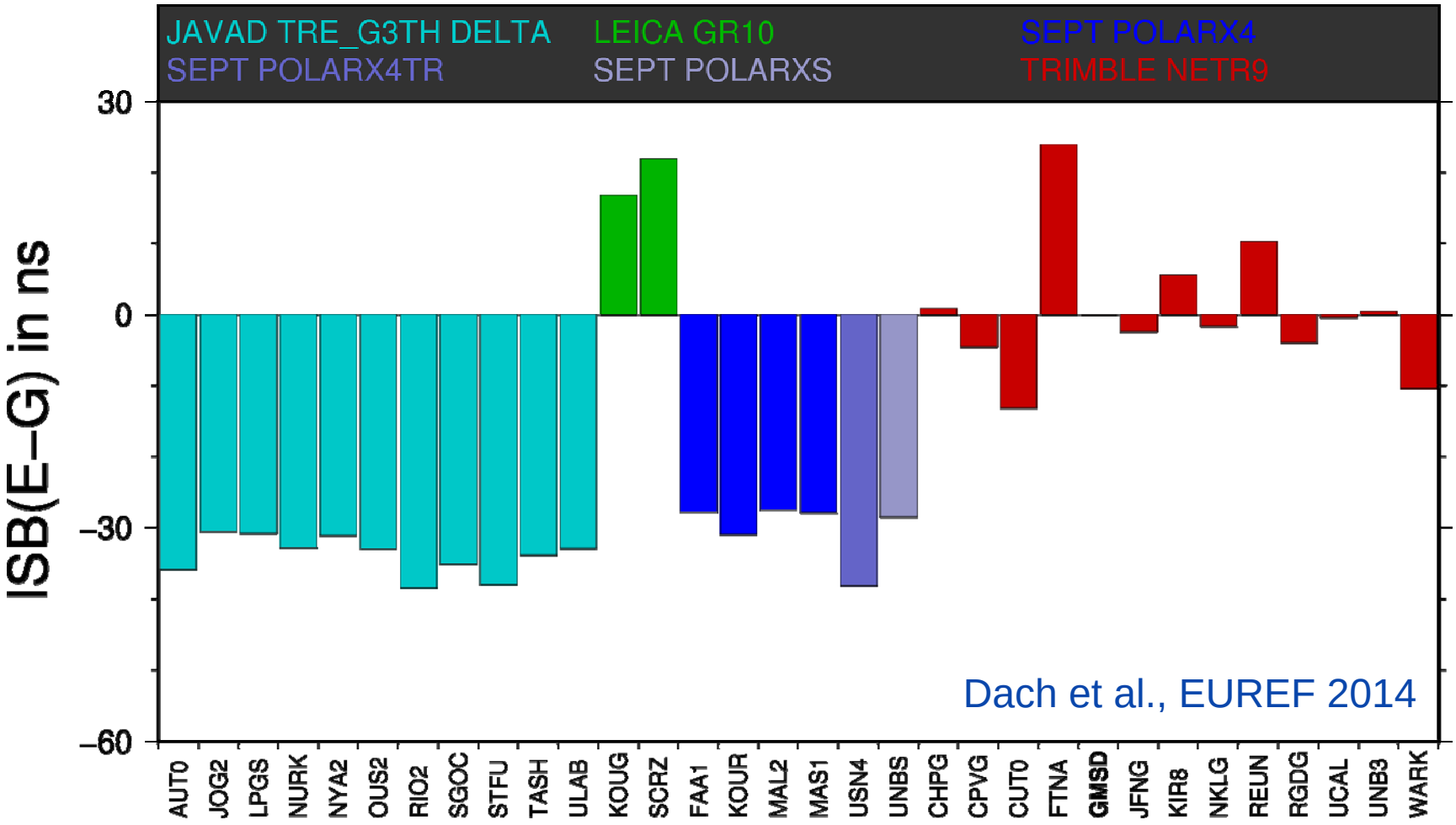
# DCB Product – Problems

- Improper compensation of ionospheric delays using GIMs
- Independence of DCBs for pilot-only vs. pilot+data tracking (no common receivers)
- Lack of observations for analysis of pilot-minus-data DCBs
- Lacking self-consistency,
  i.e. DCB(a-b)+DCB(b-c) ≠DCB(a-c)
  - Receiver dependence of satellite biases
  - Site multipath
- Wide range of station biases
  - Impact on estimated inter-system-biases in orbit/clock products

# Inter-System Biases

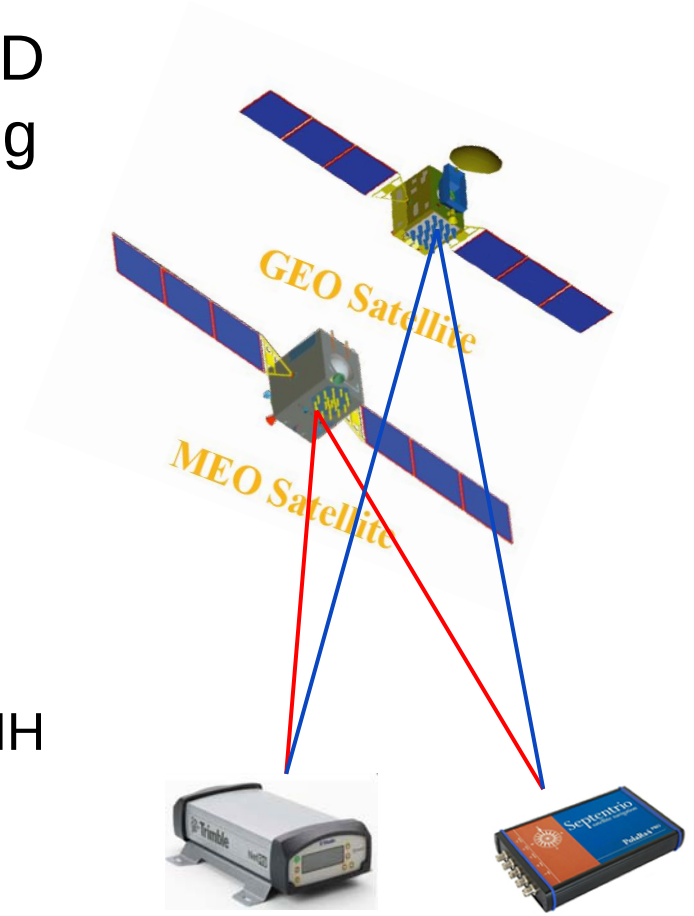
- Difference of constellation-specific receiver clock offsets
  - Solve-for parameter in PPP
  - Absorbs difference in system time scales of broadcast or precise clock products
- One degree of freedom in multi-GNSS orbit and clock determination (system time scale vs. ISB)
  - Define ISB=0 for selected reference receiver
  - Zero-mean constraint over all stations
- Realization of multi-GNSS system time scales depends largely on selected contraints and receiver set
  - Up to 100ns „uncertainty“ due to range of receiver DCBs

# GAL-GPS Inter-System-Bias (CODE)



# BeiDou Inter-Satellite-Type Biases

- Half-cycle ambiguities in BeiDou DD carrier phase observations involving
  - One GEO and one non-GEO (MEO/IGSO) satellite
  - Receivers of different brand (Trimble/Javad/Septentrio)
- Origin
  - Neumann-Hoffman (NH) secondary code for MEO/IGSO onlyEO
  - Mapping of logic levels ( “0”s/”1”s of NH code) to signal levels (-1 and +1) not explicitly specified in ICD




Nadarajah et al. (2013), Sensors, 13 (7): 9435–9463
Nadarajah et al. (2014), GPS Solutions (in press)

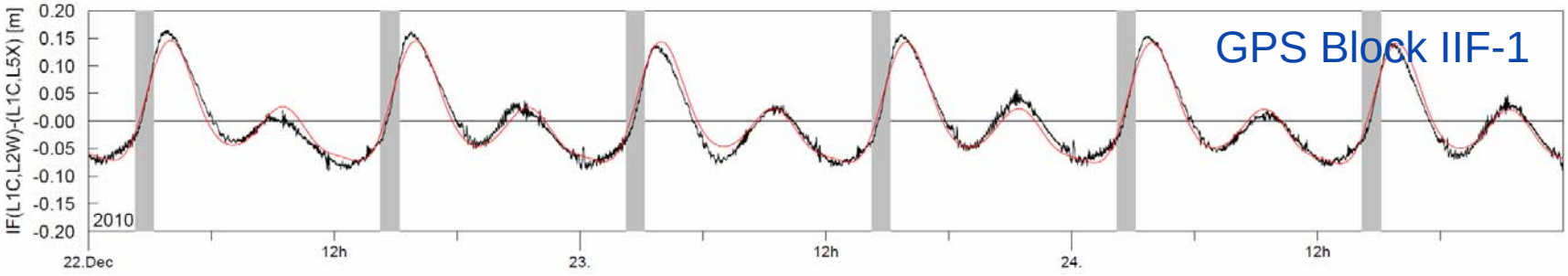
# Raw/Uncombined Processing (1)

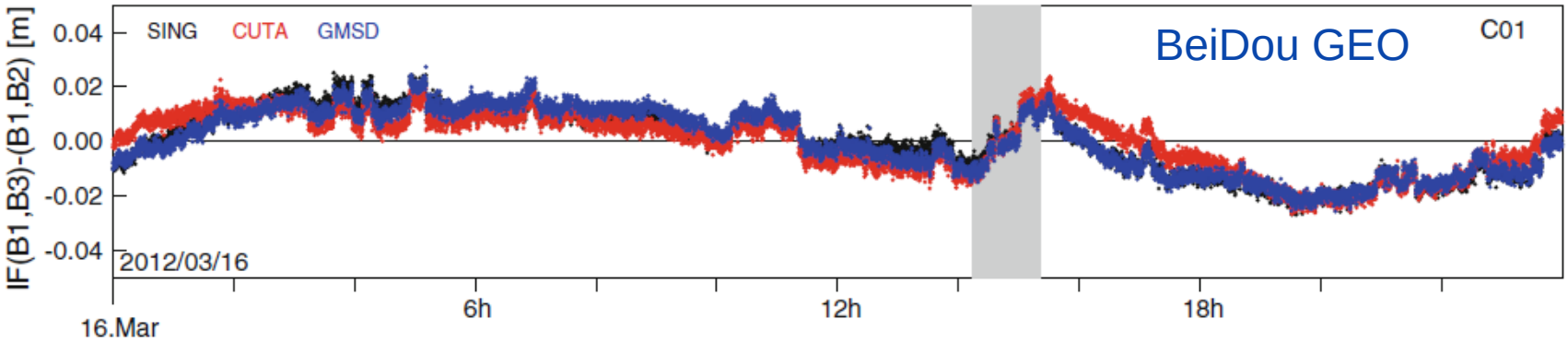
- New signals, multiple frequencies
  - GPS L1/L2/L5
  - Galilei E1, E5a, E5b, E5ab
  - BeiDou B1, B2, B3
- Multiplicity of signals suggests new treatment of ionospheric path delay
  - Uncombined observations, no ionosphere-free combination
  - Ionosphere delay (at reference frequency) treated as solve-for parameter
- Problems
  - how to treat biases (characterization, constraints)?
  - weighting of individual signals

Springer et al. AGU_G51B-02 (2013), Chen et al. CSNC 2014

# Raw/Uncombined Processing (2)

Inconsistency of ionosphere-free linear combinations from 3 signals




(see Montenbruck IGS Bias WS Jan 2012)

# Biases – Open Issues

- Systematic characterization of code and phase biases
- Need to agree on IGS Bias Data Format (Bias/clock RINEX vs Bias SINEX)
- Multiplicity of signals: need to decide on supported set and handling of tracking modes (pilot/data/pilot+data)
- How to cope with heterogenous receiver sets?
- Definition of clock reference signals for Galileo (E1/E5a?), BeiDou (B1/B2?) and post-2020 GPS
- New processing concepts (uncombined)?