
IGS WORKSHOP 2018



Signal-in-space Accuracy Analysis for BDS in 2016-2017

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Motivation

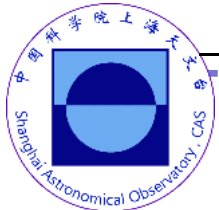
- BeiDou is different from other GNSS
 - Hybrid constellation: GEO/IGSO/MEO
 - Regional monitoring station networks
 - Nearly-static viewing geometry of GEO satellites
 - Time synchronization: TWTT and TWSTFT
 - Broadcast Ephemeris (BCE): orbit information from regional OD&TS, while clock information from TWTT and TWSTFT
 - Weak correlation between satellite orbit and clock of BeiDou navigation message





Motivation

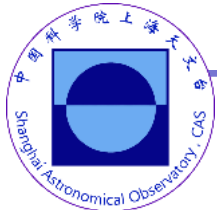
- BeiDou is different from other GNSS
 - Real-time satellite orbit monitoring and correction algorithm based on TWTT satellite clock: decrease the UERE, enhance the correlation of radial orbit and clock of BCE and improve the SISA
- SISRE monitoring [*Montenbruck et al., 2018*]
 - Orbit and clock state comparisons is preferred
 - Different conventions and pseudorange models for different types of ephemeris, **reference point: CoM**
 - Antenna offsets, group delay corrections, time systems,
 - Beidou-special: SISRE computation, and GEOs

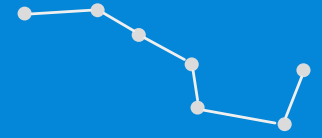




Antenna offsets reference point CoM

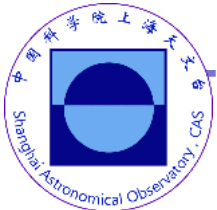
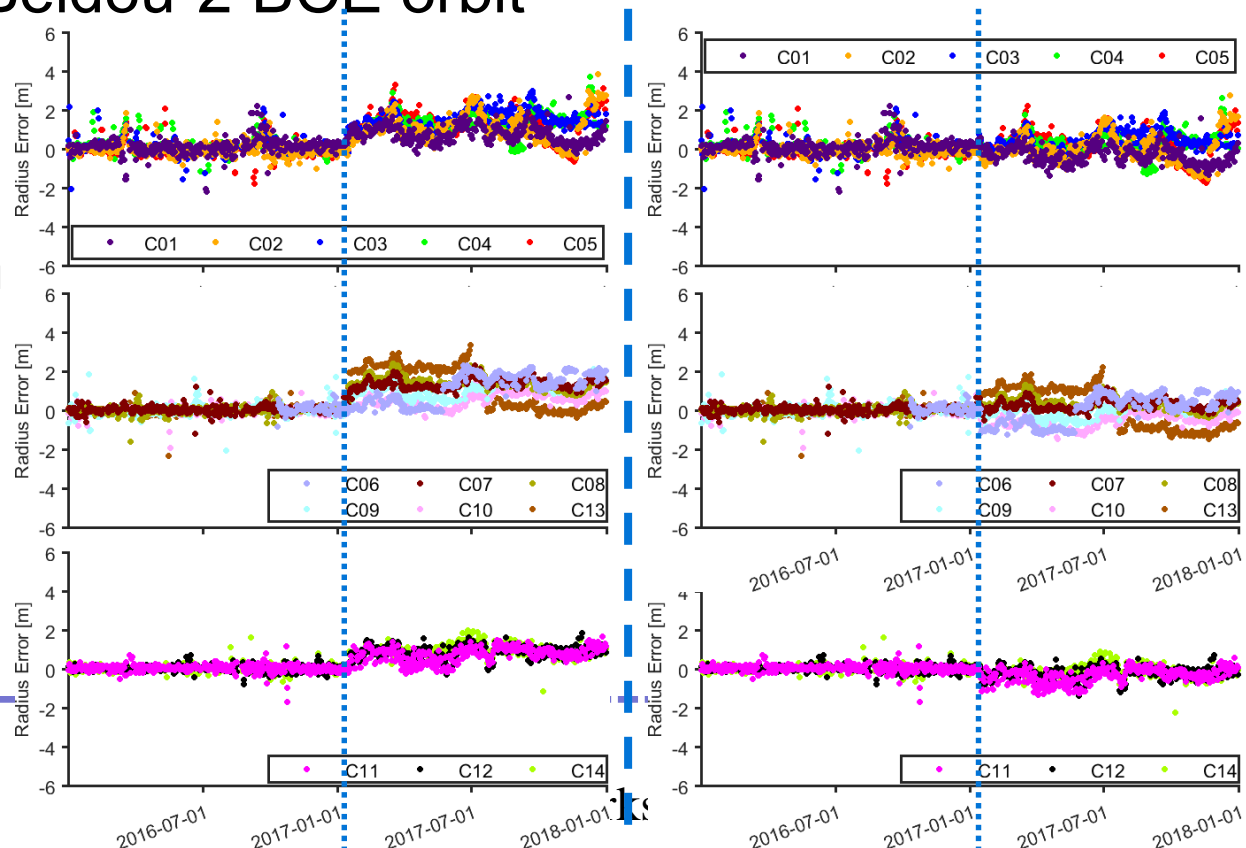
- Orbit state comparison
 - Ref. point of IGS/MGEX precise orbit: CoM
 - Ref. point of Beidou-2 BCE orbit: CoM? CoP
 - Clock state comparison
 - Ref. point of IGS/MGEX precise clock: different
 - CODE: IGS ANTEX model
 - GFZ: ESA estimation model [*Dilssner et al.*, 2014]
 - WHU: WHU estimation model [*Guo et al.*, 2016]
 - Ref. point of Beidou-2 BCE clock: CoP of B3 (or some point close to it)
 - **[0.6, 0. 1.1] is used**
-





Antenna offsets reference point CoM used

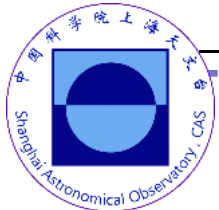
- Orbit state comparison
 - infer z through comparison [*Montenbruck et al., 2015*]
 - Ref. point of Beidou-2 BCE orbit
 - 2016, CoM
 - 2017, CoP
 - z-offset ~ 1.1m





Group delay corrections

- Different reference signals considered in clock comparison **B1/B2 Ionosphere-Free signal are defined**
- Ref. signal of IGS/MGEX precise clock **B1B2 IF**
- BeiDou-2 BCE clock **B3**
 - IF Corrections: $(f_1^2 \text{TGD}_1 - f_2^2 \text{TGD}_2) / (f_1^2 - f_2^2)$
 - Accuracy of TGD [Montenbruck et al., 2014]
- Comparison of TGD and offline DCB
 - MGEX DCB products of DLR and IGG
 - References: calibrated value or zero-mean condition
 - DCB comparison: reference satellite can be chosen

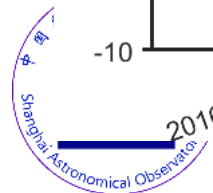
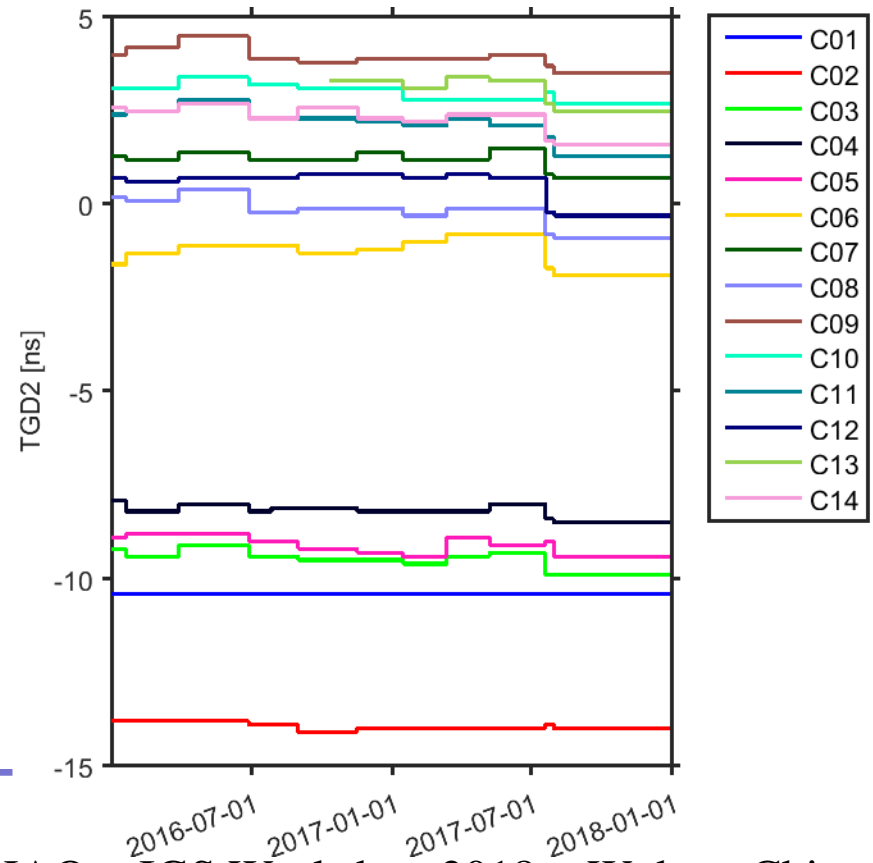
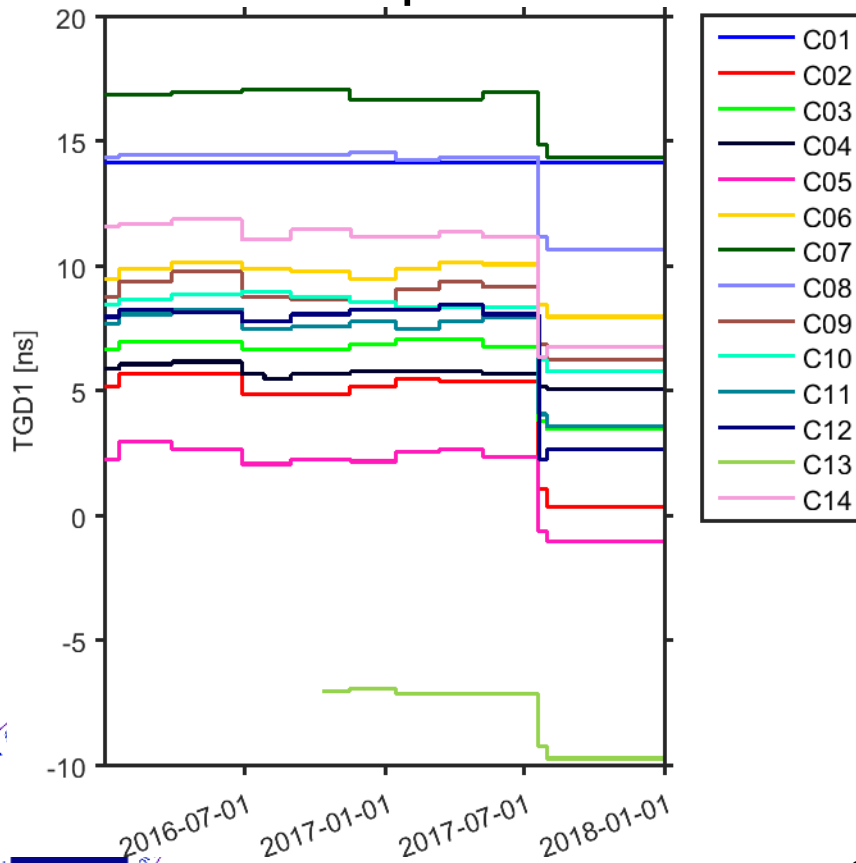




Group delay corrections

- Comparison of TGD and offline DCB

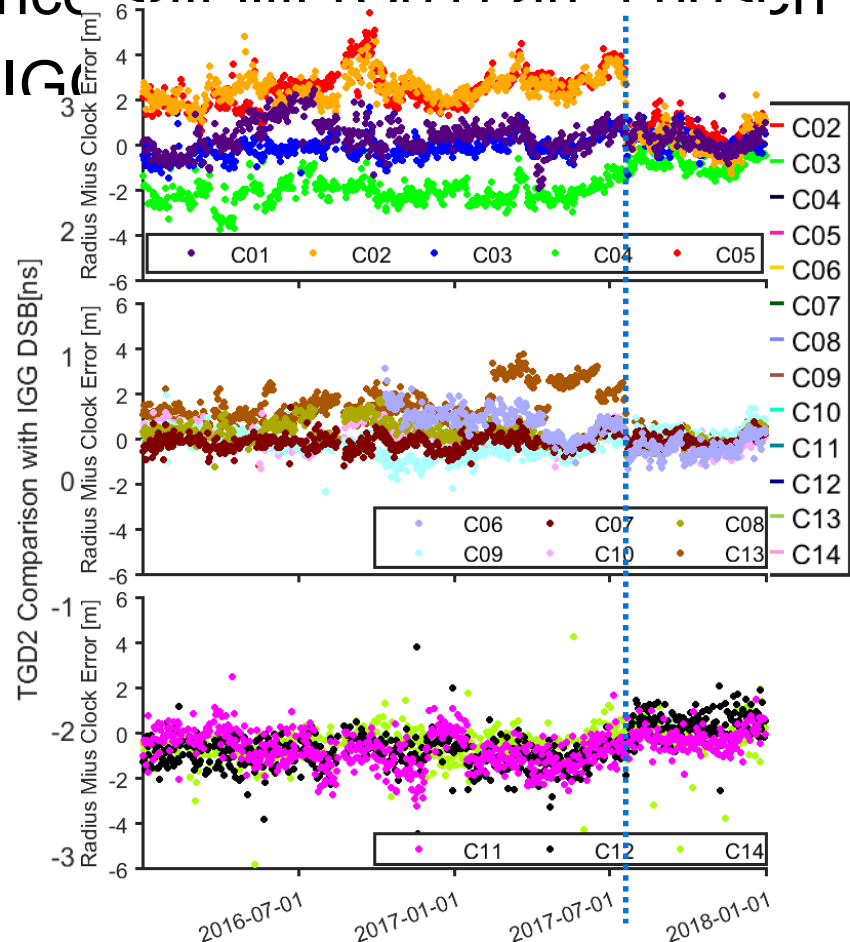
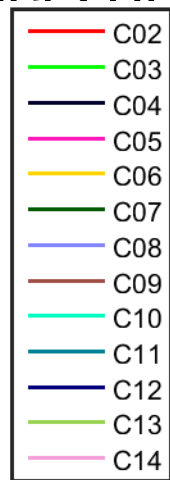
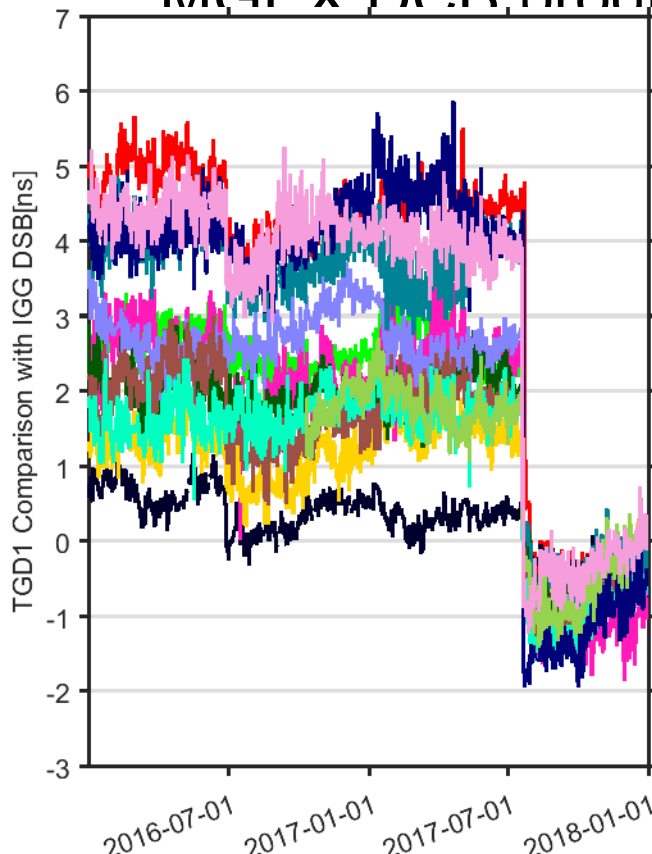
- TGD Update





Group delay corrections

- Comparison of TGD and offline DCB
 - DCB comparison: reference satellite (C01) are chosen
 - MGFEX DCB products of IGG





Time systems

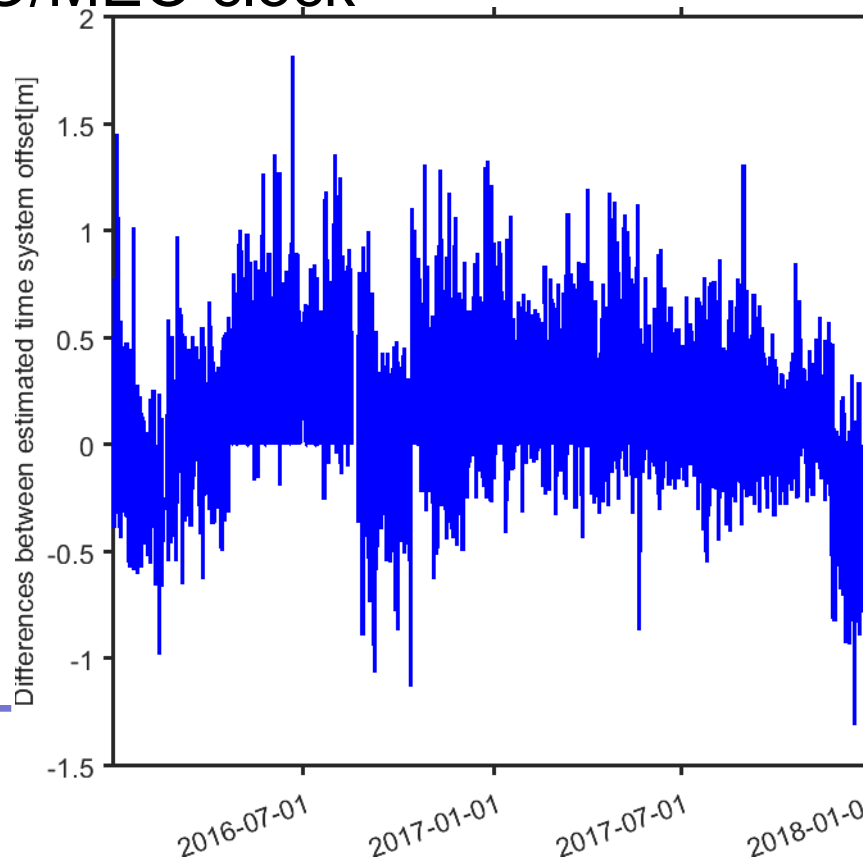
- Ref. of Beidou-2 BCE clock is BDT
- Ref. of Precise clock is product-specific time.
- Time system offset is unknown but common to all satellites that doesn't contribute to SISRE
- Robust mean value of epoch-wise clock difference
 - **Notice: Influences of GEO orbit errors on GEO clocks**
 - Mean value of IGSO/MEO clock diff. should be used?
 - Separation of orbit and clock error based on SLR?
 - While, small number of GEO SLR NPs





Time systems

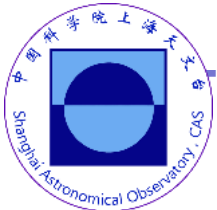
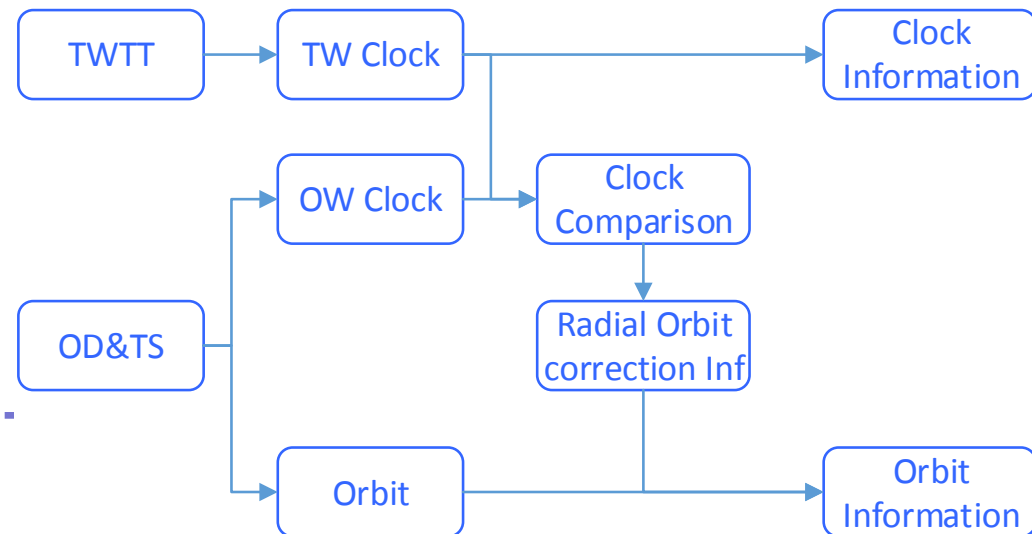
- Robust mean value of epoch-wise clock difference
 - Comparison of median value of IGSO/MEO clock and of GEO/IGSO/MEO clock





SISRE computation

- Correlation between radial orbit and clock errors
 - Orbit and clock information of Beidou BCE is from two independent techniques: OD&TS and TWTT
 - Consistency between radial orbit and clock is not good
 - Consistency enhancement algorithm [*He et al.*, 2014]
 - Expediency, dedicated algorithm would be designed

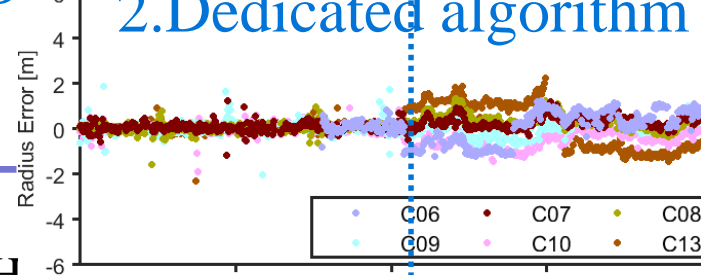
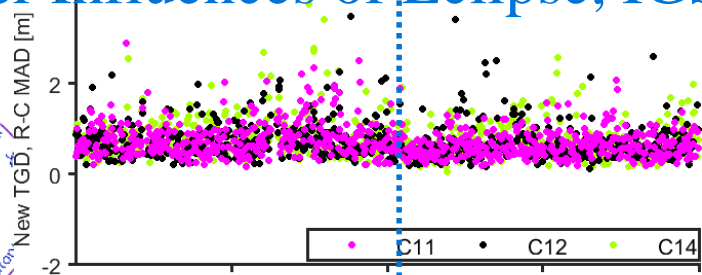
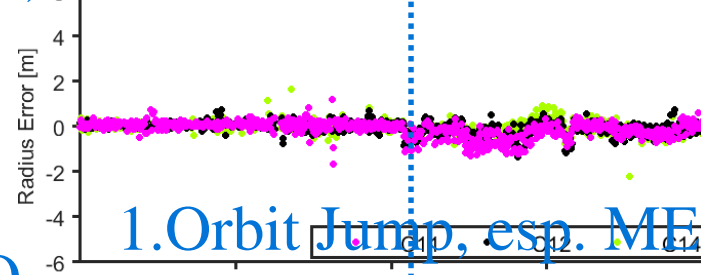
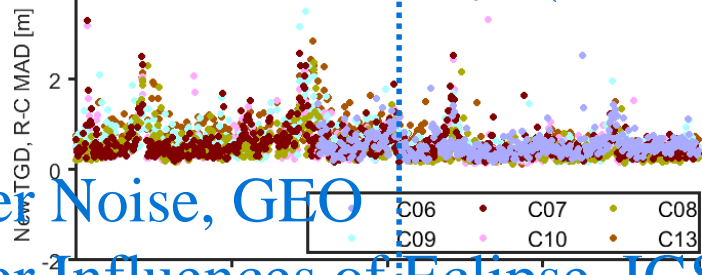
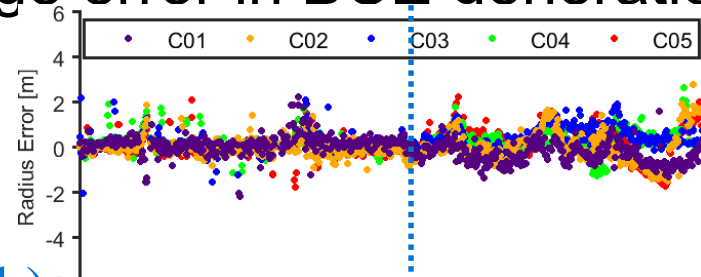
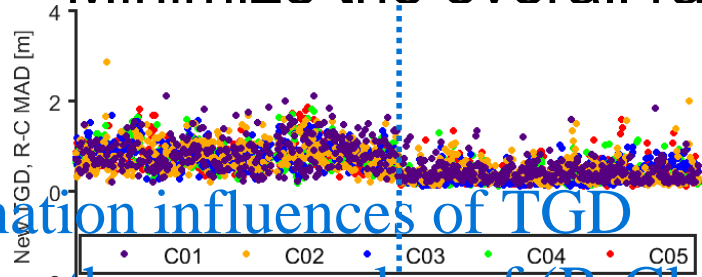




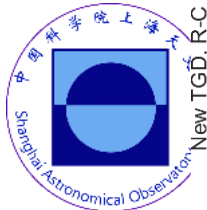
SISRE computation

- Correlation between radial orbit and clock errors
- Minimize the overall range error in BCE generation

1. Elimination influences of TGD
2. Remove the mean value of (R-Clock)
3. Smaller Noise, GEO
4. Smaller Influences of Eclipse, IGSO



1. Orbit Jump, esp. MEOs
2. Dedicated algorithm needed





GEOs

- Nearly-static viewing geometry
- Large orbit determination errors
- Unreliable SISRE assessment through comparison
- Evaluation of positioning error performed on evenly distributed locations of service area to assess the contribution of constellation SISRE.

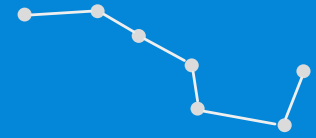




Summary and Conclusions

- BeiDou is different from other GNSS
- To perform SISRE assessment, consider following
 - Antenna offsets, since 2017, CoP
 - group delay corrections, continuous monitoring
 - time systems offset, robust mean value of IGSO/MEO
 - SISRE computation, consistency between R and C
 - Contributions of GEOs, positioning analysis?





Thank you for your attention

