# Hourly Updated GNSS Orbit and Clock Correction

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# Outline

- Background
- Method and strategy
- Analysis of hourly updated GNSS orbit and clock
- Conclusion and summary

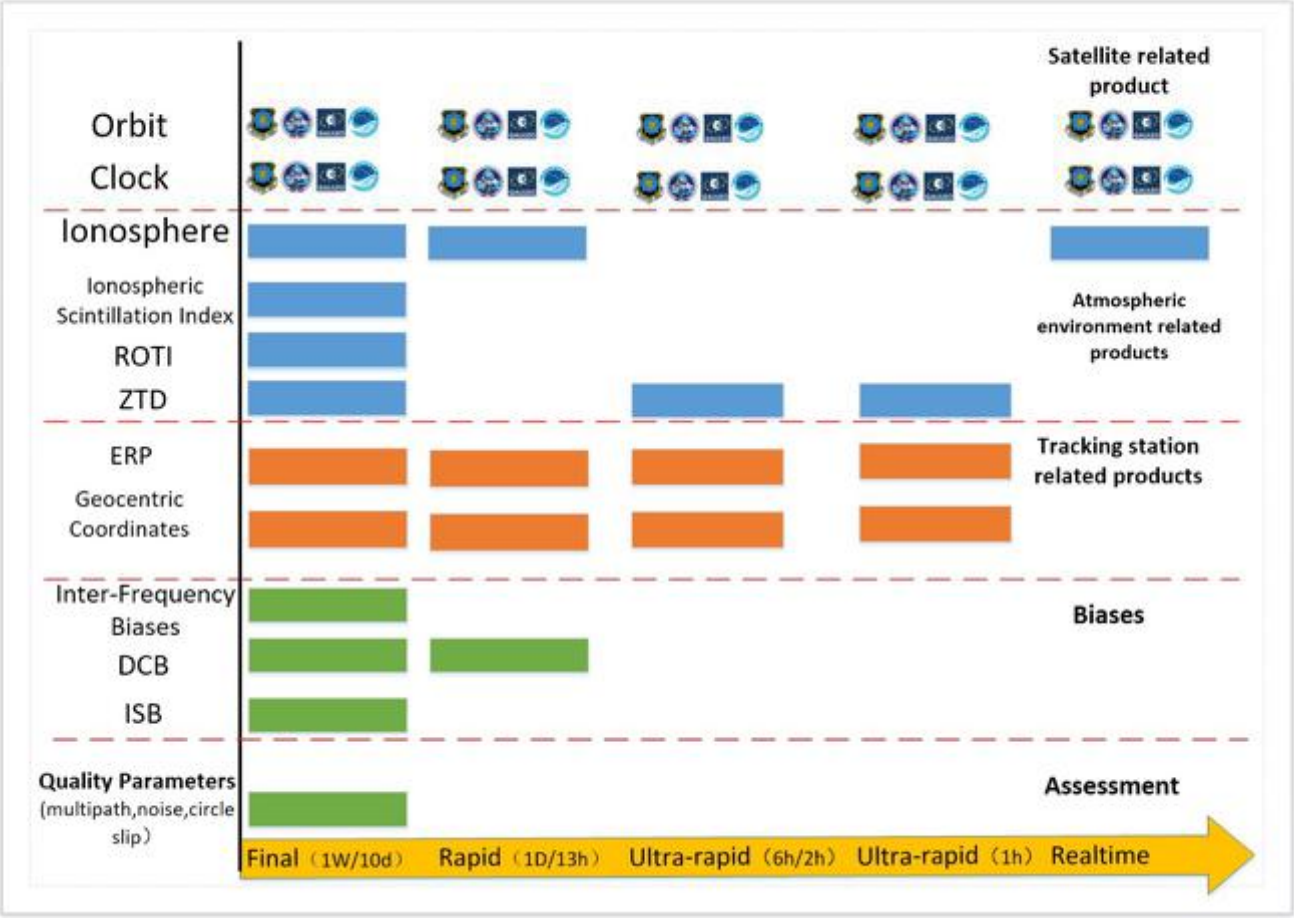
# Background

- The performance of the Global Navigation Satellite System (GNSS) is improving, and the hourly updated orbit and clock of GNSS will be used by most users because of the timeliness and high accuracy.

- The possible breakdown satellites or stations can be found earlier, and productions with better accuracy are the advantages for the hourly updated orbit and clock.

- The hourly updated BDS/Galileo/GPS/GLONASS orbit and clock have been produced routinely in Shanghai Astronomical Observatory(SHAO) Analysis Center of the International GNSS Monitoring and Assessment Service (iGMAS), and the accuracy is analyzed in this study.

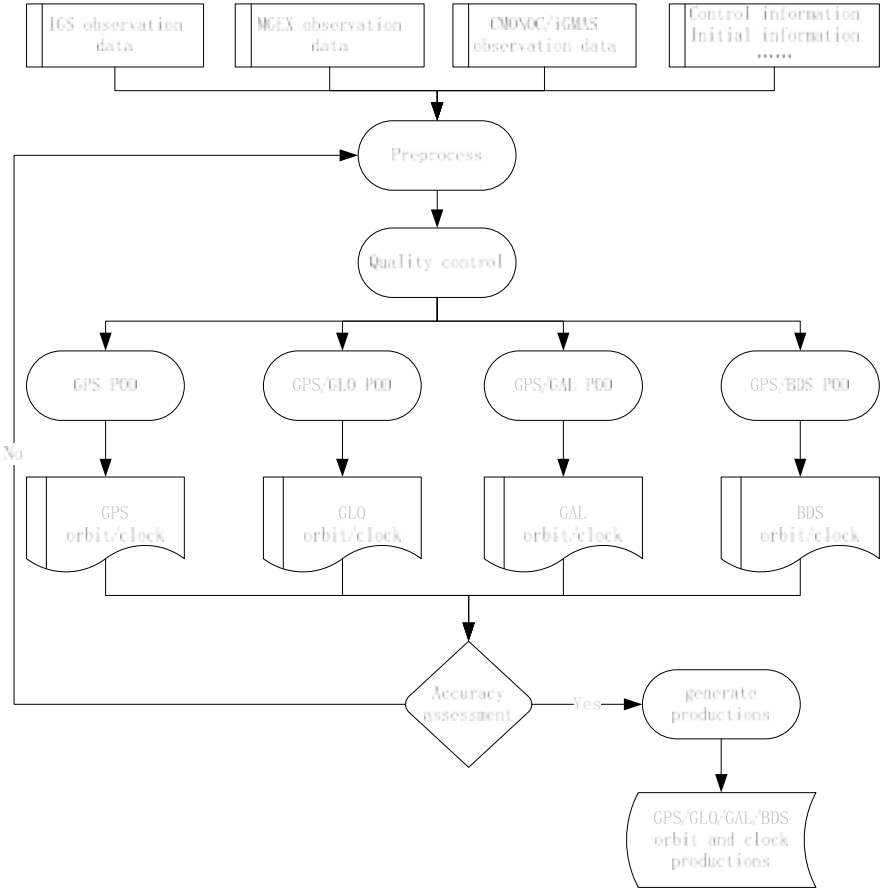
The productions of SHAO iGMAS AC



# Method and strategy

## ➢ Flow chart

The software package was developed based on the PANDA software provided by Dr. Maorong Ge at GFZ. The flow chart of the software which generate the hourly updated GNSS orbit and clock productions is showed as following:



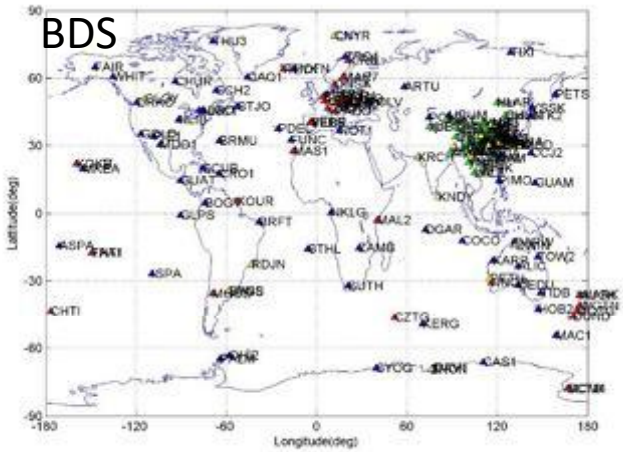

1. Collect: the data from IGS/MGEX/CMONOC/iGMAS, and other information…
2. Preprocess: data uncompressed, data combined.
3. Quality control: data check, delete the bad data, quality control.
4. POD: combined with GPS with GLO/GAL/BDS respectively.
5. Accuracy assessment: conclude the accuracy and precise of orbit and clock.
6. Generate productions: combine and output GNSS orbit and clock productions.

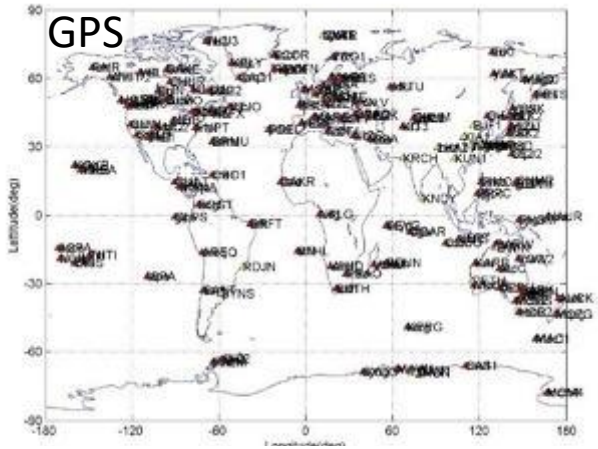
# ➢ Observation models and force models

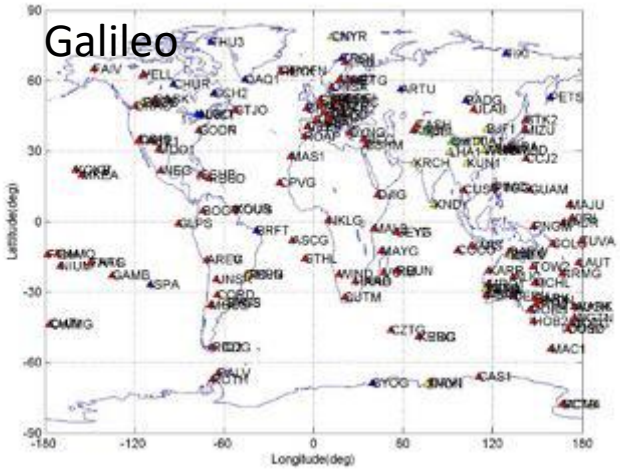
| | GPS | GLONASS | Galileo | BDS |
|---|---|---|---|---|
| **combination** | GPS | GLO+GPS | GAL+GPS | BDS+GPS |
| **Basic observation** | Un-differenced iono-free and phase combination of L1/L2 | Un-differenced iono-free and phase combination of G1,G2, L1,L2 | Un-differenced iono-free and phase combination of E1,E5a,L1,L2 | Un-differenced iono-free and phase combination of L1/L2 and B1/B2 |
| **Arc length** | 24 hour | | | |
| **Station phase center** | Igs08_wwww.atx | | | PCO and PCV for GPS and BeiDou assumed the same igs08_wwww.atx |
| **Satellite phase center** | Igs08_wwww.atx | | | Igs08_wwww.atx for GPS PCO/PCV(from Guo J et al. JG,2016) for BDS |
| **Phase wind up** | Corrected[12] | | | |
| **Tropospheric delay** | GMF[13], priori delay[14], 2-h ZTD gradients | | | |
| **Satellite clock error** | White noise | | | |
| **Receiver clock error** | White noise | | | |
| **Tide displacement** | IERS conventions 2003[15], FES2004[16] | | | |
| **Relativity effect** | IERS conventions 2003 | | | |
| **Earth gravity** | EGM 12X12 | | | |

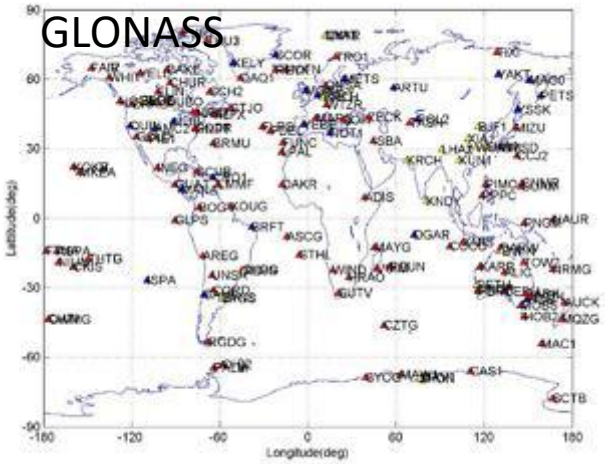
## ➢ Geographical distribution of stations for BDS/Galileo/GPS/GLONASS

red – IGS stations, blue-MGEX stations, green-CMONOC stations, yellow-iGMAS stations



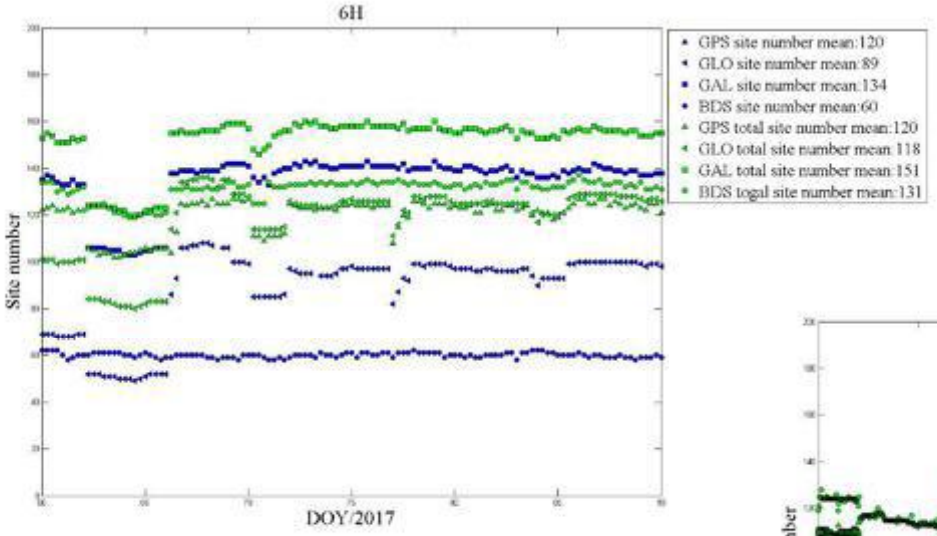



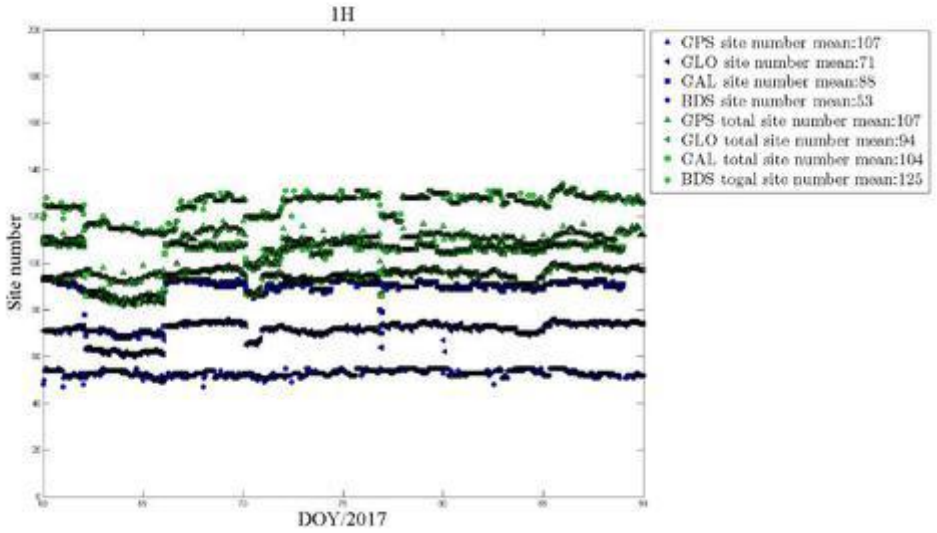



# ➢The mean number of stations used in POD

The site numbers of POD are showed in this figures. The 6H represents 6 hourly updated GNSS productions, while hourly updated GNSS productions are marked by 1H.



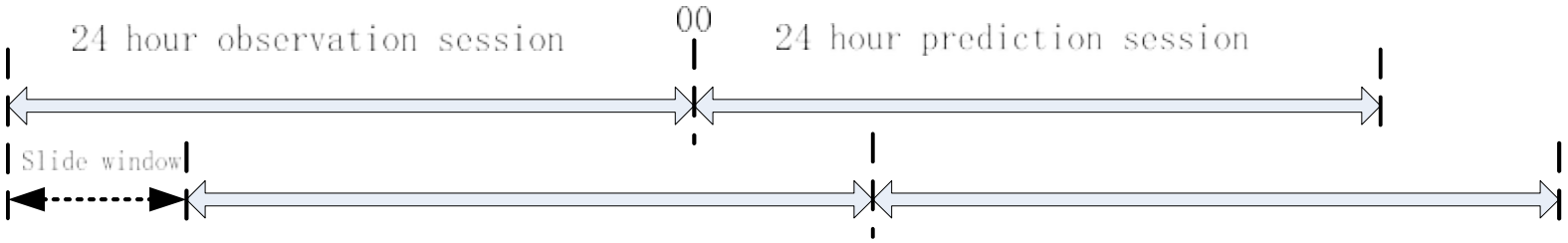




- The hourly observation data is collected in this study, and the time span is from 060 to 090 in the year 2017.

- The mean site numbers used in POD for 6H/1H are showed in the table.

| Satellite system | Site numbers used in POD | |
|---|---|---|
| | 6H | 1H |
| BDS | 131<br>(60 sites which have BDS data included ) | 125<br>(53 sites which have BDS data included ) |
| Galileo | 151<br>(134 sites which have Galileo data included ) | 104<br>(88 sites which have Galileo data included ) |
| GPS | 120 | 107 |
| GLONASS | 118<br>(89 sites which have GLONASS data included ) | 94<br>(71 sites which have GLONASS data included ) |

## ➢Slide window




●The slide window is 6 hours for 6-hourly update GNSS orbit and clock productions, while 1 hour slide window is for hourly productions.

●There is 24 hours observation session and 24 hours predict session included in orbit and clock productions. The predict orbit is calculated by two day orbit fit, the predict clock is computed by modified ARIMA method.

# Analysis of hourly updated GNSS orbit and clock

## ➢Reference productions

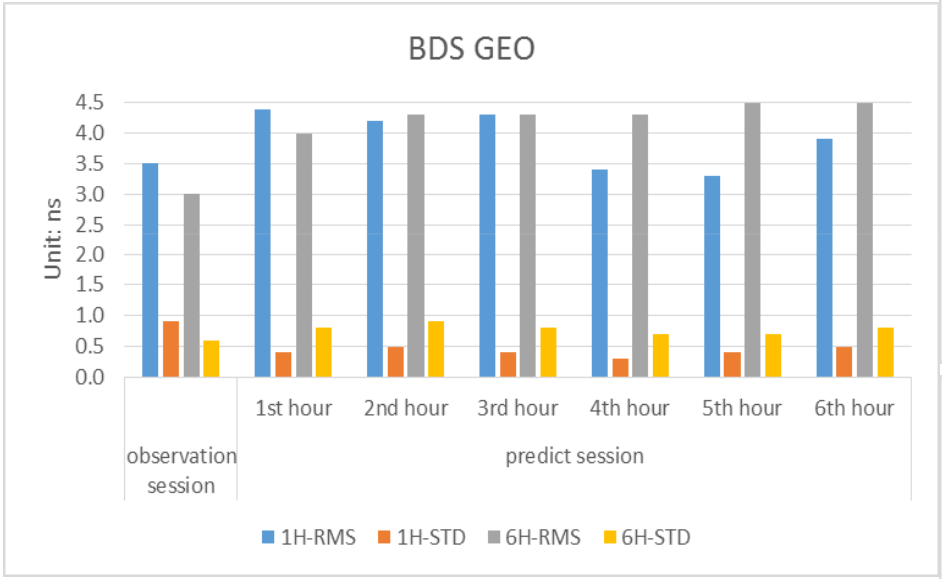
| Satellite system | Clock reference | Orbit reference |
|---|---|---|
| BDS | GBM | GBM |
| Galileo | COM | COM |
| GPS | IGS | IGS |
| GLONASS | ESA | IGL |

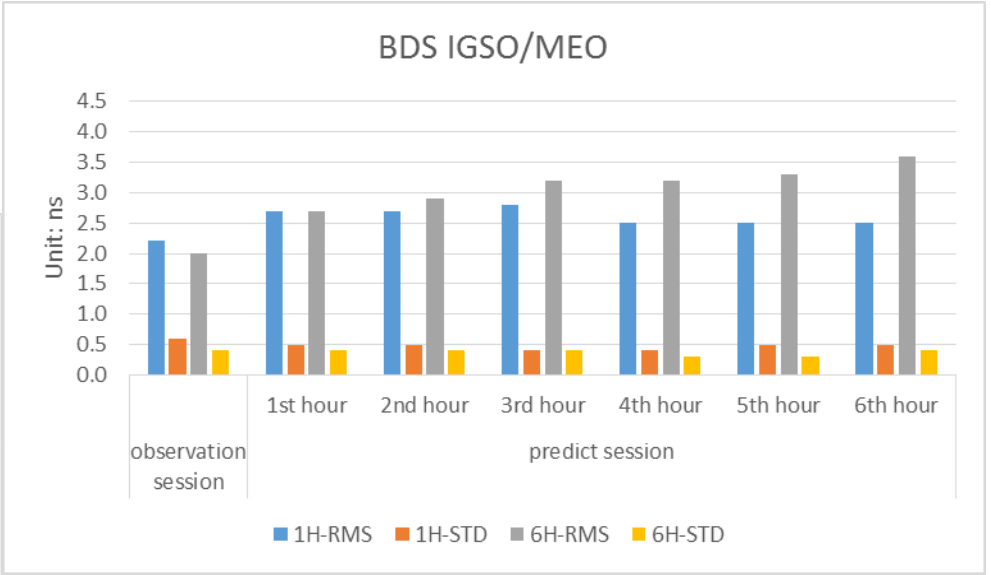
- BDS orbit and clock are compared with GBM productions from GFZ AC.
- The reference orbit and clock of Galileo is COM productions from CODE AC.
- GPS productions are compared with IGS final productions.
- The reference orbit of GLONASS is IGL from IGS final productions, while the reference clock of GLONASS is from ESA AC.

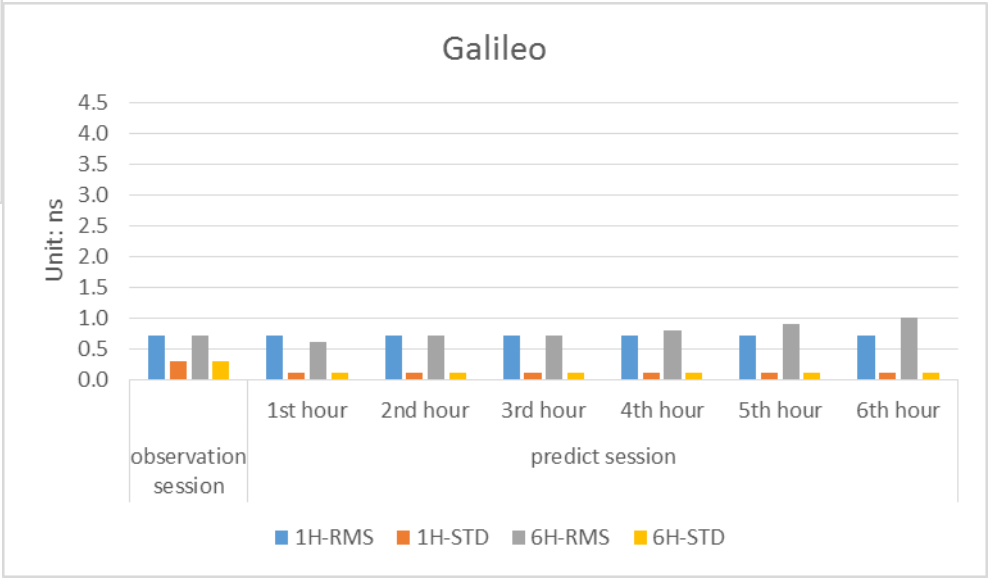
# Analysis of hourly updated GNSS orbit and clock

The RMS and STD of BDS/Galileo/GPS/GLONASS 1H and 6H clocks are showed in following figures.

## Clock accuracy

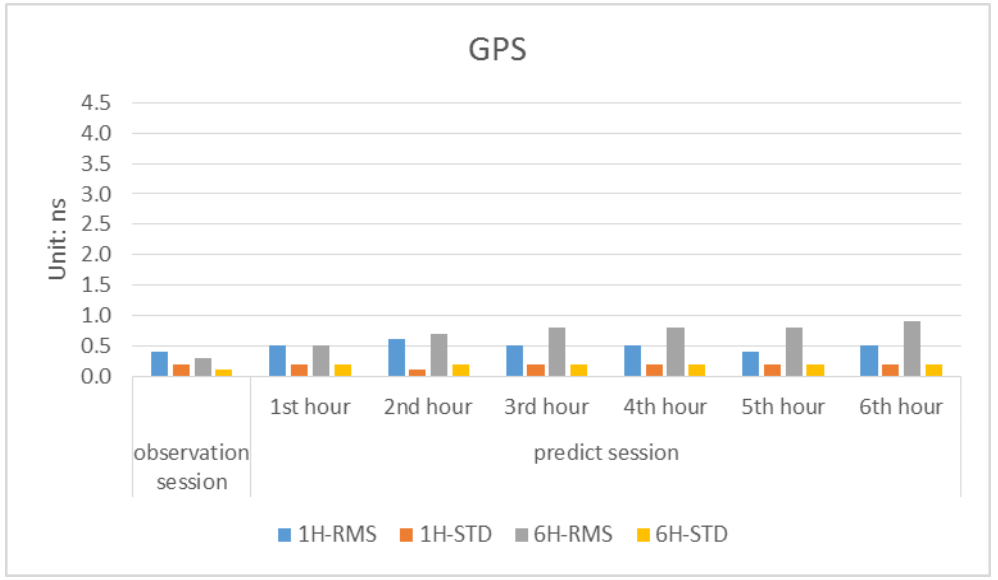


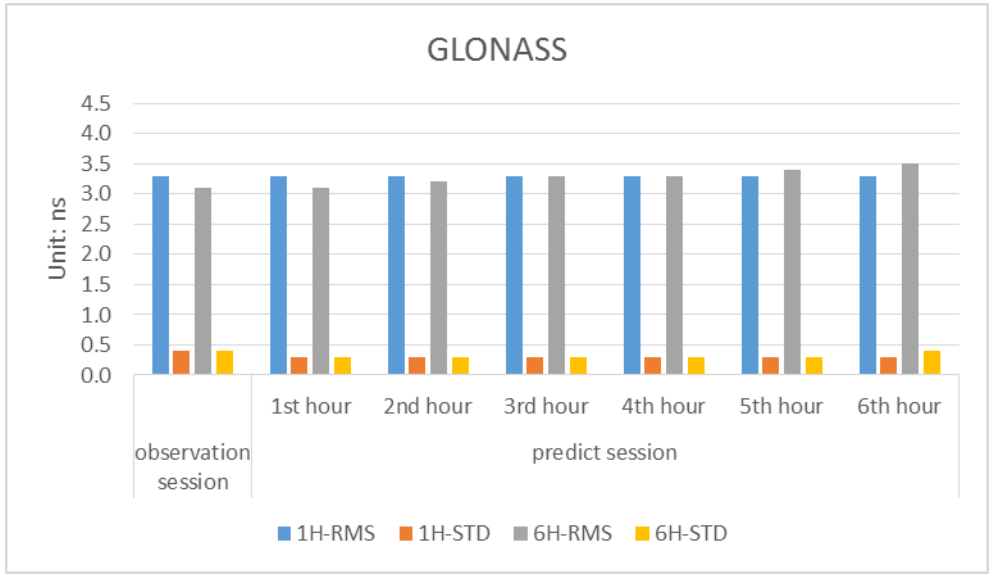



# Clock accuracy

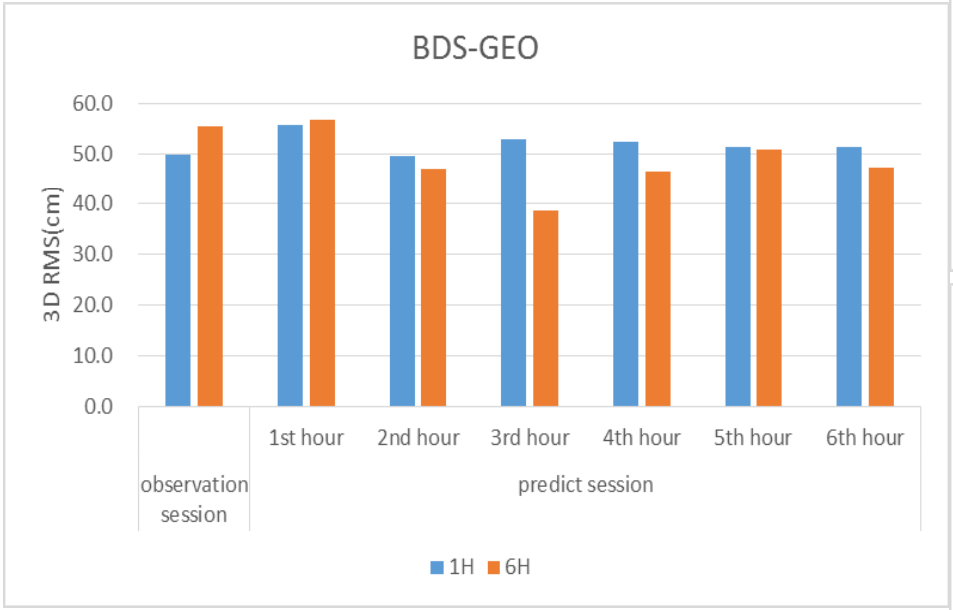
- there's no much difference between the mean RMS and STD of 1H and 6H for the observation session .
- The RMS of 6H clock prediction session is increasing from 1st to 6th hour, but the STD is not change larger.
- The RMS and STD of prediction session for 1H clock are relatively stable.
- The obvious improvement from 0.1ns to 1.1ns is found for the accuracy of the 1H clock relative to those from 6H.
- The accuracy of BDS GEO are worse than BDS IGSO/MEO, which may be affected by no enough sites and poor satellite constellation.

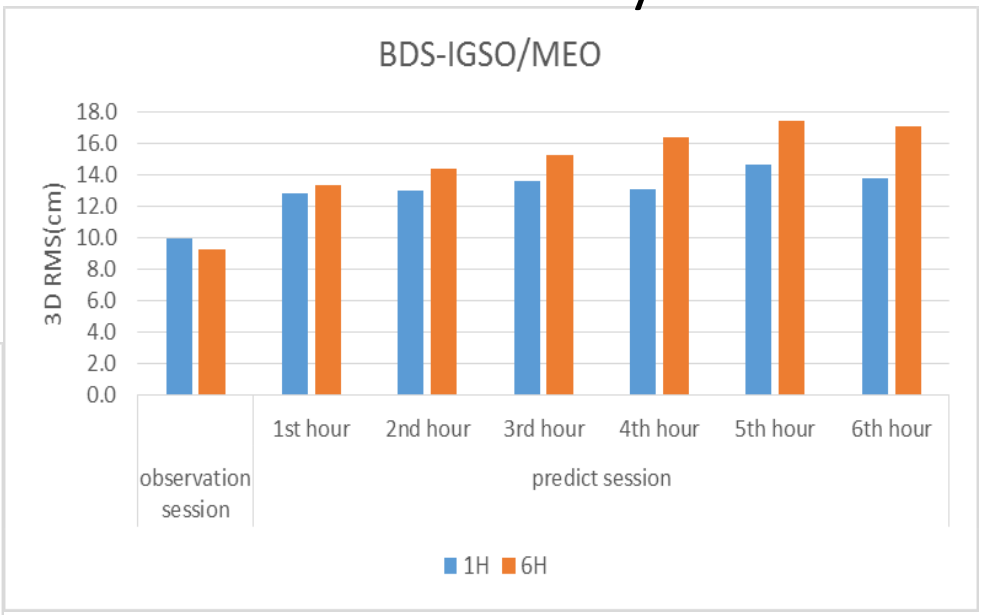


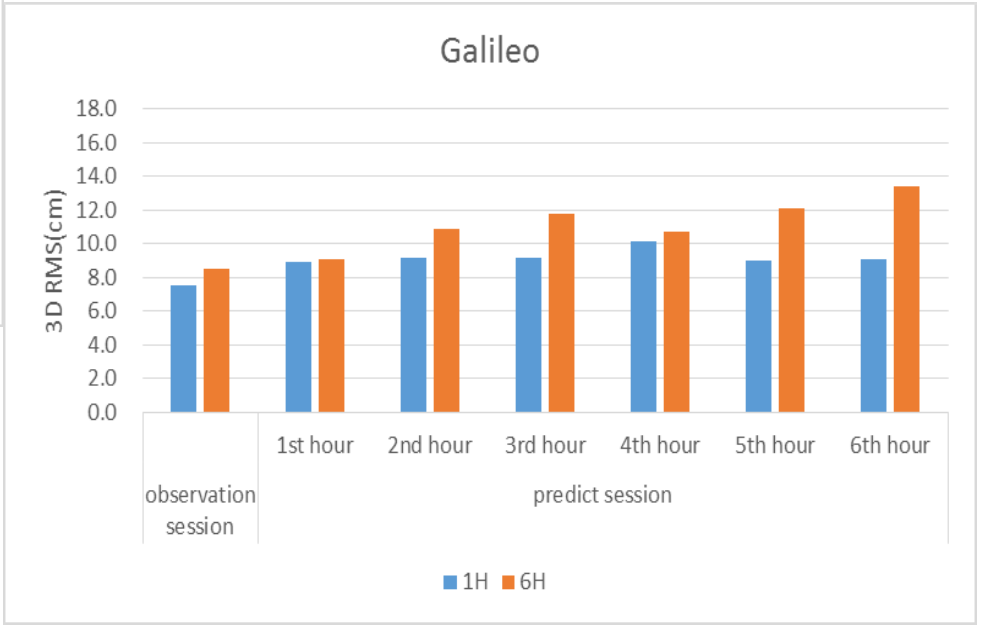



# orbit accuracy

The RMS of 1H and 6H GNSS orbits are showed in the figures.

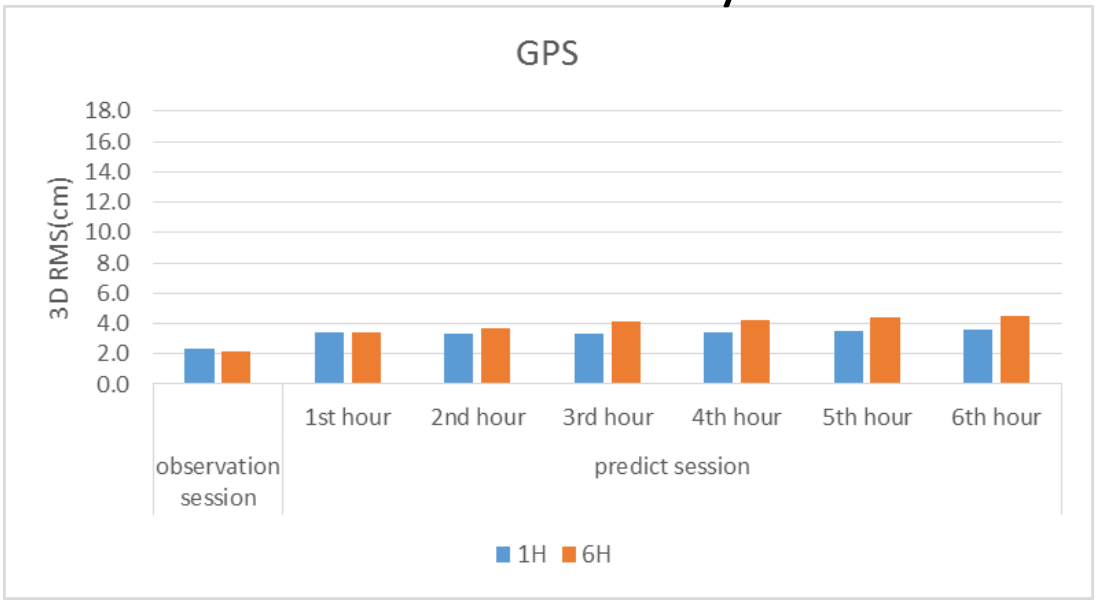


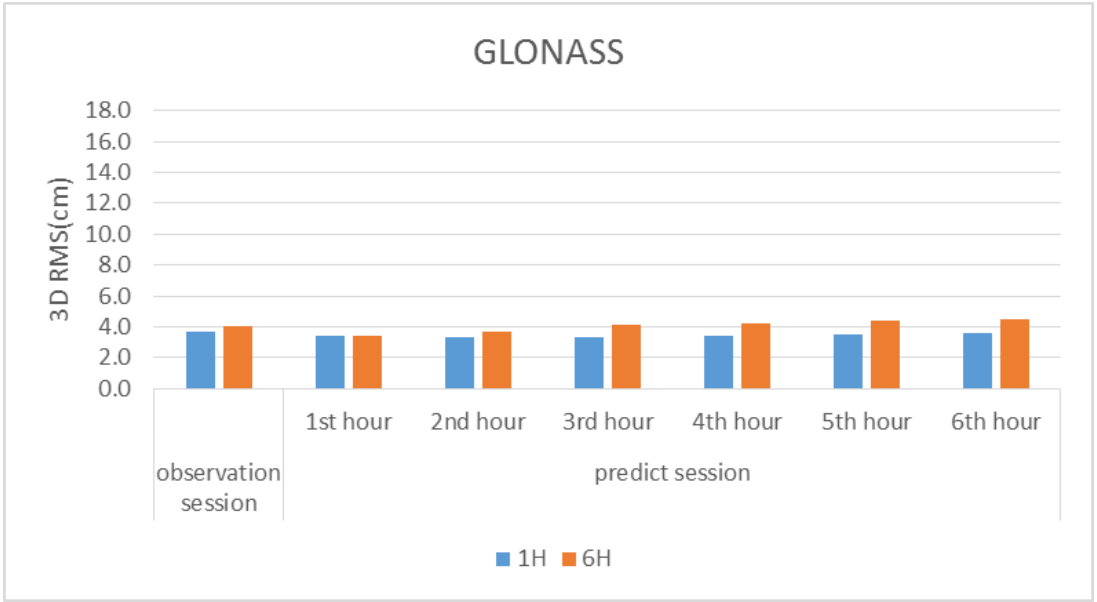



# orbit accuracy

- The RMS of observation session for 1H and 6H orbit is approximately at the same size.
- the RMS of 6H predict orbit is increasing from 1st to 6th hour prediction session, while the RMS of 1H predict orbit is relative stable, and shows an improvement accuracy from 0.2cm to 4.3cm relative to 6H.



# Conclusion and summary

- ✓ In general, the accuracy and precise of the hourly clock and orbit production are nearly equal to 6 hourly updated productions, which can be use by users who need near-real-time and high accuracy clock and orbit.

- ✓ The obvious improvements from 0.1ns to 1.1ns are found on the accuracy of the hourly updated clock than those from 6-hourly updated. For BDS and Galileo at present stage, the hourly-updated orbit and clock prediction productions are more accurate for users than 6-hourly updated.

- ✓ On the other hand, the possible breakdown or unhealthy satellites or stations can be found earlier is the obvious advantage for hourly updated productions.

- ✓ More stations should be included, the strategy and algorithm should be improved in the future work for getting better accuracy and precise productions.

Thanks for your attention !