15th Meeting of the International Committee on Global Navigation Satellite Systems

# New results of single Stational GNSS to GNSS Time Offsets and Its Prediction

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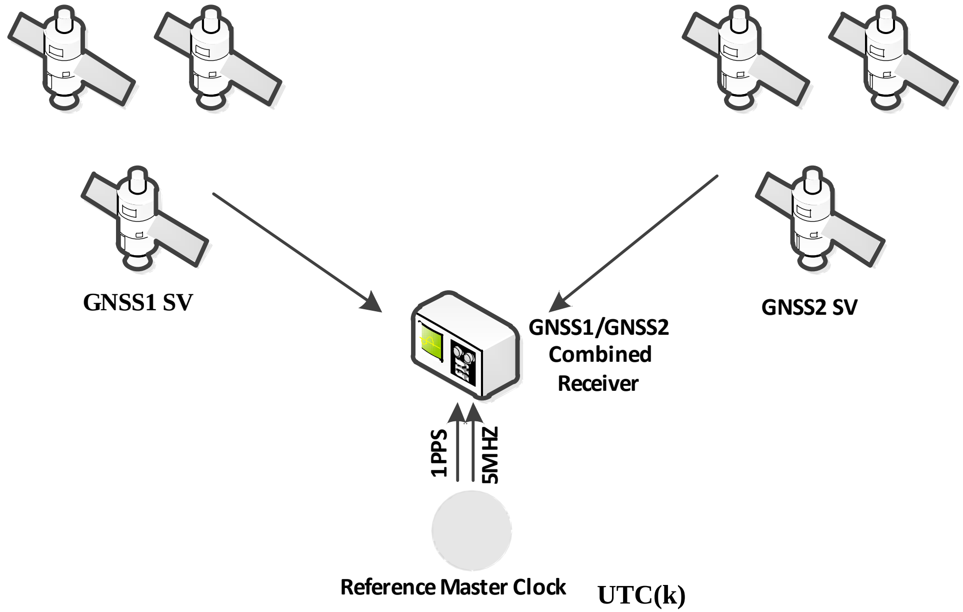
STEP1:

**UTC(k)- GNSST(i)**

**UTC(k)- GNSST(j)**

STEP2:

**GNSST(i) - GNSST(j)**




GNSS to GNSS Time Offset ------GGTO

01

# GNSS to GNSS time offset monitoring Method – ----single station

## Basic requirement

1. **The performance of UTC(k) should be very accurate and stable vs UTC.**

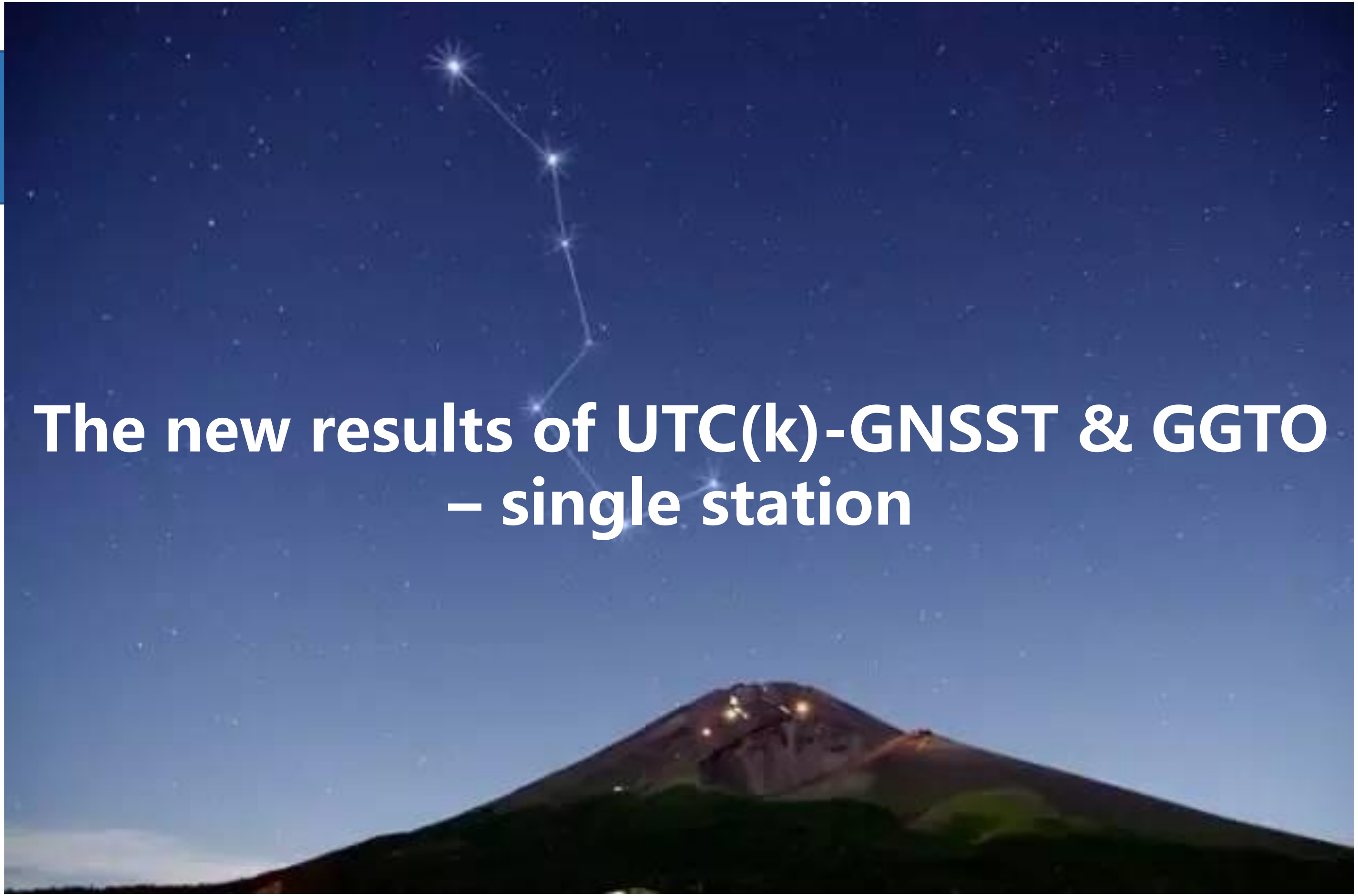
**The accuracy of UTC(k) determined whether the results of UTC(k)-GNSST are accurate.**

**The stability of UTC(k) affect the prediction performance of GNSS to GNSS time offsets.**

2. **The receiver used in the single station GNSS to GNSS time offset must be calibrated absolutely.**

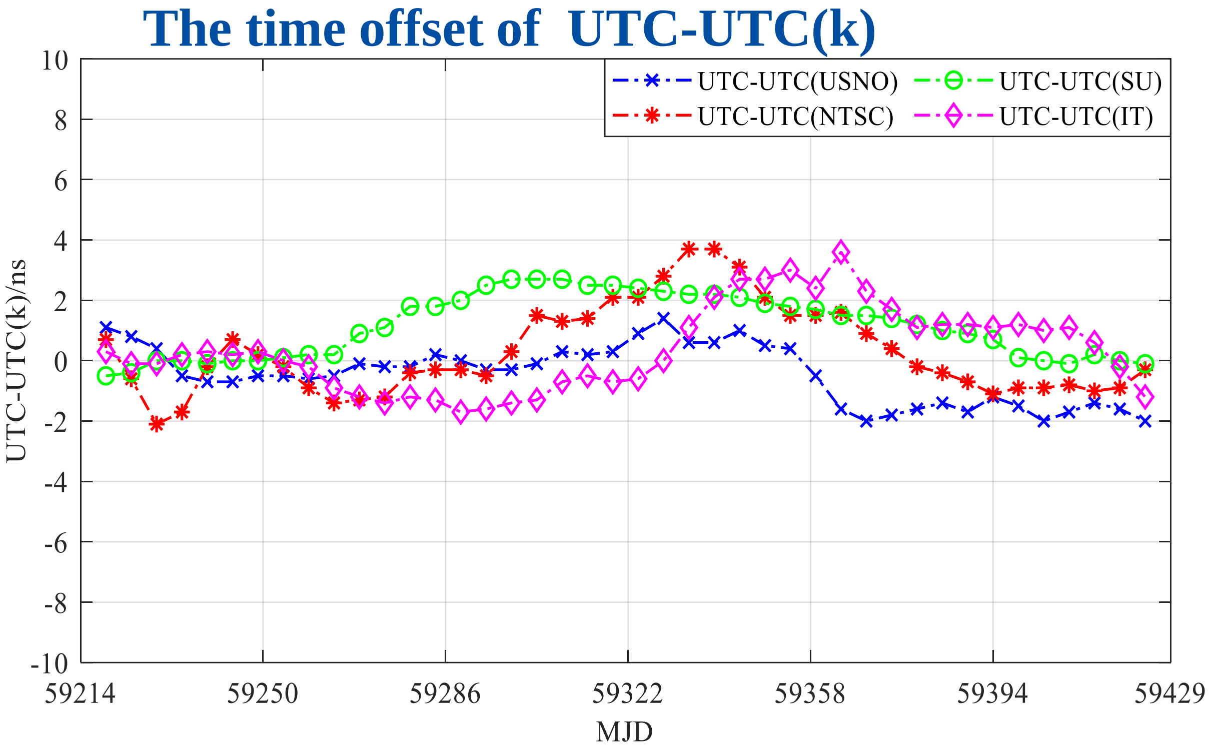
The above requirements have been explained in ICG 14.

02



# The new results of UTC(k)-GNSST & GGTO – single station

## 02 The new results of UTC(k)-GNSST & GGTO – single station

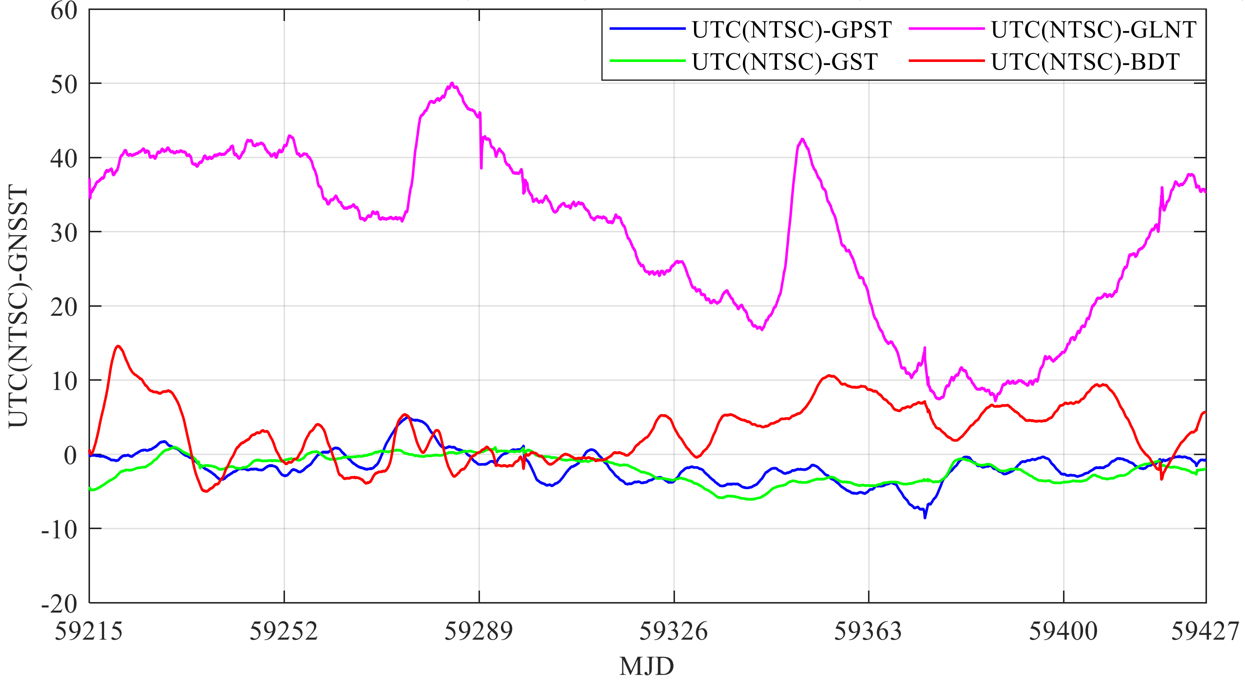



As a direct reference to GNSST, the performance of UTC(k) can already meet the requirements of GGTO monitoring.

02

# The new results of UTC(k)-GNSST & GGTO – single station

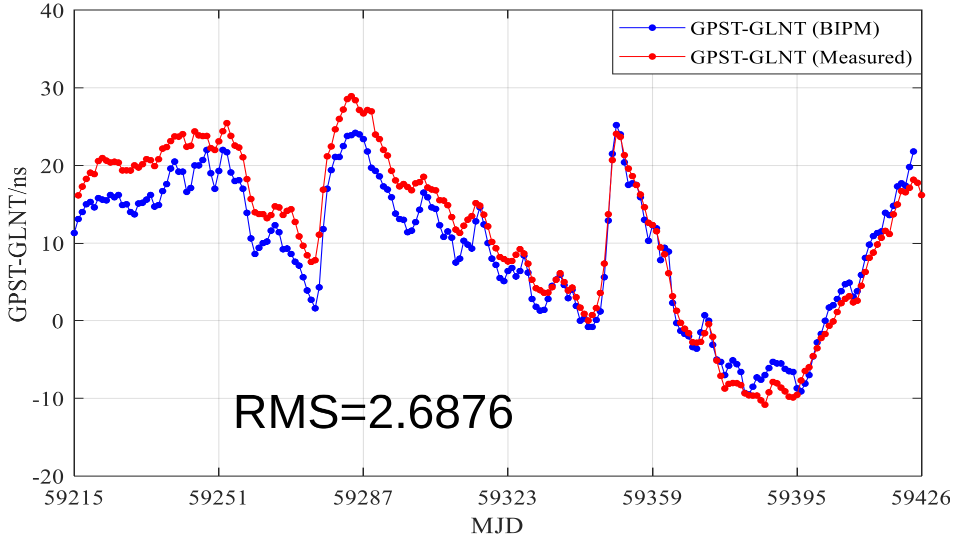
## Time Offsets between UTC(NTSC) and GNSST (2021-1-1 ~ 2021-7-31)



02

# The new results of UTC(k)-GNSST & GGTO – single station

➢ **GGTO of GPST – GLNT monitored by NTSC & BIPM**

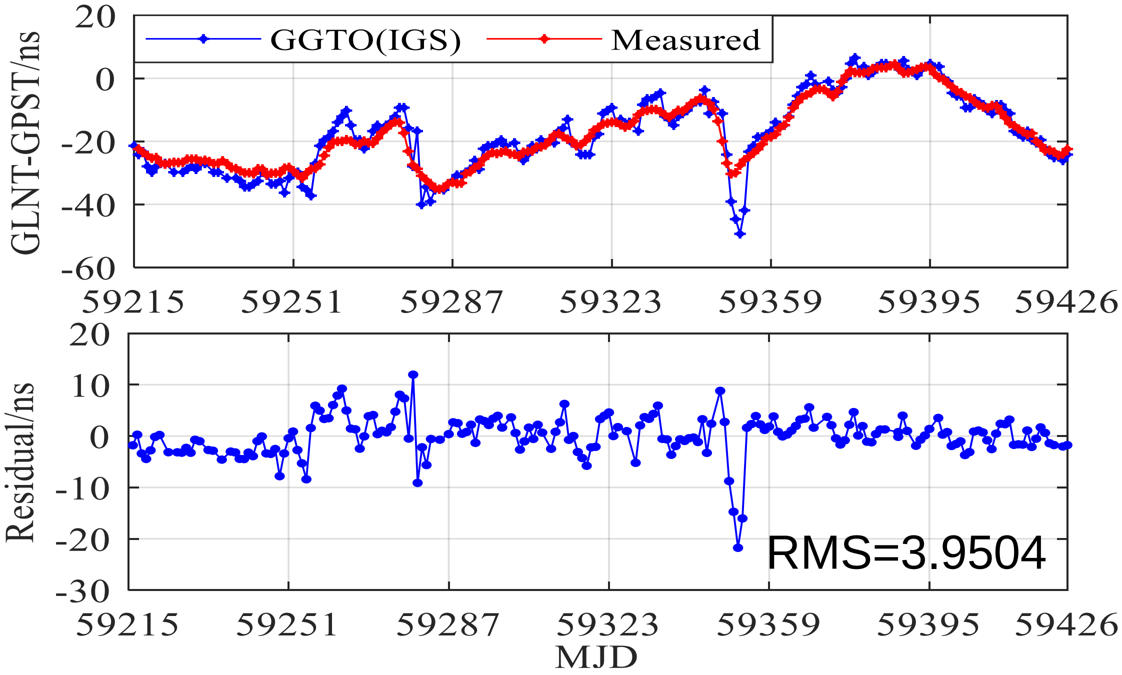



(2021-1-1 ~ 2021-7-31)

GPST-GLNT monitored in NTSC has a good consistency with the data released by BIPM.

## 02 The new results of UTC(k)-GNSST & GGTO – single station

➢ **GGTO of GPST – GLNT monitored by NTSC & IGS**




Compared with the data released by IGS through the time offset quadratic model, the consistency is also good except several points.

03

# 03 GGTO Prediction – single station

## Neural Koopman Algorithm

$$h(t) = f(x(t))$$

$$h(t+1) = Kh(t)$$

$$x(t+1) = f^{-1}(h(t+1))$$

$$\begin{aligned} h(t) &= Kh(t-1) \\ &= K^{(t-1)} * h(0) \\ &= \sum_{i=1}^{n} (\lambda_i h_0 \phi_i) e^{\mu_i t} \end{aligned}$$

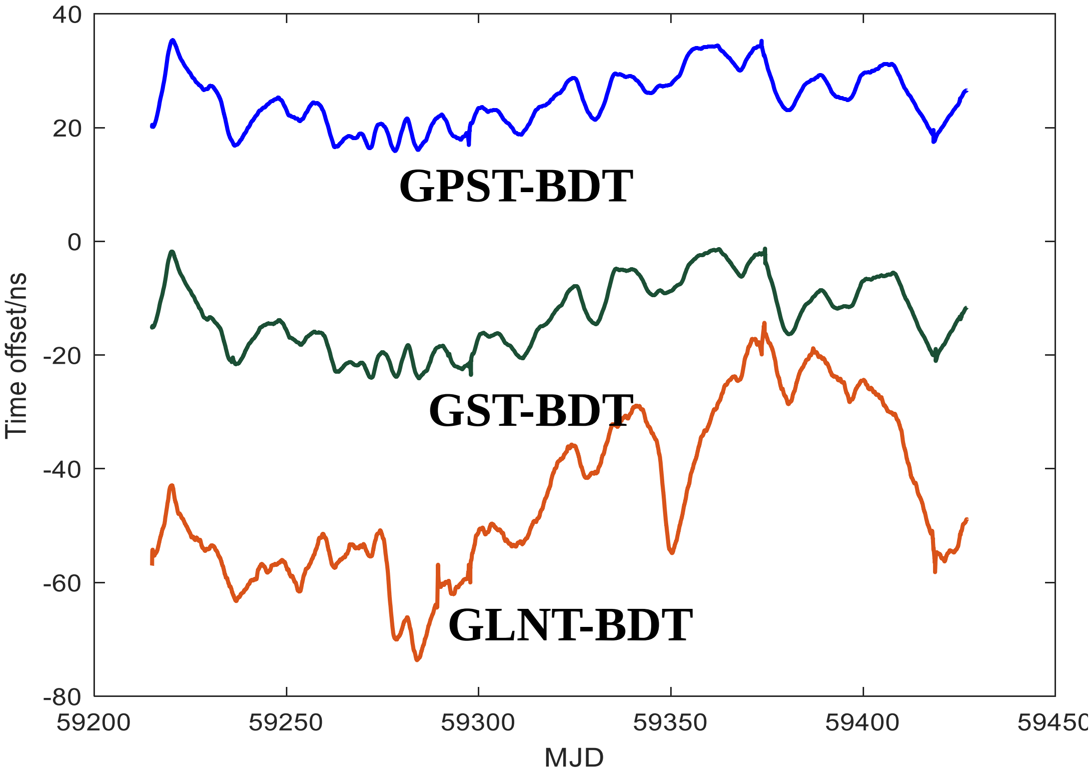
The core idea of Koopman theory is to lift trained data to a higher dimension where the data is linear. Then, the data will be predicted in higher space with linear factor *K*. Koopman operator is commonly noted as *K* and *h(t)* is referred to coordinate of data in higher dimension. *K* evole *h(t)* into future to get the future predicted data in higher dimension. At last, predicted data in higher space is dropped to the original space. Neural networks are used to confirm parameters.

# 03 GGTO Prediction – single station

**Monitoring results: GNSST-BDT**
**From 1， 1， 2021 -7， 31， 2021**

**Blue line: GPST-BDT**
**Green line: GST-BDT**
**Red line: GLNT-BDT**

In order to clearly distinguish among different GGTOs, the inter-system constant offsets are not deducted.



# 03 GGTO Prediction – single station

## GPST-BDT Predicted Results

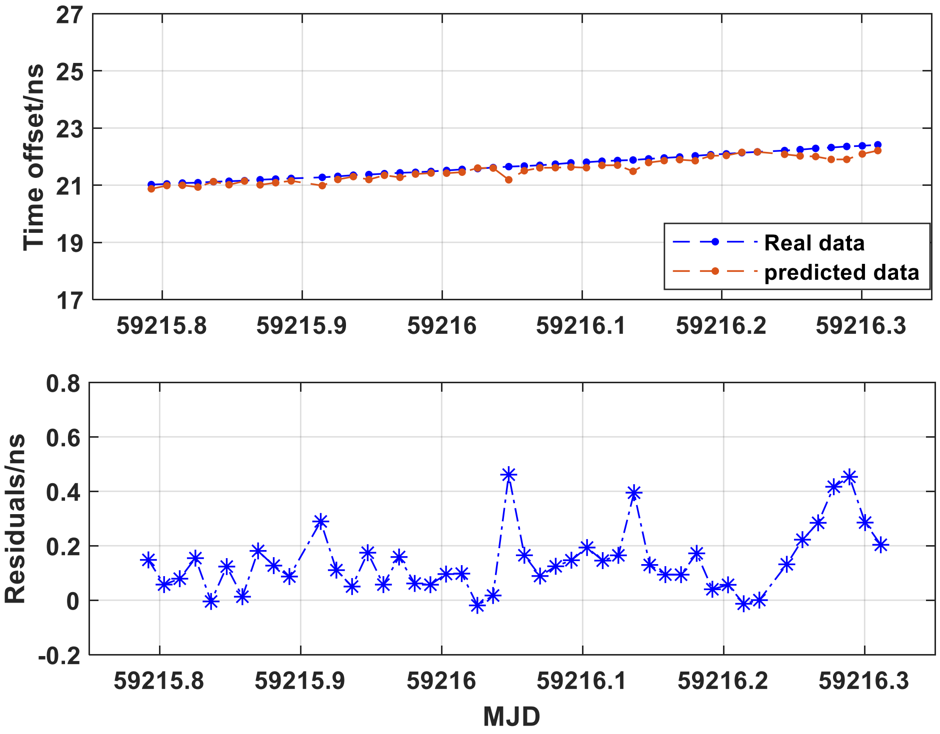
**46points**

**From 1,1, 2021 21’24’ 30**

**——1,1, 2021 09’52’30**

**Performance: Residuals**

**RMSE= 0.184**

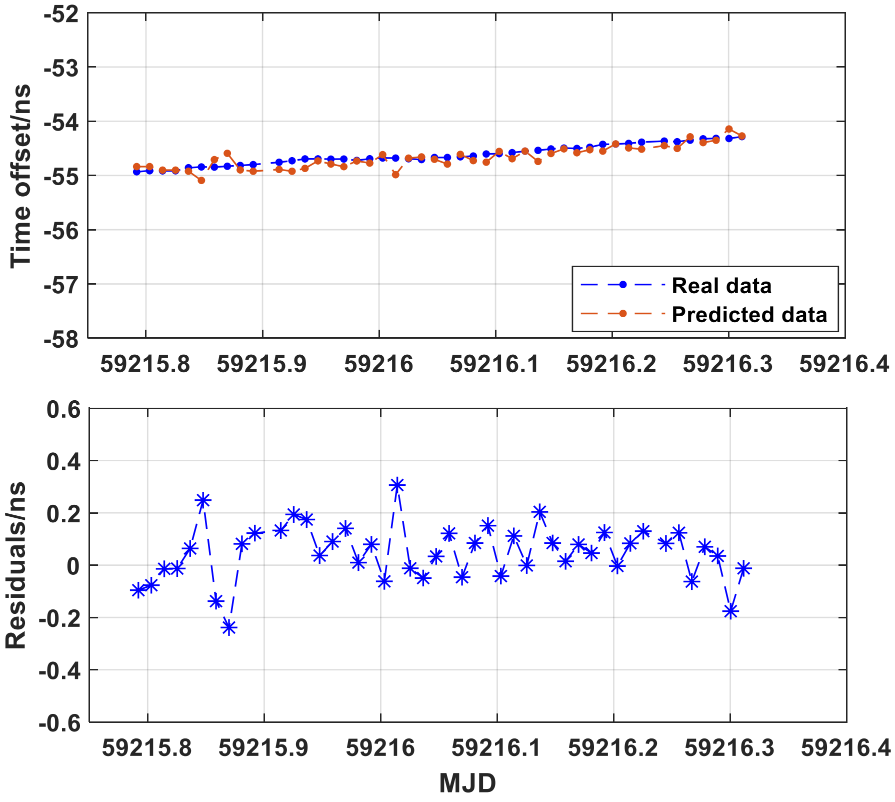


## 03 GGTO Prediction – single station

### GLNT-BDT Predicted results

**46points**
**From 1,1, 2021 21’24’ 30**
**——1,2, 2021 11’12’30**

**Performance : Residuals**
**RMSE= 0.1164**

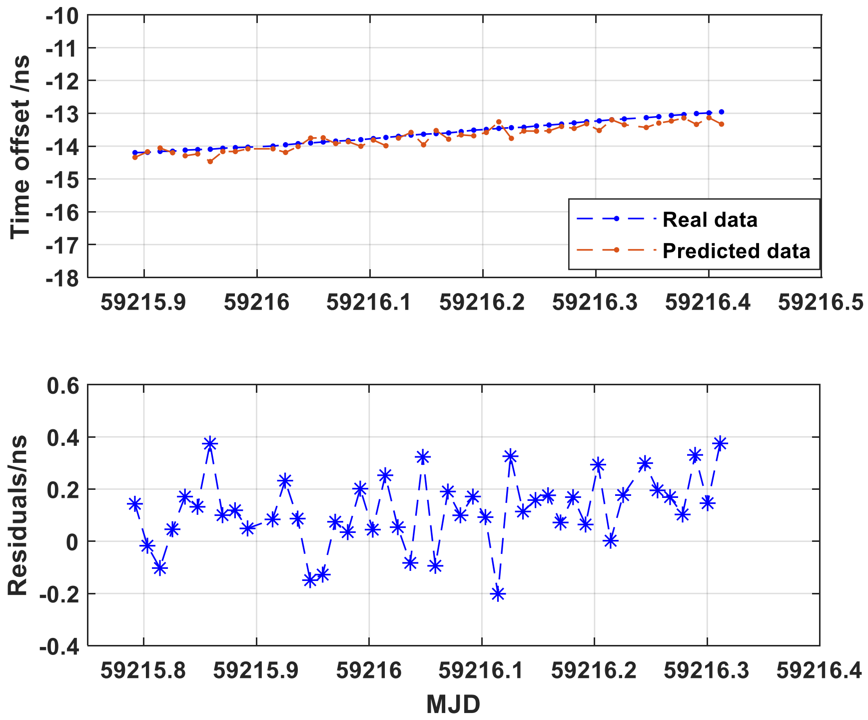


## 03 GGTO Prediction – single station

### GLNT-BDT Predicted Results

**46points**
**From 1,1, 2021 21’24’**
**——1,2, 2021 09’52’30**

**Performance : Residuals**
**RMSE= 0.1797**



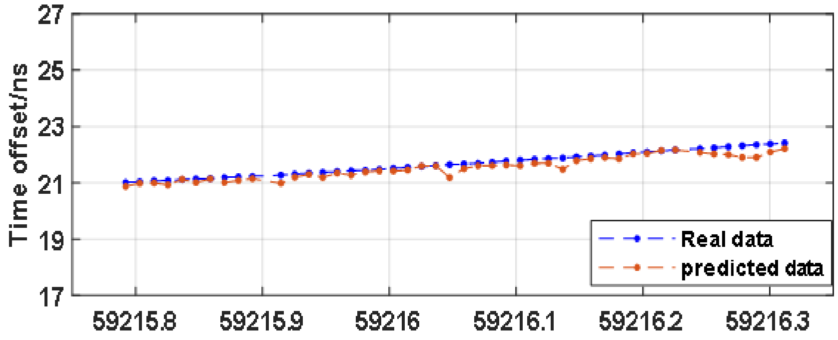
# 03 GGTO Prediction – single station

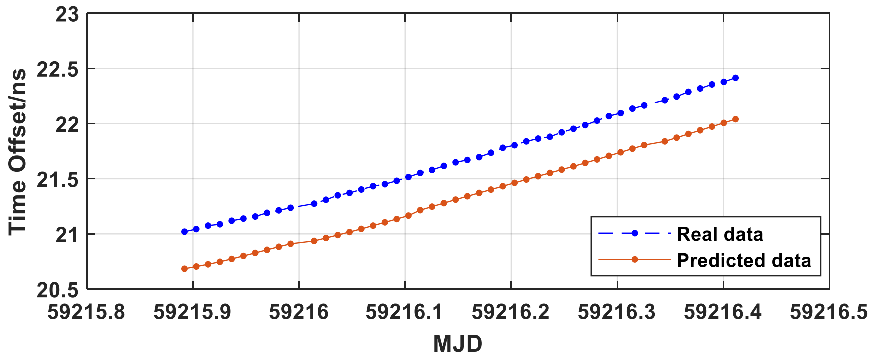
## Comparing the Neutral Koopman algorithm with Linear algorithm

Neutral Koopman algorithm results
RMSE=0.184

Linear algorithm results
RMSE=0.348

GPST-BDT



04

# Conclusions

# 04 Conclusions

## Time interoperability using existing satellite broadcast parameters

- The performance of UTC(k) referenced by GNSST is already within 5ns to UTC, which can meet the needs of high-precision single-station GGTO monitoring and predicting.
- Taking UTC(k) the intermediate reference, GNSST-UTC can be monitored , and the GGTO can be calculated accurately.
- In order to obtain accurate monitoring results, GNSS multimode multi-system receivers in single-station method time offsets monitoring must be strictly calibrated.
- The best solution to the GNSS time interoperability issues is from the system level. Therefore, it is recommended that each GNSS provider consider how to broadcast the GGTOs parameters in the future.

## NEXT WORKS

- Continue to carry out the research of GNSS time offset monitoring and prediction technology to improve the precision of GGTO.
- Research how to improve the accuracy of GGTO broadcast parameters.
- Carry out the receiver calibration technology.

Thanks for your attention and support for BDS!

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