Predicting Atmospheric Biases for Rapid AR in PPP

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Outline

- Background
- Rapid Re-initialization methods
- Results and analysis
- Conclusions

1. Background

- Current state of real-time PPP
  - widely applied in precise surveying, navigation, timing, meteorology….
  - float solution, 5-10cm of accuracy, >30 minutes of initialization time
  - fixed solution in recent years, improved accuracy of 3-5cm, shortened initialization time of about 15 minutes

1. Background

- Re-initialization problem
  - In practical application, especially in the city, GPS satellite signal blocking or interruption results in frequent ambiguity resetting. It requires a long time to recover correct ambiguity.
  - Compared to NRTK, no double-difference is made in PPP, biases from clock, orbit, especially atmosphere will be a significant limitation for rapid re-initialization.

2. Methods to overcome the re-initialization problem

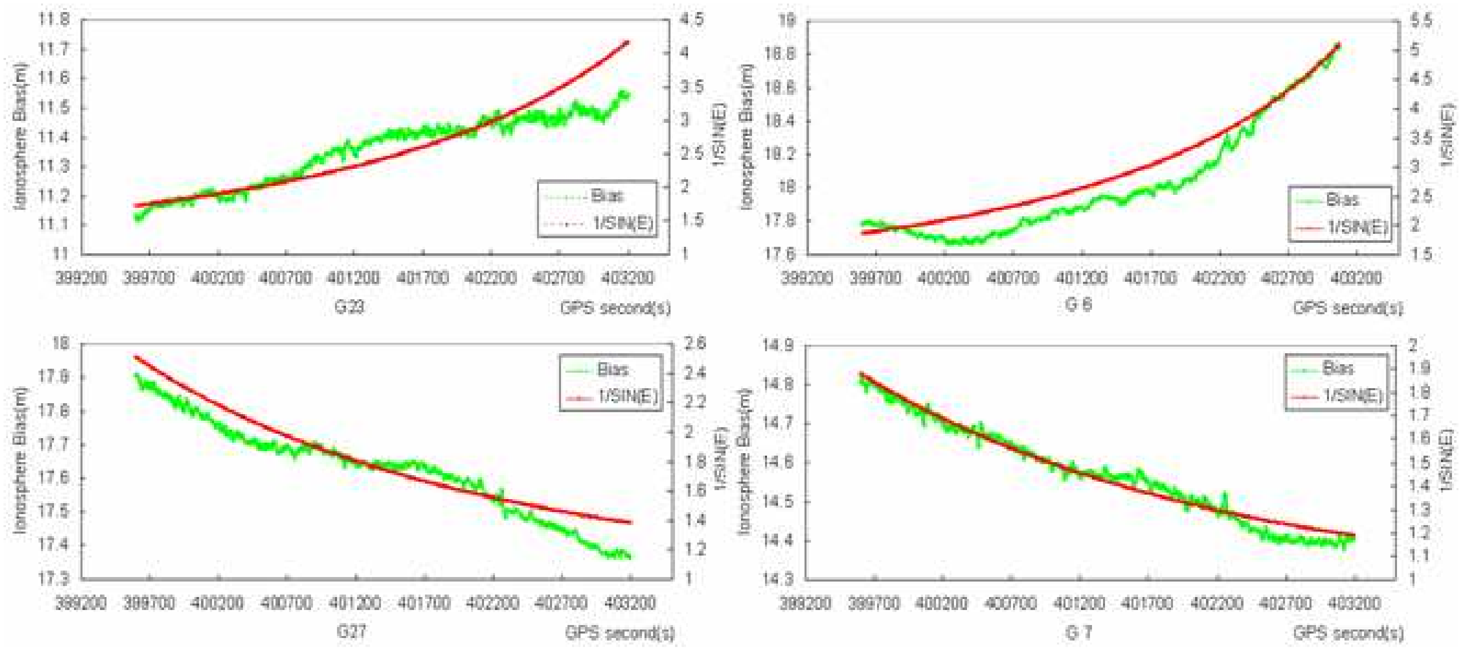
- time-difference solution with WL/GF, ignore the ionospheric variation (Banville,2009)
- re-converge rapidly from 1000s to 25s with ICAF WL observations (Geng,2009), and improved to few seconds using WL instead of noisy MW (Geng,2010)
- cycle-slip fixing based float solution (Zhang and Li,2010)

Epoch-by-Epoch Ionospheric Bias Estimation

ZD ambiguity is successfully fixed after the initialization, coordinates with cm level accuracy and zenith path delay (ZPD) with mm-level accuracy could be obtained with the GPS observations collected during the initialization stage at the PPP user end. It is straightforward to compute zero-difference ionospheric bias accurately with the following equation:

$$I_i^k = \rho_{i\,g}^k - L_i^k + T_i^k + \lambda(f_i - f^k) + \lambda N_i^k + \varepsilon_i^k$$

Epoch-by-Epoch Ionospheric Bias Estimation



Relationship of estimated ZD ionospheric delay and 1/SIN (E)

Apparently, strong temporal correlation exists. These biases exhibit a high degree of correlation with elevation angle.

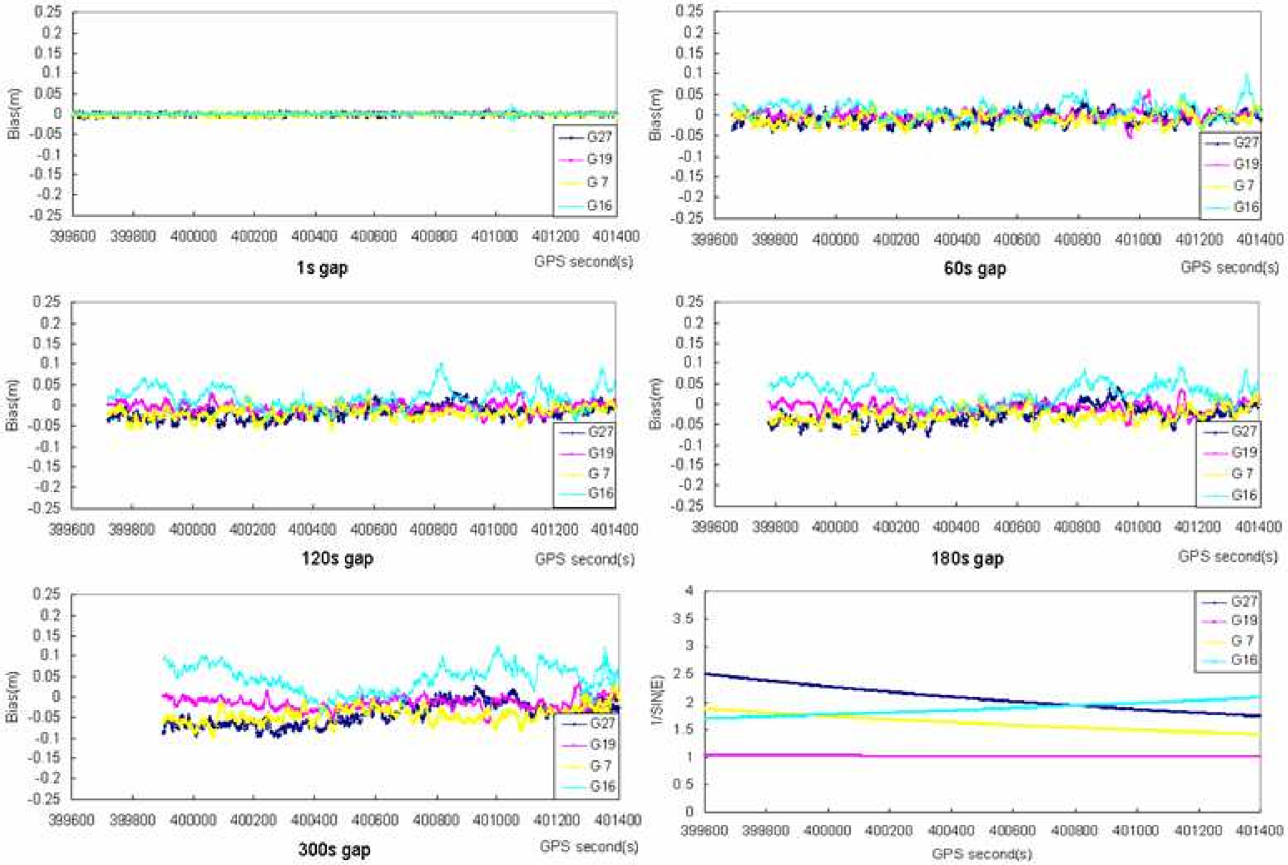
Temporal Modeling and Prediction of Ionospheric Bias

A linear bias model based on sliding window is adopted for modeling and prediction. A certain amount of epochs (few minutes are generally appropriate) are selected as time-line window.

The following elevation-angle-related variance function is also taken into account, in which E is satellite elevation angle:

$$\sigma^2(E)=\begin{cases}\sigma^2 & , E\geq 30\\ \sigma^2 \square 2\sin(E), & 5\leq E<30\\ 0 & , E<5\end{cases}$$

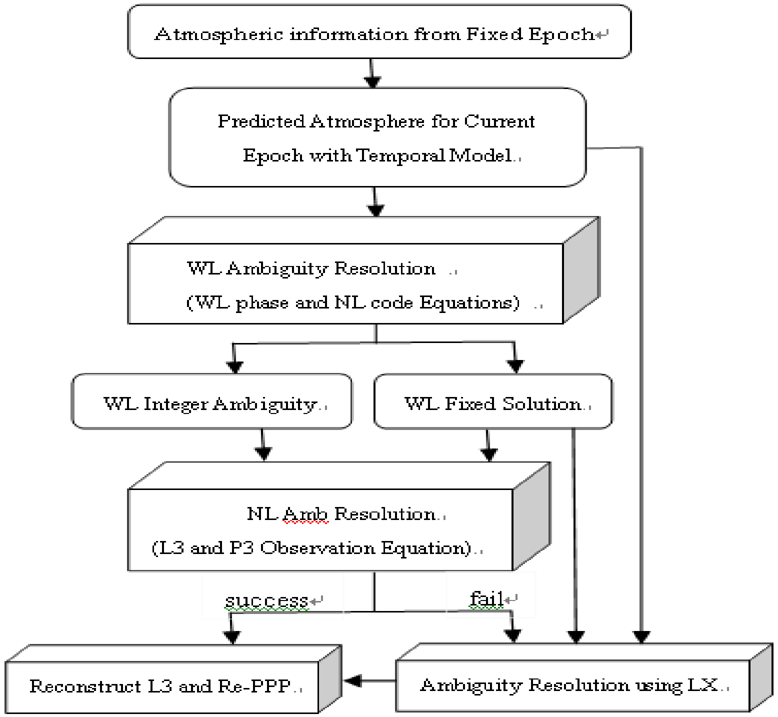
Temporal Modeling and Prediction of Ionospheric Bias



The predicted error of ionospheric path delays with different latency

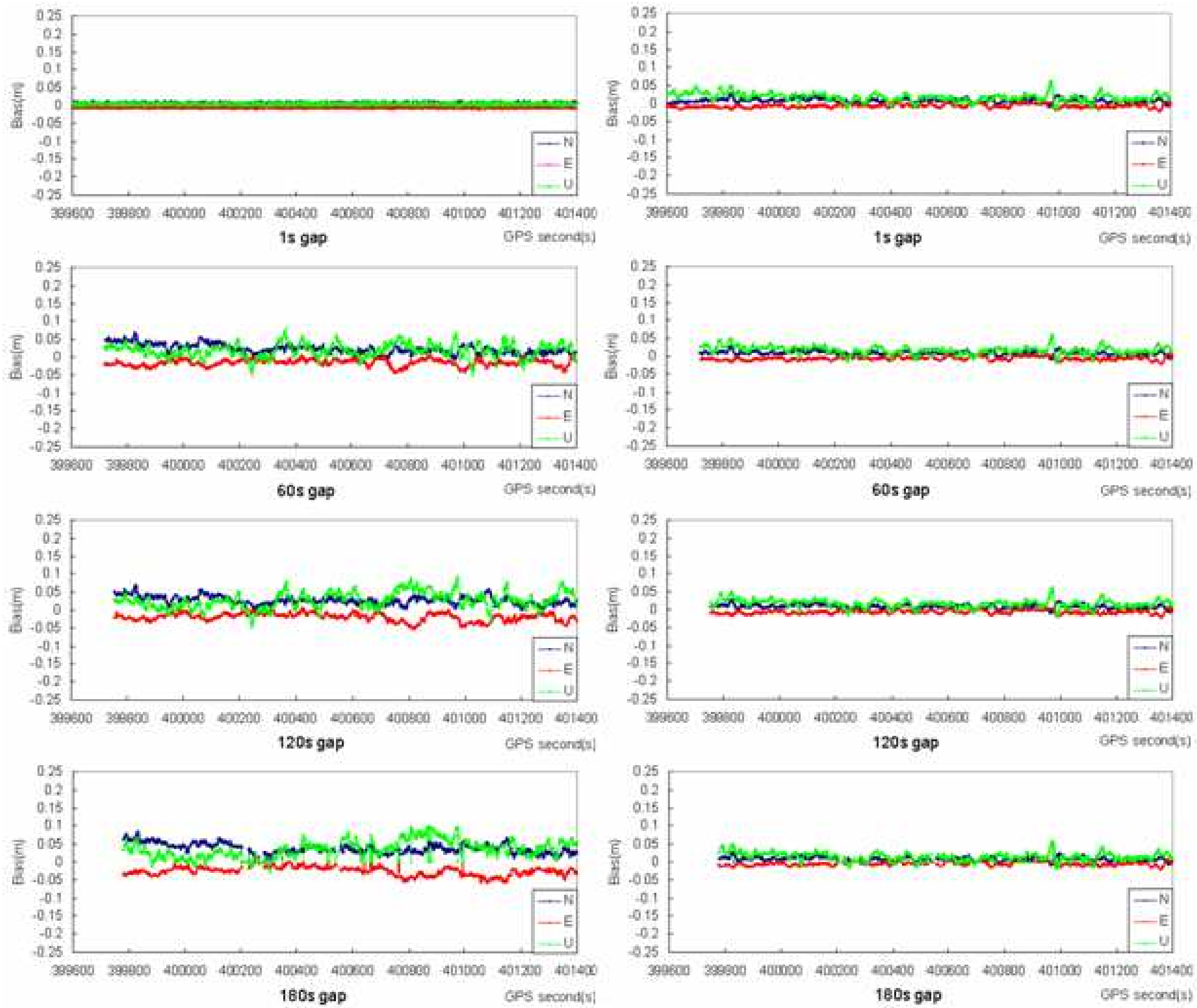
To establish more precise atmospheric temporal model by taking elevation angle and other factors into consideration.

Instantaneous Ambiguity Resolution with Predicted Ionospheric Bias

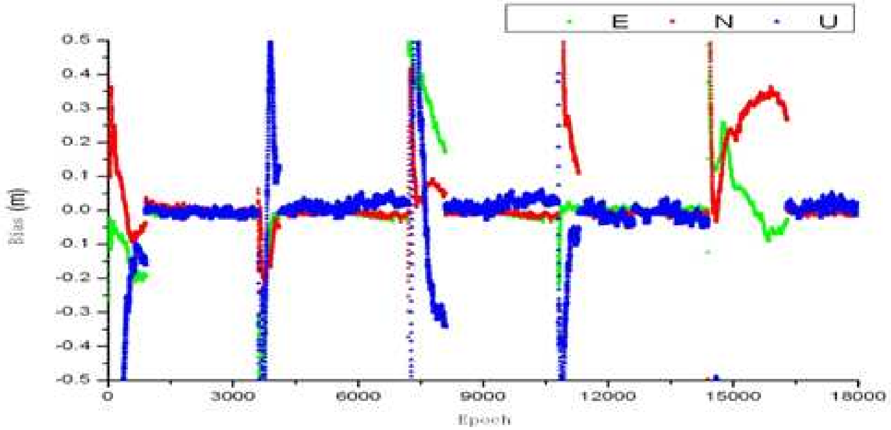


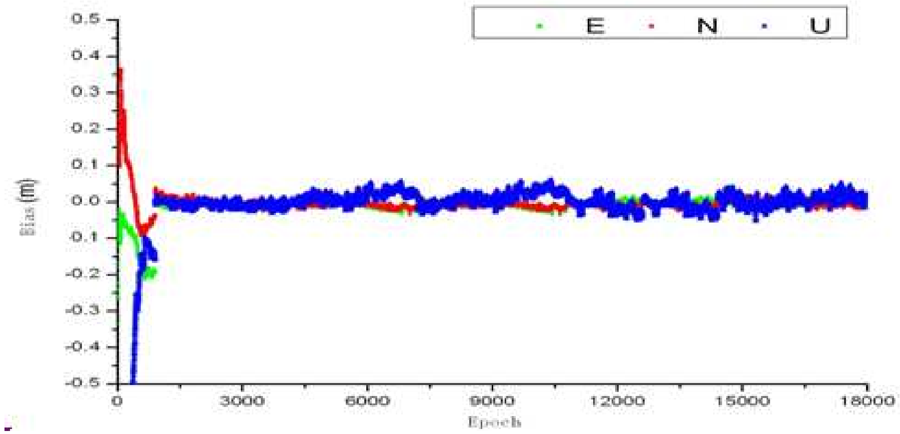
The atmospheric information derived from previous fixed epochs is passed to subsequent new epochs for connecting the data gap . The corrected ZD carrier phase observation could be employed to implement the instantaneous AR.

Performance of Instantaneous AR



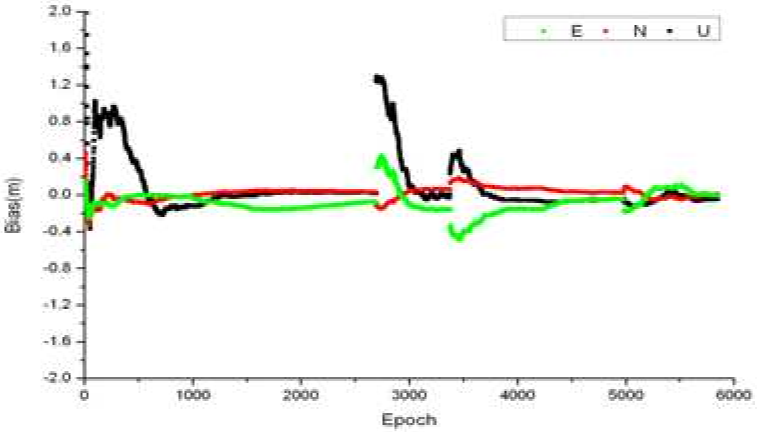
Land Walking Data



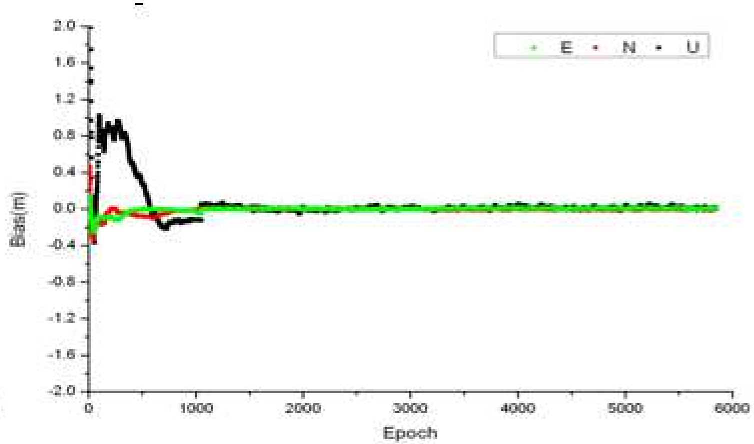


a moving trajectory, lasting approximately 5 hours, Trimble dual-frequency GPS receiver with 1-s sampling interval

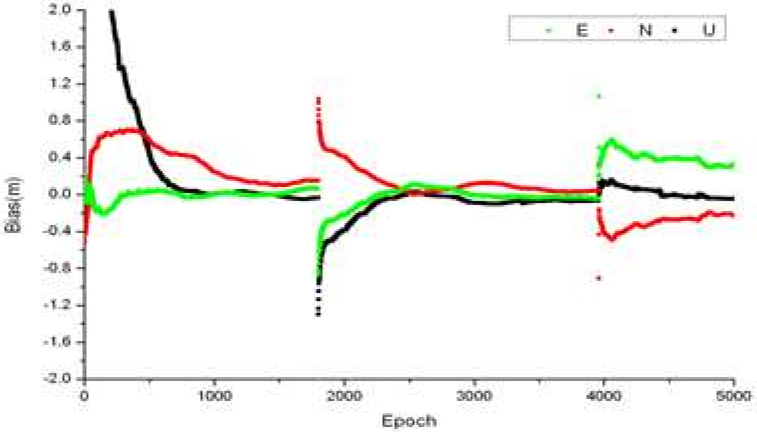
Ship-borne and Airborne Data



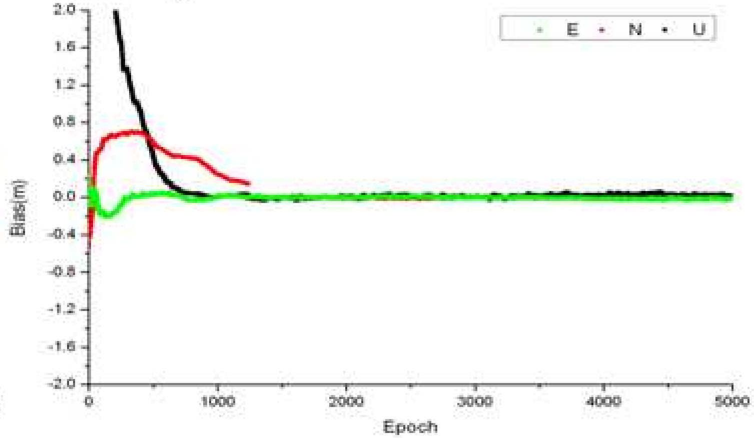
Ship-borne PPP with re-initialization



Ship-borne PPP solution with instantaneous AR

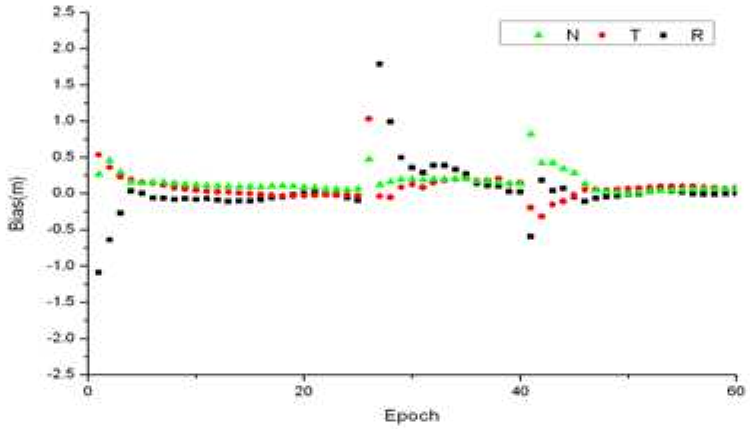


Airborne PPP with re-initialization

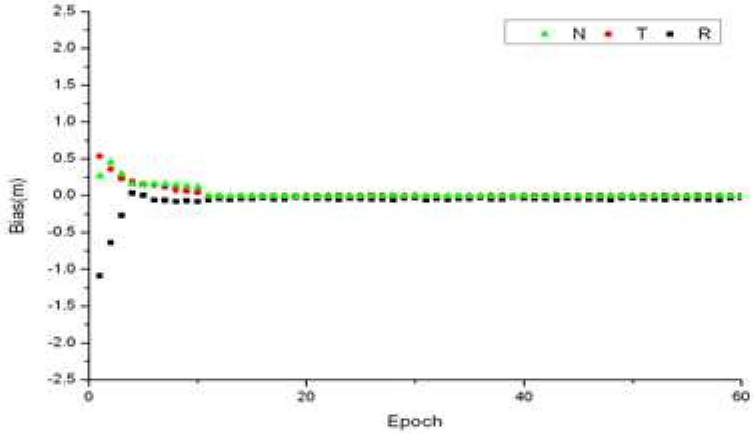


Airborne PPP solution with instantaneous AR

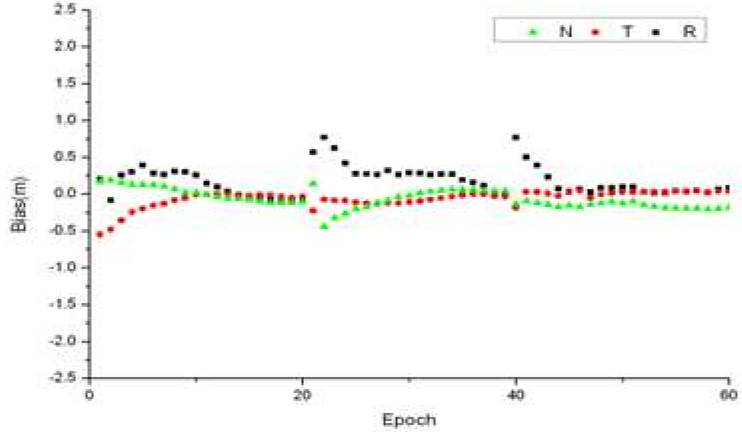
Space-borne Data (Grace A and B)



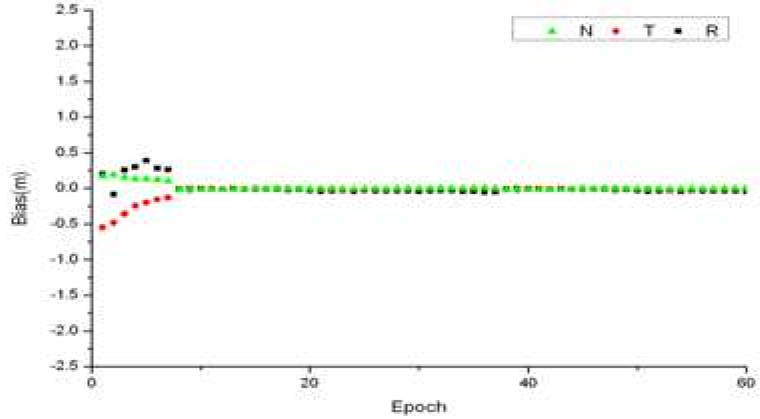
PPP solution of Grace-A based traditional model



PPP solution of Grace-A with instantaneous AR↵



PPP solution of Grace-B based traditional model



PPP solution of Grace-B with instantaneous AR↵

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3 Conclusion and outlook

- ZD ambiguities could be fixed successfully with one epoch even if all satellites are interrupted and the signal interruption lasts up to 200s.
- loss lock does not always occur on all carrier-phase measurements at one epoch, the continuous phase measurements can be used to constrain the ambiguity candidates search space.
- data gap can be possibly extended longer if more precise temporally atmospheric prediction is available.

Thanks for your attentions!