Some aspects of improving precision of ionospheric modeling

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Introduction

It is well known that ionospheric delay is one of the main error sources when positioning and navigating with GNSS. A high-precision ionospheric model is of great significance for GNSS based single-frequency navigation and positioning users. For the ionosphereic related scientific researches of ionosphere (eg. ionospheric storm, ionospheric scintillation, anomalous variations of geomagnetic storms, earthquakes and tsunamis), a precise and reliable ionospheric model is also required.

The International GNSS Service created the Ionosphere Working Group in 1998 with the goal of generating reliable VTEC maps (Hernández-Pajares et al. 2009). Since then, many scholars have done a lot of research in the field of ionosphere modeling. In this study, we analyze some aspects of improving the precision of ionospheric modeling in detail

Outline

Ionospheric modeling using GPS (G) only, GPS+GLONASS (GR), GPS+BeiDou (GC), GPS+GLONASS+Galileo (GRE), and GPS+GLONASS+BeiDou+Galileo (GREC) observations have been performed to evaluate the contribution of Multi-GNSS

Phase-smoothing pseudorange, standard precise point positioning (PPP) and ambiguity fixed PPP methods are adopted to extract slant total electron content (STEC) measurement

The accuracy of the derived STEC is validated by co-located receivers

Global Ionospheric Map (GIM) have been derived based on ambiguity fixed PPP, and the accuracy of the derived GIM is assessed

Contribution of Multi-GNSS

Observations from over 400 IGS and MGEX stations for 366 days from January 1 to December 31, 2016, have been used to produce Global Ionospheric Map (GIM). The Phase-smoothing pseudorange method is used to derive STEC observations. The mean and standard deviation (STD) of bias between different observation combination are calculated to evaluate the contribution of Multi-GNSS. The mean and STD of the bias between some selected combinations are shown in Fig 1. Fig. 1 shows that the mean and STD of bias between G and GR are within 0.5 and 0.8 TECU, respectively. The mean and STD of bias between G and GREC is slightly larger, but not larger than 1.2 and 0.8 TECU. Since the accuracy of traditional ionospheric modeling is in the range of 2 to 8 TECU, the contribution of Multi-GNSS is not obvious.

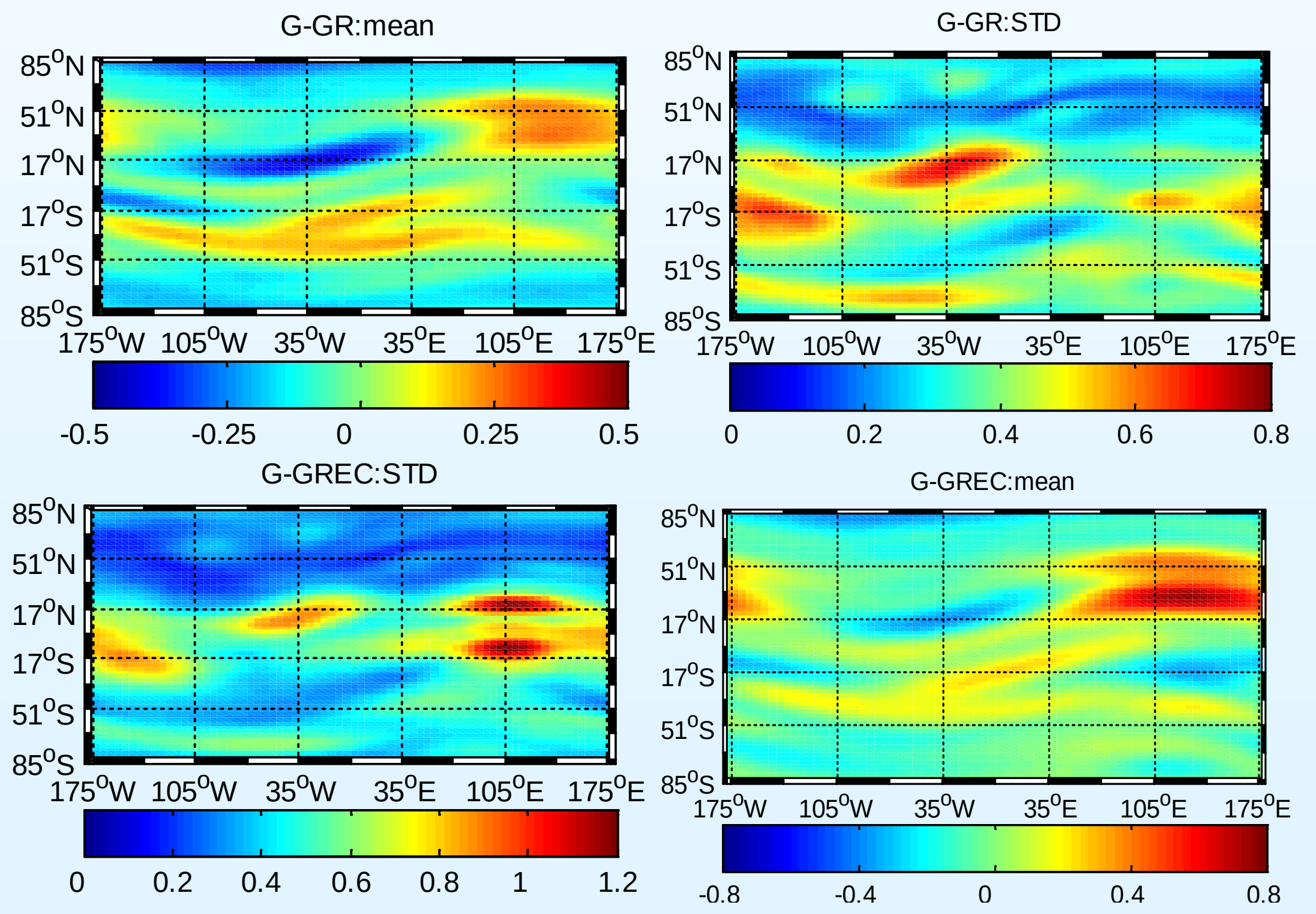

Fig.1 Mean and STD of the bias between some selected combinations

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Validation of STEC

Since the ionospheric delay of a satellite is same for the co-located stations, differencing STEC derived by two stations cancels out the satellite biases as well as the ionospheric delays. The remaining receiver-dependent bias between stations is expected to be identical for all satellites. Fig. 2 show the time series of receiver-dependent bias between stations ZIM2 and ZIM3 using Phase-smoothing pseudorange and standard PPP for GPS sytem.

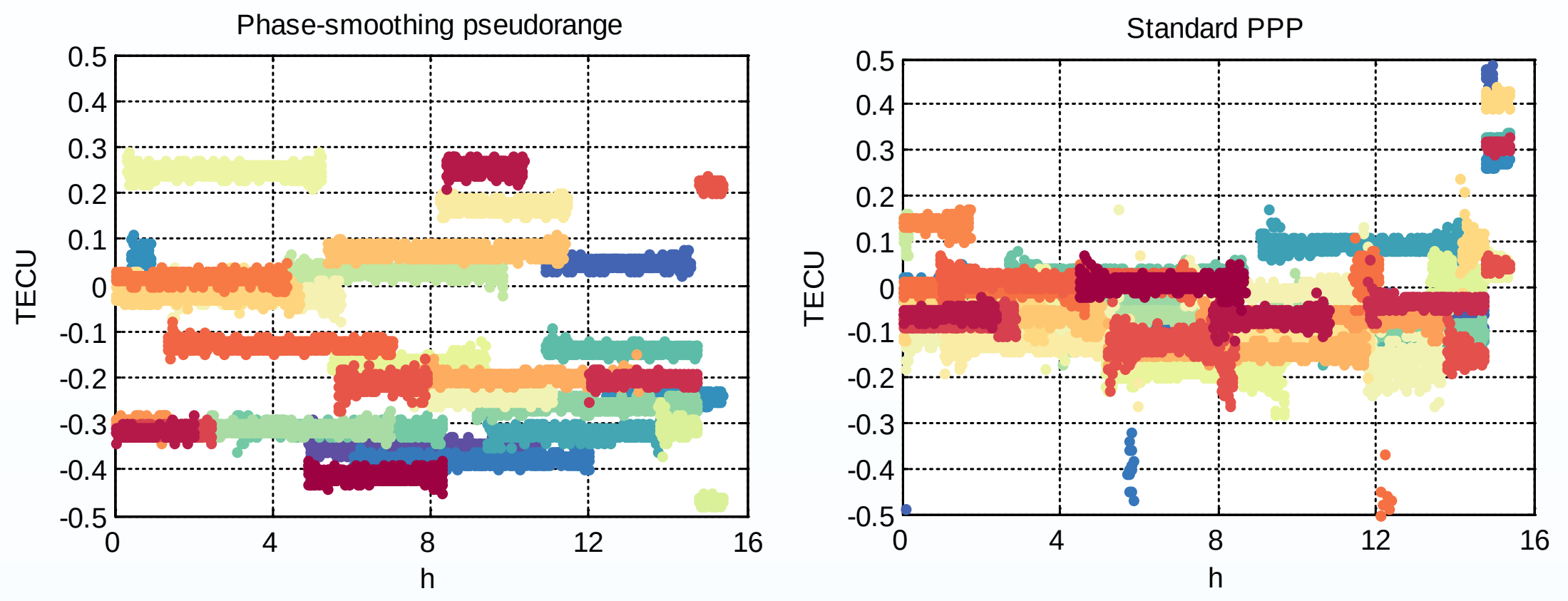

Fig.2 Time series of receiver-dependent bias between stations ZIM2 and ZIM3 using Phase-smoothing pseudorange (left) and standard PPP (right)

Fig. 2 illustrates that the differences of STEC are mainly within 0.8 and 0.5 TECU for Phase-smoothing pseudorange and standard PPP, respectively. The time series of receiver-dependent bias using ambiguity fixed PPP are also obtained for GPS, GLONASS, Galileo and BeiDou, they are plotted in Fig. 3.

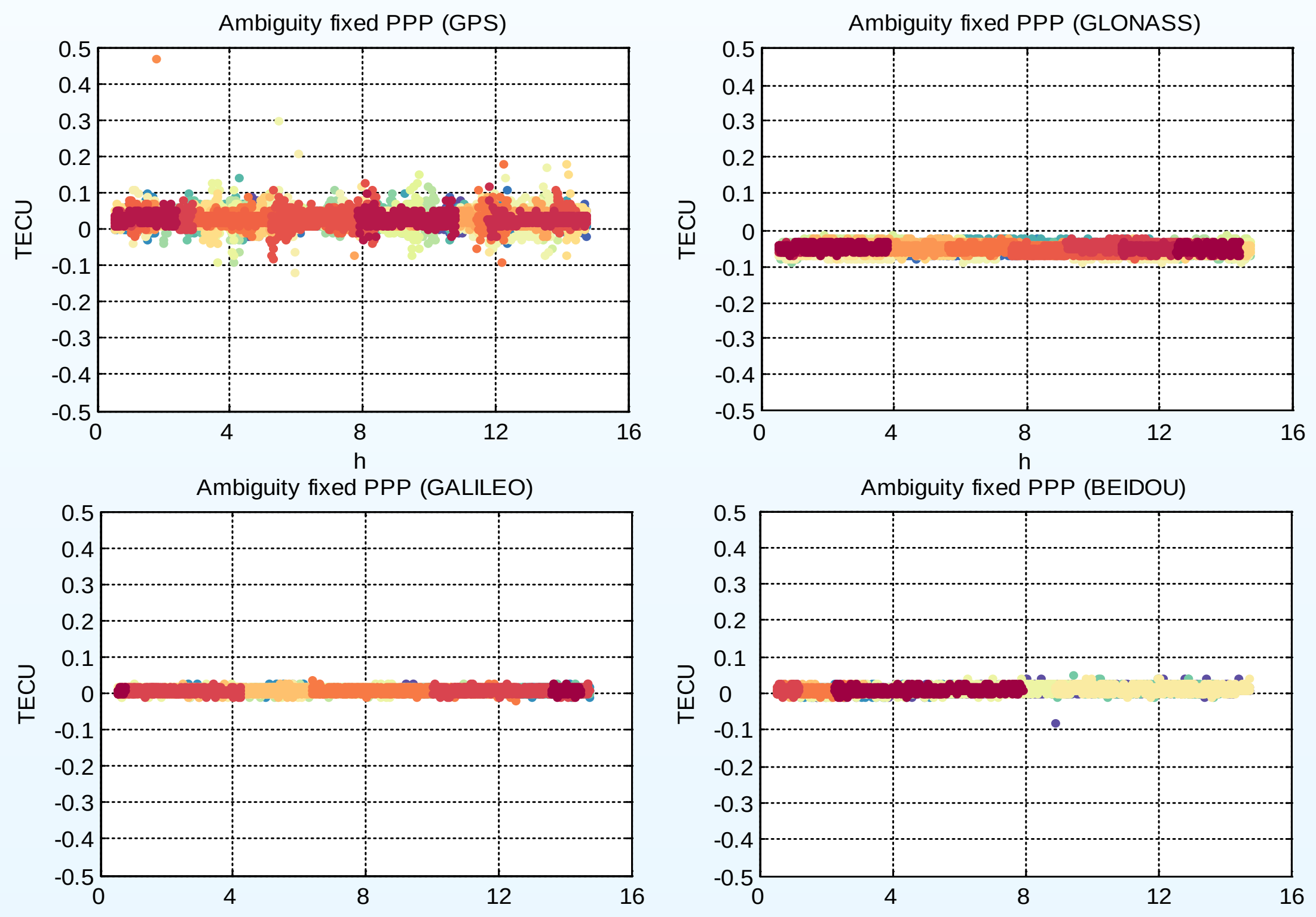

Fig.3 Time series of receiver-dependent bias between stations ZIM2 and ZIM3 using ambiguity fixed PPP

As shown in Fig.3, the difference of STEC are mainly within 0.1 TECU for GPS, GLONASS, Galileo and Beidou while using ambiguity fixed PPP, which is much smaller than the results shown in Fig. 2.

Validation of GIM

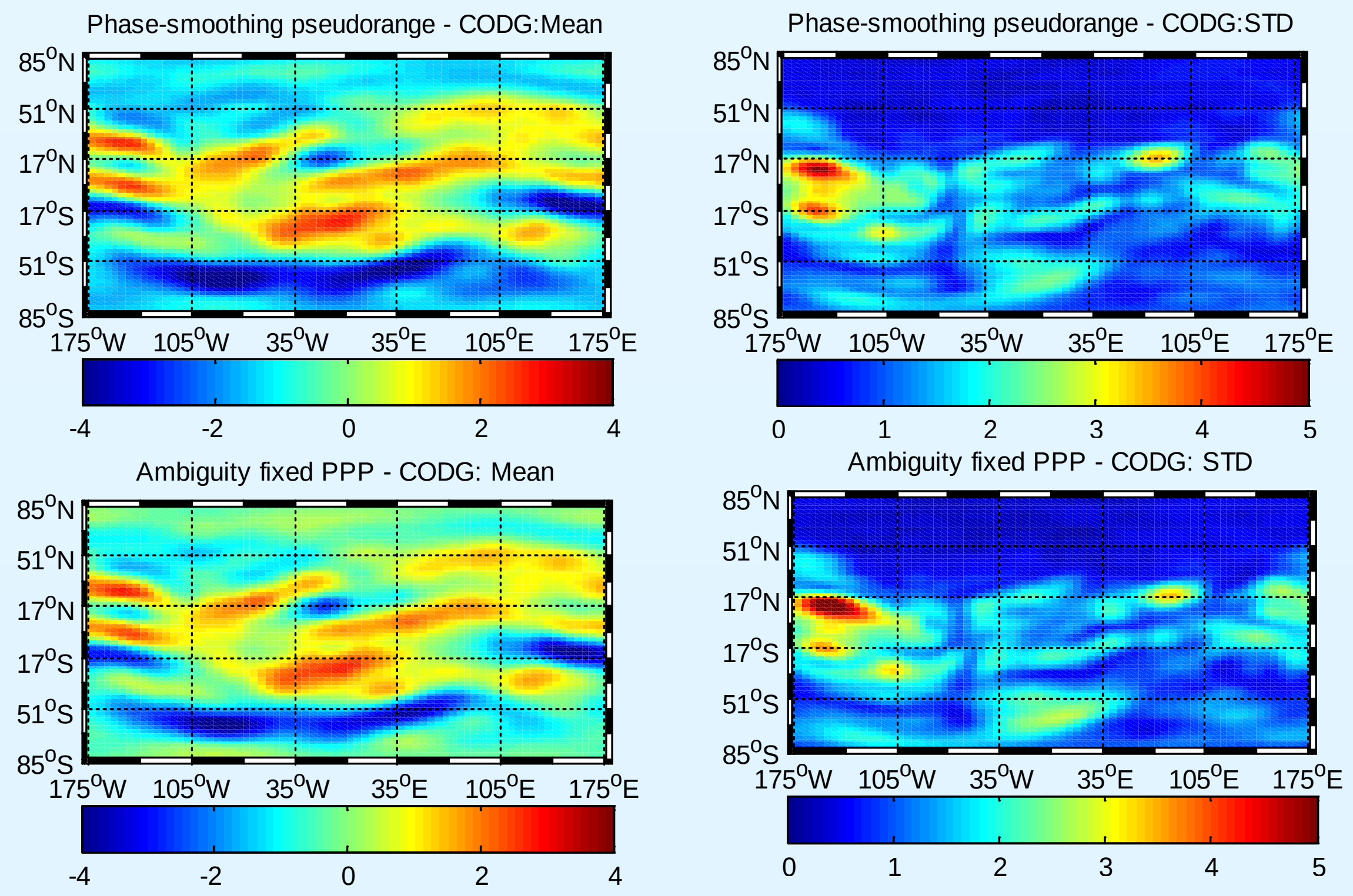

Fig.4 the mean difference and standard deviation (STD) of Phase-smoothing pseudorange and ambiguity fixed PPP with respect to CODE

Fig 4 shows the mean difference and STD of Phase-smoothing pseudorange and ambiguity fixed PPP with respect to CODE. It can be seen that the estimated GIMs agree well with the CODE product, with the differences being less than 2 TECU in most areas. But the difference between the two solutions is very small。

Single-frequency kinematic PPP

The estimated GIMs are used to correct the ionospheric delay of single frequency kinematic PPP. The root mean square (RMS) of positioning errors for some selected stations are shown in Fig. 5. It can be seen that CODE has the best performance in the three products, with the Minimum positioning error among most stations. The GIM derived by ambiguity fixed PPP is better than Phase-smoothing pseudorange among most stations, but the advantage is not very obvious. It should be noted that the accuracy of current ionospheric modeling is limited, the advantege of ambiguity fixed PPP can not be fully demonstrated

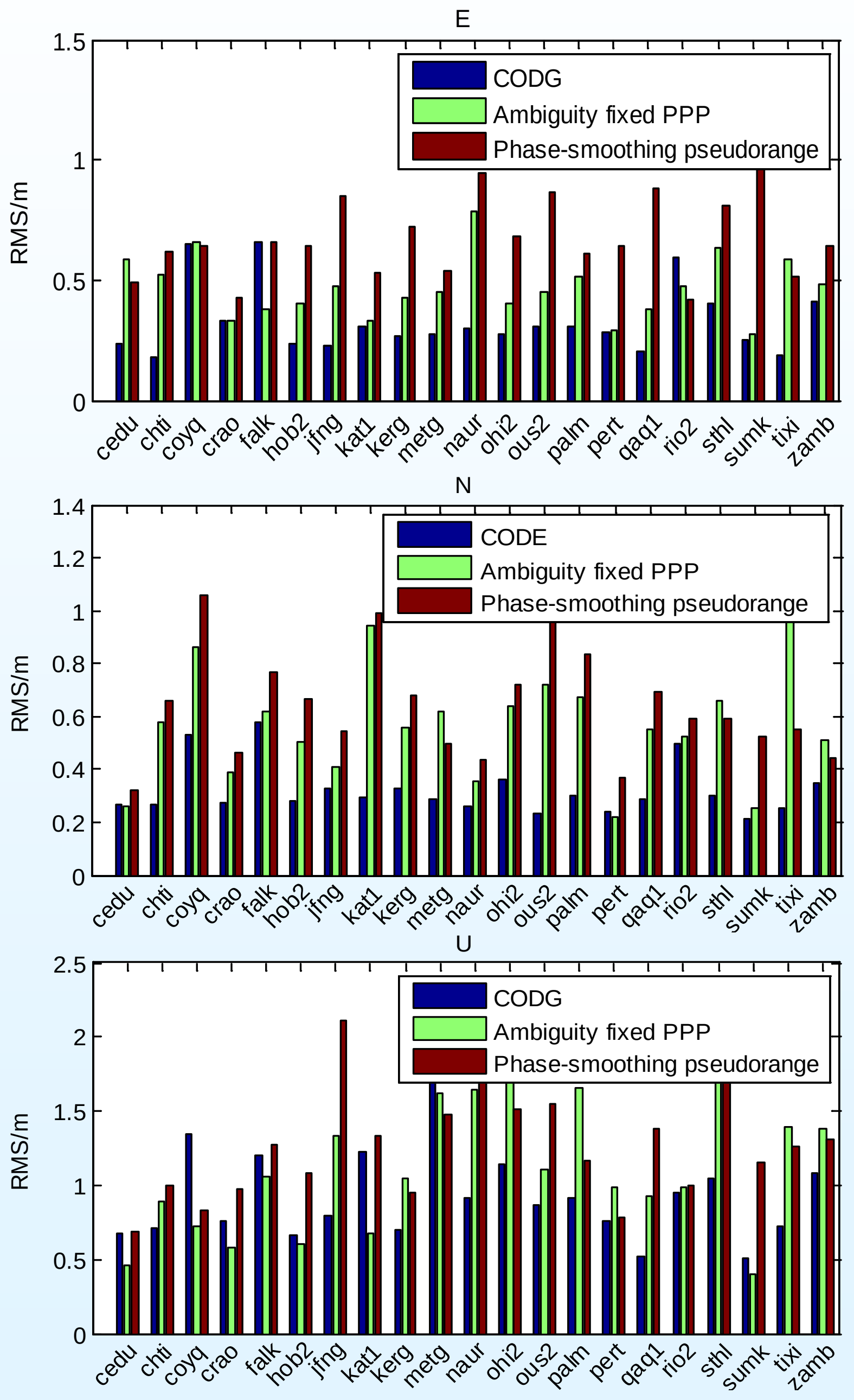

Fig.5 The RMS of positioning error for some selected stations with different ionospheric correction.

Conclusion

The mean and STD of bias between different observation combination are mainly within 1 TECU, which is smaller than the accuracy of traditional ionospheric modeling. The contribution of Multi-GNSS is not obvious.

The derived STEC is validated by co-located stations, the results show that STEC derived by ambiguity fixed PPP is more accurate than Phase-smoothing pseudorange and standard PPP

Estimated GIM agree well with the CODE product, with the differences being less than 2 TECU in most areas. Based on the results of single frequency kinematic PPP, CODE has the best performance in the three products. The GIM derived by ambiguity fixed PPP is better than Phase-smoothing pseudorange among most stations, but the advantage is not very obvious

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