

AN INVESTIGATION OF THE EFFECT OF IONOSPHERIC MODELS ON PERFORMANCE OF NETWORK-BASED RTK GPS IN THAILAND

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ABSTRACT:

Thailand established a Network-based Real Time Kinematic (NRTK) GPS system using the Virtual Reference Station (VRS) concept in 2008. Currently the Thai NRTK consists of 11 reference stations located in the central part of Thailand with average reference station spacing of about 60 km. (Charoenkalunyuta et al., 2012) suggested that the ionospheric bias is the main error source which degrades NRTK performance in Thailand since the rate of ambiguity-fixing is significantly decreased when an irregular ionospheric variation occurs. In this paper, the position performance of NRTK is tested with a large number of GPS observations (31 consecutive days) and different reference receiver spacing, 10-20, 30-50, 50-60 and 60-80 km, with the use of final Global Ionospheric Maps (GIM) from the Center for Orbit Determination in Europe (CODE) and all available Continuous GPS (CGPS) stations in the central part of Thailand. Test results indicate that the NRTK positioning performance is improved when the final GIM was used, especially in the case of large reference receiver spacing. Thus it is concluded that the final GIM can mitigate the ionospheric bias in the NRTK mode.

1. INTRODUCTION

Nowadays, the Network-RTK GPS (NRTK) is widely used in many countries. The main idea of this technique is to estimate distance-dependent errors (ionospheric delay, tropospheric delay and orbit biases) for each reference station, then generate the network corrections within the network coverage and transmit these directly to users. These corrections can be separated into dispersive (ionospheric-related) and non-dispersive (tropospheric and orbit-related) components (Lim et al., 2008). Dispersive component typically exhibit rapid changes with high variations due to the effect of free electrons in the ionosphere (Hernandes, 1999; Odijk, 2002; Memarzadeh, 2009). On the other hand, the non-dispersive component changes slowly and smoothly over time due to the characteristic behavior of the tropospheric and orbit biases (Lim et al., 2008). In Thailand, the Department of Lands (DOL) has established since 2008 the Virtual Reference Station (VRS) - NRTK system mainly to support cadastral surveying applications. Currently, the DOL NRTK system comprises 11 reference stations located in the Central Plain region with spacing ranging from 27.8 to 125.6 km, and average spacing of around 60 km. Charoenkalunyuta et al. (2012) suggested that the ionospheric bias is the main error source which degrades NRTK performance in Thailand.

Since Thailand is in a low-latitude region, the ionospheric bias is highly problematic. This is due to the fact that, in a low-latitude region, the ionospheric activity is much higher than in mid-latitude regions (Musa, 2007; Lim et al., 2008). Previous studies (Attaviriyasuwon et al., 2005; Gwal et al., 2004 and SEALION, 2012) have shown the high variation of ionospheric activity in Thailand region and confirmed that ionospheric irregularities usually occur at night time. Considering the ionospheric effect in this region, mitigating ionospheric bias through the using of Global Ionospheric Maps (GIM) from the Center for Orbit Determination in Europe (CODE) may improve reliable and

accurate positioning solutions of the NRTK especially because of the long average reference station spacing. This paper aims to test the performance of NRTK in the Thai region by incorporating the available Continuous GPS (CGPS) stations in the central part of Thailand with the aid of the final GIM. In the following sections, the final GIM are described, followed by the GPS data and software used. The data processing is then explained. Next, discussion of the test results is given. Finally, some concluding remarks are made.

2. FINAL GLOBAL IONOSPHERIC MODELS (GIM)

The final Global Ionosphere Maps (GIM) are generated on a daily basis at The Center for Orbit Determination in Europe (CODE) using data from about 150 GPS sites of the International GNSS Service (IGS – <http://igs.org>) and other institutions. A value for the Vertical Total Electron Content (VTEC) is generated every two hours starting from 0 to 24 UTC time at the grid points in the IONEX (IONosphere map EXchange) format (Schaer, 1999). The resolution of the maps is 5° in longitude and 2.5° in latitude. The VTEC is modeled in a solar-geomagnetic reference frame using a spherical harmonics expansion up to degree and order 15. Piece-wise linear functions are used for representation in the time domain. To convert line-of-sight TEC into vertical TEC, a modified single-layer model mapping function approximating the Jet Propulsion Laboratory (JPL) extended slab model mapping function is adopted. The mapping function is evaluated at geodetic satellite elevation angles. For the computation of the ionospheric pierce points, a spherical layer with a radius of 6821 km is assumed, implying geocentric, not geodetic IONEX latitudes. The final GIM are made available with a delay of approximately 3 days. The VTEC provided by final GIM has a standard deviation of 2-8 TEC units (TECU) depending on the epoch in the solar cycle, season, and location. (CODE, 2012)

3. GPS DATA AND SOFTWARE USED

This research focuses on the benefit of final GIM on performance of NRTK in Thailand with different reference receiver spacing distances. The GPS datasets were those used as in the previous study (Charoenkalunyuta et al., 2012), i.e. datasets from the Department of Lands (DOL), the Department of Public Works and Town and Country Planning (DPT), the Royal Thai Survey Department (RTSD), the Thai Meteorological Department (TMD), S.D.M. Company Limited (SDM), and Chulalongkorn University (Fig. 1). All stations operated dual-frequency geodetic-grade GPS receivers. For a reliable statistical analysis, common GPS observation periods for all CGPS stations between February 1st, 2010 and March 3rd, 2010 (31 days) were selected. The GPS data were sampled at a 30-second rate giving rise to a total of 89,280 epochs. Trimble Total Control (TTC) version 2.73, a commercial post-processing software, was used to compute the coordinate solutions for roving receivers

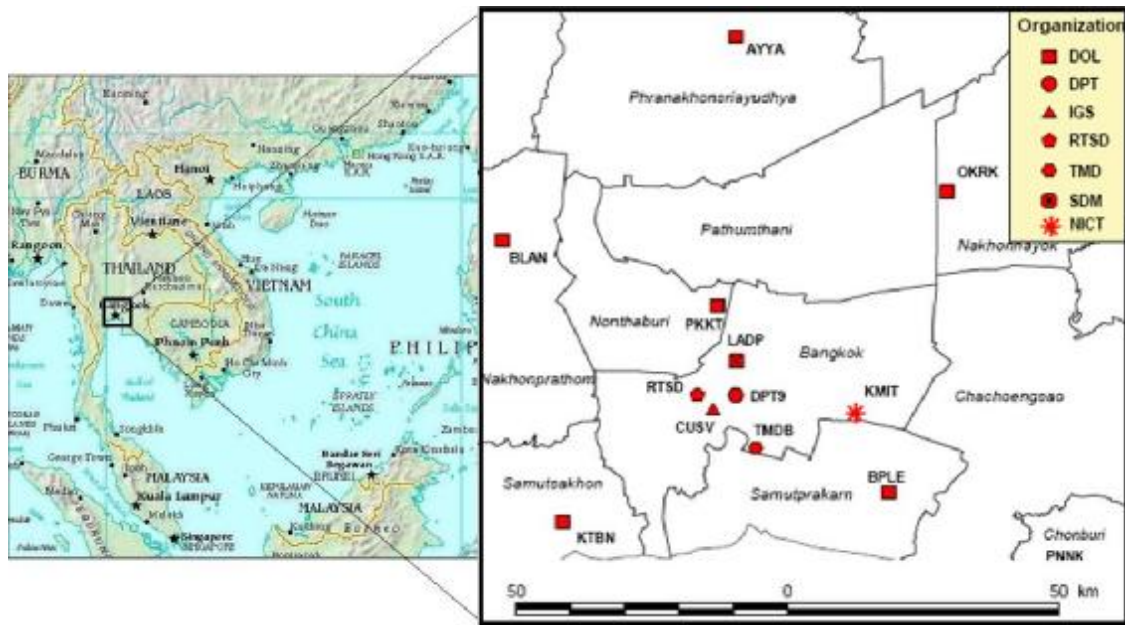


Fig. 1. The location of CGPS stations used in this research (Charoenkalunyuta et al., 2012)

4. DATA PROCESSING

All test data were processed in an off-line mode. Similar to the previous study (Charoenkalunyuta et al., 2012), the processing consisted of three main steps. The first step was to establish the reference stations' coordinates using the BERNESE software, while the second step dealt with the generation of the VRS observations for different reference receiver spacing distances nearby each roving station (Fig. 2). The final step was the post-processing of NRTK solutions using VRS observations generated from the previous step. The details of each step can be found in Charoenkalunyuta et al. (2012). However, in this study we introduce the final GIM to account for the ionospheric bias in the second step.

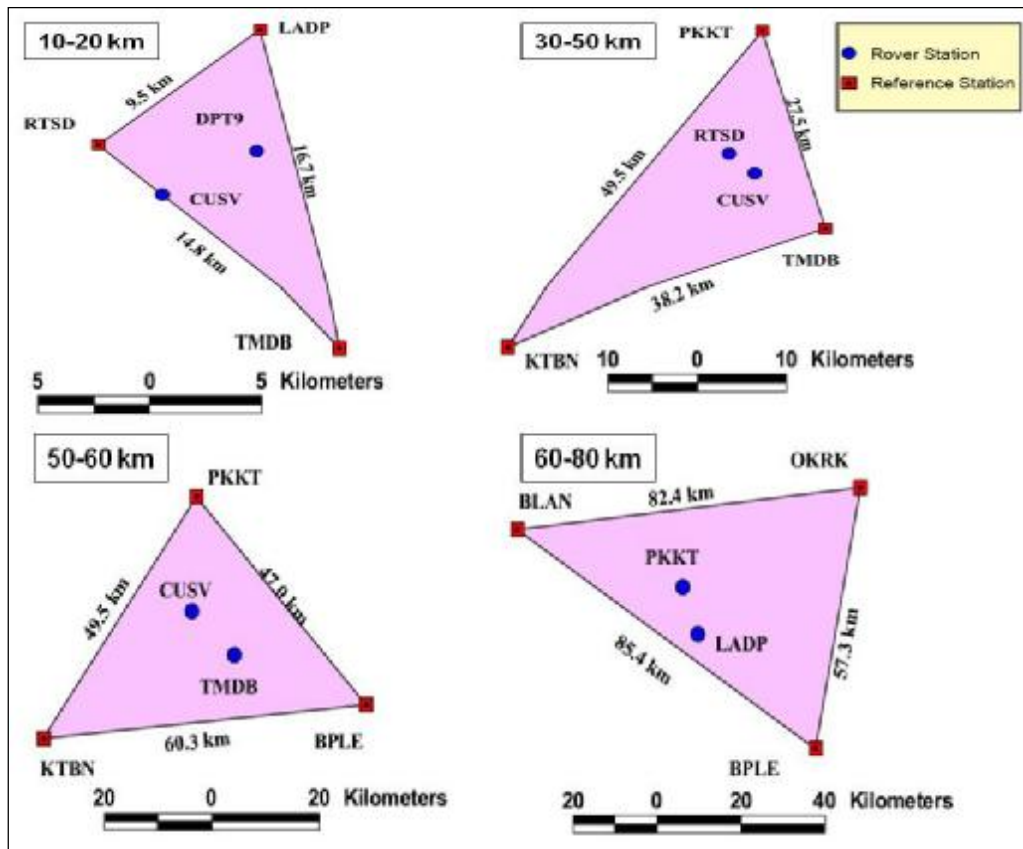


Fig. 2. Four different reference station spacing and roving receivers (Charoenkalunyuta et al., 2012)

5. TEST RESULTS AND DISCUSSION

After all data were processed, the final coordinates were compared with the reference coordinates in both cases, i.e. with the use of the final GIM and without the use of the final GIM. The performance of the NRTK technique can be characterised by two main indicators: namely the rate of ambiguity-fixing and Root Mean Square Error (RMSE). In this investigation, the RMSE in both cases (with and without the final GIM) is calculated separately for horizontal and vertical components. It should be noted that all indicators are the averaged values of the solutions obtained from two roving stations in each VRS triangle (Fig. 2). These quality indicators are shown in Table 1. Further test comparisons are plotted in Figs. 3 and 4.

Table 1. Summary of the performance of NRTK with and without final GIM for different reference station spacing

Reference receiver spacing	Amb.-fixing rate (%)		RMSE (m)			
	No GIM	GIM	No GIM		GIM	
			Hor.	Vert.	Hor.	Vert.
10-20 km	89	91	0.011	0.023	0.011	0.022
30-50 km	62	71	0.012	0.036	0.013	0.036
50-60 km	32	72	0.014	0.044	0.014	0.043
60-80 km	27	29	0.035	0.072	0.029	0.071

Table 1 shows that the performance of NRTK has been improved when the final GIM is used in all reference station spacing. Considering the rate of ambiguity-fixing, the use of the final GIM can significantly improve the NRTK performance in the middle reference station spacing (i.e. 30-50 km and 50-60km). In the case of RMSE values, overall values show no significant difference, as illustrated in Fig. 4.

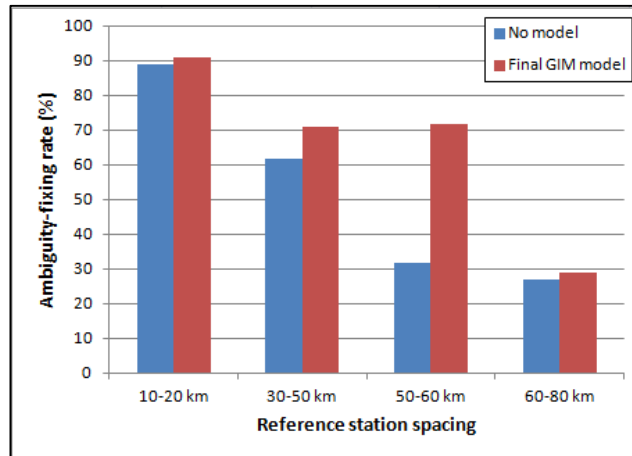


Fig. 3. Ambiguity-fixing rate with and without GIM for different reference station spacing

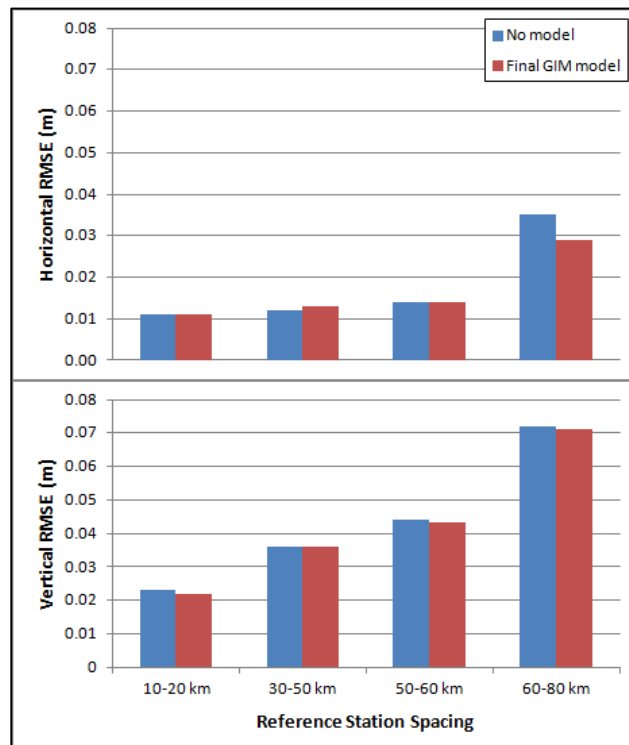


Fig. 4. RMSE values obtained from different reference station spacing with and without GIM (Top: Horizontal RMSE. Bottom: Vertical RMSE)

6. CONCLUDING REMARKS

In this paper the performance of NRTK in Thailand was tested using real GPS observations collected for 31 consecutive days. Based on the available GPS observations, four different reference station spacings of 10-20 km, 30-50 km, 50-60 km, and 60-80 km have been tested with and without the introduction of the final Global Ionosphere Models derived from IGS data. Test results show that the performance of the NRTK is improved when the final GIM are introduced into the data processing step. This investigation confirms that the ionospheric error is the main error source which degrades the NRTK performance in Thailand since the rate of ambiguity-fixing is significantly improved when the final GIM model is applied. Since the final GIM is a global ionospheric model, our future work will focus on the generation of the local ionosphere models to further improve the performance of NRTK in the Thai region.

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