The Effect of Surface Meteorological Measurements on High-precision GPS Positing Determination

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Abstract: In this study, the Global Positioning System (GPS) data collected by the GPS receivers that were established as continuously operating reference stations by Central Weather Bureau and Industrial Technology Research Institute of Taiwan are utilized to investigate the impact of atmospheric water vapor on GPS positioning determination. The surface meteorological measurements that were concurrently acquired by instruments co-located with the GPS receivers include temperature, pressure and humidity data. To obtain the influence of the baseline length on the proposed impact study, four baselines are considered according to the locations of the permanent GPS sites. The length of the shorter baseline is about 66 km, while the longer is about 118 km. The results from the studies associated with different baseline lengths and ellipsoid height were compared for the cases with and without *a priori* knowledge of surface meteorological measurements. The finding based on 66 days measurements is that the surface meteorological measurements have a significant impact on the positioning determination for the longer baseline case. The associated daily maximum differences are 1.1 cm and 1.4 cm for the baseline and ellipsoid height respectively. The corresponding biases are -8.1 mm in length and -7.3 mm in ellipsoid height.

Keywords: GPS, Surface Meteorological Measurement.

1. Introduction and Objectives

The GPS has been used for the purposes of navigating and positioning for many years [1]. Later, it is applied to a variety of research and applied fields for a wide spectrum of positioning accuracy requirement such as crustal deformation studies. However, the need of positioning accuracy is especially rigorous, generally on the order of mm, for the crustal deformation studies by using GPS and differential interferometric synthetic aperture radar where the effect of atmosphere on the positioning accuracy can not be neglected due to the presence of highly spatially inhomogeneous and temporally various water vapor.

In this study, we investigated the impact of surface meteorological measurements (temperature, pressure and humidity) on high accuracy GPS positioning determination.

2. Data Collection

The GPS data were collected from five GPS tracking Stations operated by the Central Weather Bureau (CWB) and Industrial Technology Research Institute (ITRI) of Taiwan. The surveying time was DOY 55~165, 2003. Of the six GPS tracking stations, the model of the GPS receiver and the meteorological instruments are the same so that the system errors associated with the instruments can be neglected. The meteorological instruments were connected with the GPS receiver. GPS data, ground temperature, pressure, and humidity were recorded at the same time. The models of the GPS receivers and the meteorological instruments are listed in table 1.

Table 1. The Model of GSP Receivers and Meteorological Instruments.

GPS station name	Model of GPS receiver	Model of meteorological instrument	Organization
TCMS	Leica RS500	MET3-A	ITRI
NSHE	Leica RS500	MET3-A	CWB
HUAN	Leica RS500	MET3-A	CWB
PEPU	Leica RS500	MET3-A	CWB
SLIN	Leica RS500	MET3-A	CWB

3. Computing Method

Four baselines are chosen in this study. In the positioning determination, we used precise ephemeris from the International GPS Service (IGS) and information of the phase center of antenna from U.S. National Geodetic Survey (NGS). Analysis is performed for all baselines with and without additional surface meteorological data. The lengths of the four baselines were listed in table 2. The Bernese software V4.2 that was developed by the Institute of Astronomy, University of Berne was used in the data processing. The ambiguity resolution algorithm of the double difference equations is Quasi Ionosphere-Free (QIF) [2]. The data and computation processing are by the Bernese Processing Engine (BPE) [2].

Table 2. The Lengths of Baselines.

Baseline	Length (km)
TCMS-NSHE	66
TCMS-HUAN	78
TCMS-PEPU	107
TCMS-SLIN	118

4. Results

Based on results from the determinations of the four baseline cases, we quantify the effect of surface meteorological measurements on the ellipsoid height and length of baselines. Note that in all of the tables and figures, "-M" indicates that the surface meteorological measurements are used in the positioning computation

1) Baseline

Figures 1 and 2 show the daily lengths of the baselines determined by the GPS data for the shortest (TCMS-NSHE) and longest (TCMS-SLIN) baseline cases. It is clearly seen that the baselines are shortened as the surface meteorological measurements are incorporated into the determination of the positions. In another word, the use of surface meteorological measurements has an impact on the GPS positioning determination.

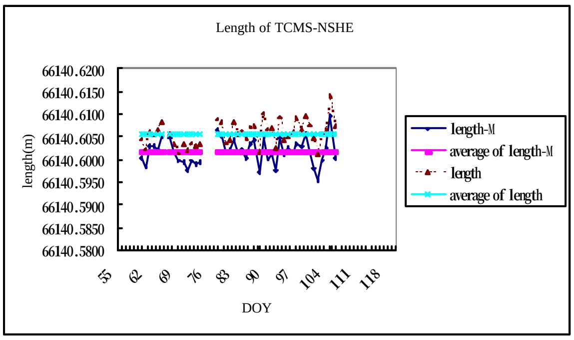

Fig. 1. Daily Variation of the Baseline Length (TCMS-NSHE)

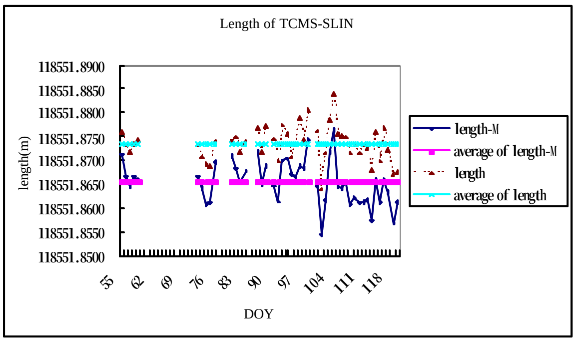

Fig. 2. Daily Variation of the Baseline Lengths (TCMS-SLIN)

2) Ellipsoid Height

Figures 3 and 4 show daily variations of the elliposid heights for the baselines NSHE (the shortest) and SLIN (the longest) cases, respectively. We observe that there is a larger improvement in the ellipsoid height determination for the longer than the shorter baseline cases when the surface meteorological measurements are taken into account.

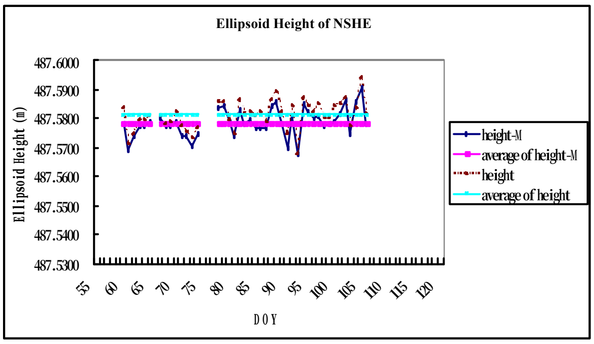

Fig. 3. Daily Variation of the Elliposid Height (NSHE)

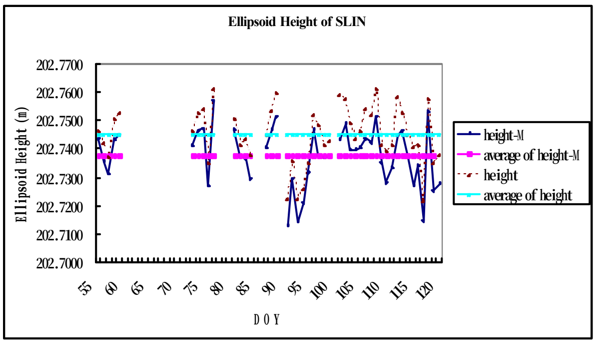

Fig. 4. Daily Variation of the Elliposid Height (SLIN)

3) Data Comparison

Comparisons among Figures 1, 2, 3, and 4 demonstrate that the baseline lengths and ellipsoid heights are in general decreased when surface meteorological data are incorporated into positioning determination. We only show results from two of the four baseline cases for simplicity. Based on the 66 days data analysis, we found that the daily maximum differences are 1.1 cm for the baseline length and 1.4 cm for the elliposid height. The average and stand deviation of baseline length and ellipsoid height between results from the cases with and without surface meteorological data are listed in table 3 and table 4, respectively.

Table 3. The Average and Stand Deviation of baselines.

Base-line	(1) Length -M (m)	Stand Deviation -M (m)	(2) Length (m)	Stand Deviation (m)	(2)-(1) Difference (m)
TCMS-NSHE	66140.6017	0.0026	66140.6057	0.0030	-0.0040
TCMS-HUAN	78143.3282	0.0039	78143.3327	0.0026	-0.0045
TCMS-PEPU	107043.8896	0.0039	107043.8968	0.0039	-0.0071
TCMS-SLIN	118551.8654	0.0047	118551.8734	0.0040	-0.0081

Table 4. The Average and Stand Deviation of Ellipsoid Height.

Baseline	(1) Height -M (m)	Stand Deviation -M (m)	(2) Height (m)	Stand Deviation(m)	(2)-(1) Difference (m)
TCMS-NSHE	487.5787	0.0048	487.5814	0.0050	-0.0028
TCMS-HUAN	3421.5675	0.0046	3421.5700	0.0044	-0.0026
TCMS-PEPU	36.0473	0.0074	36.0498	0.0074	-0.0025
TCMS-SLIN	202.7375	0.0102	202.7448	0.0102	-0.0073

5. Conclusions

In the past, the error uncertainties associated with the instrumentations and tropospheric effects are simplified or neglected in the GPS positioning determinations. Usually, the empirical or statistical model is good enough if the purpose is for navigation or ordinary surveying. However, for the issues of highly precise positioning determination, the error uncertainties associated with atmospheric effect must be considered. In this study, we showed that the inclusion of atmospheric effect is helpful for the GPS positioning. The improvements may reach as much as 1.1 cm for the baseline length and 1.4 cm for the elliposid height from the results of this study.

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