Preliminary Study of Modeling the Precipitable Water Vapor Based on Radiosonde Data

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Key words: radiosonde, tropospheric zenith delay, precipitable water vapour

SUMMARY

GNSS meteorology is the determination of the water vapour content of the troposphere from Global Navigation Satellite System (GNSS) data. Moreover, the water vapour content is estimated from the techniques such as water vapour gradiometers, solar spectrometers, radiosondes, and lidars. Unlike GNSS, these techniques are expensive and their spatial and temporal solutions are weak. In addition, they cannot work in all weather conditions and have limited range of global coverage. Thus, GNSS has become an indispensable tool for providing the water vapour content in climate and meteorological studies.

One of the applications of GNSS is the estimation of the tropospheric zenith delay derived from ground-based GNSS data. The estimated tropospheric zenith delay is then used for the determination of the water vapour. For this reason, Askne and Nodius (1987) have developed the equation of the index of refraction. Water vapour is estimated from the wet part of the tropospheric zenith delay. There are two models to map the wet tropospheric zenith delay onto the precipitable water vapour: T_m model and conversion factor Q.

In this study, another regional T_m model is developed using a radiosonde analysis algorithm which can determine the transformation parameters between the wet tropospheric zenith delay and the precipitable water vapour. The outcomes of the algorithm are the weighted mean temperature, the wet tropospheric zenith delay, and the precipitable water vapour. The wet tropospheric zenith delay and the precipitable water vapour acquired from the algorithm is compared with the wet tropospheric zenith delay and the precipitable water vapour derived from the data of continuous GNSS stations to check accuracy and reliability of these parameters and the algorithm.

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1. INTRODUCTION

GNSS provides information about the water vapour content of the troposphere. It is an economical tool and has high spatial and temporal solutions in accordance with the determination of the water vapour content. Therefore, the continuous GNSS networks established for geodetic, engineering, navigation, etc. purposes can be converted into GPS MET networks with an extra small cost and can be utilized for meteorological purposes (Haan, 2006).Moreover, tropospheric zenith delay which is a product of GNSS data is used in the determination of the water vapour content (Hogg, 1981). Then, the wet part of the tropospheric zenith delay is mapped onto the water vapour by using T_m model (Bevis, 1992) and conversion factor Q (Emardson, 2000).

Radiosonde profile observations of Istanbul, Ankara, Samsun and Diyarbakir radiosonde stations are analyzed with a radiosonde algorithm which is developed by using Matlab sotware (Deniz, 2013). As a result of this algorithm, the weighted mean temperature, the water vapor pressure, the precipitable water vapour, the wet tropospheric zenith delay, total zenith delay and conversion factor are calculated. Thereafter, the weighted mean temperature is modelled in terms of the surface temperature by using linear regression method. Thus, a regional T_m model is developed to estimate the precipitable water vapor from GNSS data.

This study is the preliminary investigation of the "The Estimation of Atmospheric Water Vapour Using GPS Project" which is supported by The Scientific and Technological Research Council of Turkey (TUBITAK). The aims of this project are the determination of the total zenith delays and the precipitable water vapour accurately and reliably from CORS-TR data and the production of numerical models based on time and position (CORS TR, 2006). For this purpose, two Continuously Operating Reference Stations are established near the radiosonde stations in Istanbul and Ankara. The total zenith delay derived from these stations will be estimated and compared to the total zenith delay calculated from the algorithm. The compatibility of the results will be examined and an inspection and calibration will be carried out according to the examination.

2. REGIONAL T_m MODEL

A regional T_m model is developed using a radiosonde analysis algorithm which can determine the weighted mean temperature (T_m), the wet tropospheric zenith delay, and the precipitable water vapour from the parameters of radiosonde profile data. Istanbul, Ankara, Samsun and Diyarbakır radiosonde profile data for the year 2011 are analyzed using the algorithm implemented in Matlab software (Figure 1). Thus, a regional T_m model has been found as T_m=57.4+0.77.T_s by using linear regression. The RMSE of the model is found as ±2.57 K

(Figure 2). This model covers the region between Istanbul, Ankara, Samsun, and Diyarbakir radiosonde stations (Figure 3). Apart from these radiosonde stations, there are Izmir, Isparta, Adana and Erzurum radiosonde stations. These stations will be analyzed with the algorithm and a regional model which covers all of Turkey will be developed.

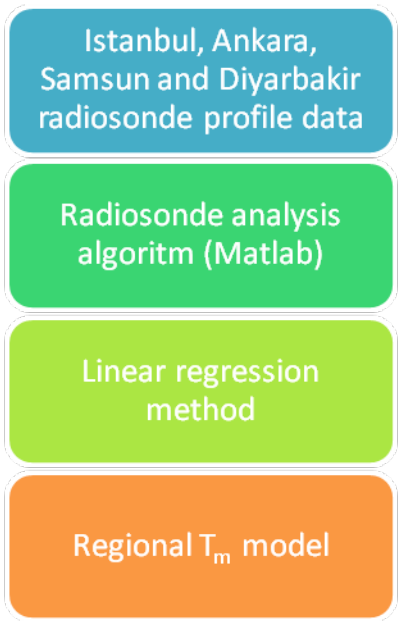

Figure 1 Flow chart of the determination of the regional T_m model

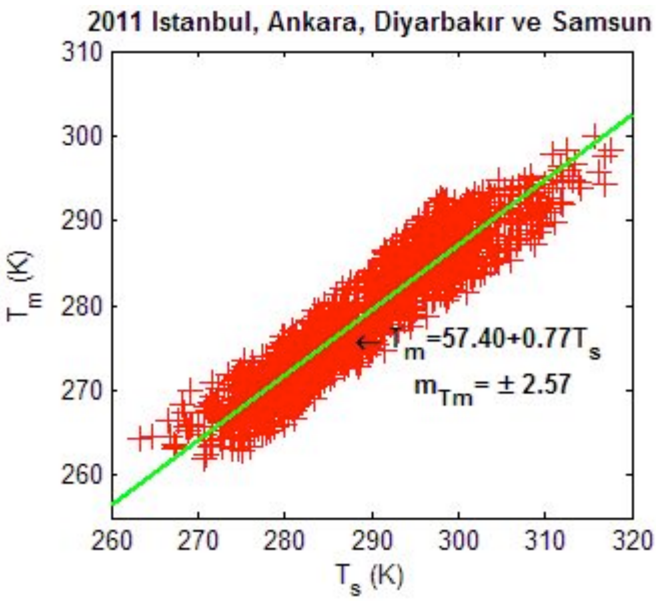

Figure 2 Regional T_m model

Figure 3 Radiosonde stations in Turkey

Other regional T_m models are given in Table 1.

Table 1 Other regional T_m models

Researcher Name	**T_m model (K)**	**RMSE (K)**
Bevis et al (1992)	T_m=70.2+ 0.72.T_s	4.74
Liou et al (2001)	T_m=1.07.T_s-31.5	1.67
Boutiouta et al (2010)	T_m=14.7+ 0.96.T_s	4.89

Two Continuously Operating Reference Stations are established near the radiosonde stations in Istanbul and Ankara (GISM and GANM) (Figure 4). The observation data of these stations are being recorded and transferred to the control center in Zonguldak, Turkey. The meteorological data of these stations are acquired from Turkish Meteorological Service.

Figure 4 Ankara and Istanbul continuously operating GPS stations

A test network will be established consisting of ISTA (Istanbul, Turkey), ANKR (Ankara, Turkey), CRAO (Ukraine) and MATE (Italy) IGS stations which have available meteorological data. Meteorological and RINEX data of IGS stations will be downloaded from the website of Scripps Orbit and Permanent Array Center. In addition, IERS pole data, precise orbit data and ionosphere data are downloaded via internet. Later, these datasets will be used in the processing of CORS and IGS stations with the Bernese GPS Processing 5.0 software from Istanbul Technical University to estimate the tropospheric zenith delays (Dach, 2007, Ozludemir, 2006).

The total tropospheric zenith delays derived from the datasets are used in the determination of the precipitable water vapour**.** The precipitable water vapour are determined with the regional T_m model T_m=57.4+0.77.T_s using Matlab software (Figure 5).

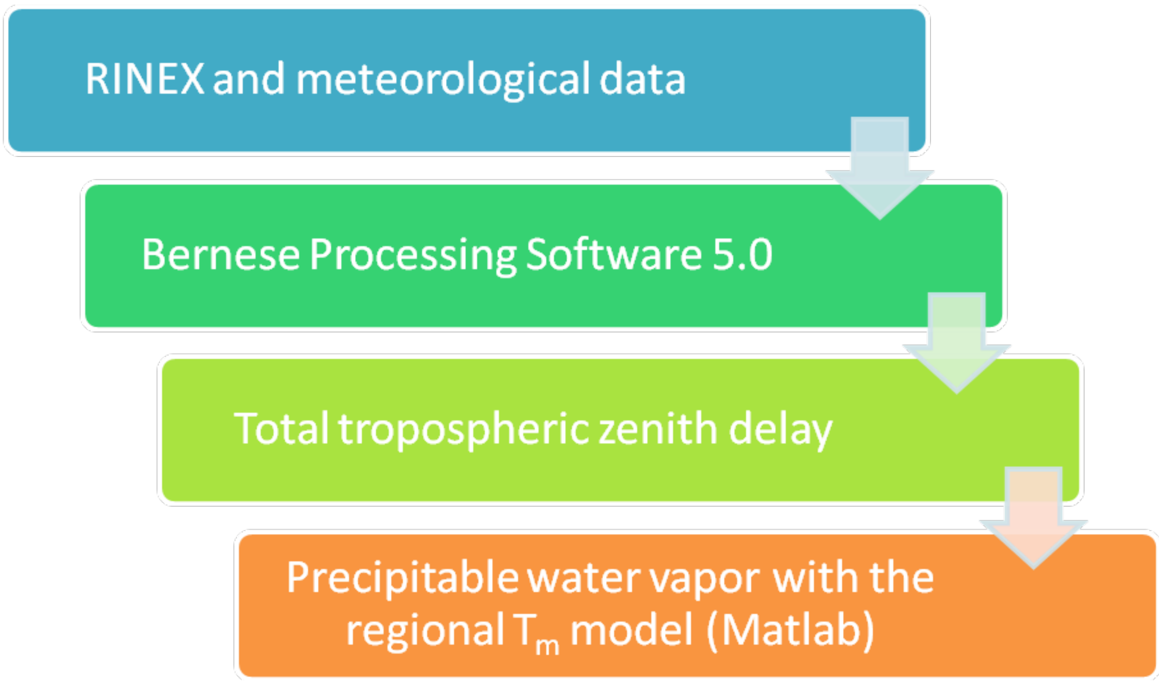

Figure 5 Flow chart of the determination of the precipitable water vapour

Consequently, to control the precision of the regional Tm models, the calculated precipitable water vapour and the precipitable water vapour obtained from the radiosonde stations will be compared.

3. CONCLUSIONS

A regional T_m model is found as T_m=57.4+0.77.T_s with a. RMSE of ±2.57 K as a result of the analysis of radiosonde profile data. It covers the region between Istanbul, Ankara, Samsun and Diyarbakır radiosonde stations. The remaining radiosonde stations (Izmir, Isparta, Adana and Erzurum) will be analyzed and a T_m model for Turkey will be developed.

RINEX data of GISM and GANM continuous GNSS stations, which are nearby the Istanbul and Ankara radiosonde stations, will be processed with IGS stations (ISTA, ANKR, CRAO and MATE) by using Bernese GPS processing 5.0 software from Istanbul Technical University. As a result of this process, tropospheric zenith delays will be estimated. Then, these tropospheric zenith delays will be used in the determination of the precipitable water vapour.

The wet part of the tropospheric zenith delay and precipitable water vapour derived from the results of GPS processing will be compared with the wet the tropospheric zenith delay and precipitable water vapour acquired from the analysis of radiosonde profile data. They will be used to check accuracy and reliability of the wet the tropospheric zenith delay, the precipitable water vapour and the radiosonde analysis algorithm.

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BIOGRAPHICAL NOTES

Dr. Cetin Mekik was born in 1967. He graduated from Istanbul Technical University in 1988 as Geodesy and Photogrammetry Engineer. He obtained M.Phil. and Ph.D. degrees from Newcastle upon University, United Kingdom. He is currently working as an Associate Professor and researcher at Geomatics Engineering Department of Bulent Ecevit University in Turkey. He has specialized in GNSS, Network RTK (CORS networks) and GNSS Meteorology, and has recently been granted a COST Project called "Water Vapour Estimation using GPS" sponsored by the Scientific and Technological Research Council of Turkey.

Ilke Deniz is a PhD student at department of Geomatics Engineering of The Institute of Natural and Applied Sciences at Bulent Ecevit University. She is a research assistant in the same department. She graduated from Yildiz Technical University in 2004 as Geodesy and Photogrammetry Engineer. She obtained M.Sc. degree from Geodesy Department of Bogazici University.

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