DOI:10.24996/ijs.2018.59.2A.18

ISSN: 0067-2904

# Estimation of The Zenith Path Delay using RTK-DGPS measurements

**Reyam R. Muhammed, Alaa S. Mahdi***
Remote Sensing unit, College of Science, University of Baghdad, Iraq,

**Abstract**

In this paper, the method of estimating the variation of Zenith Path Delay (ZPD) estimation method will be illustrate and evaluate using Real Time Kinematic Differential Global Positioning System (RTK-DGPS). The GPS provides a relative method to remotely sense atmospheric water vapor in any weather condition. The GPS signal delay in the atmosphere can be expressed as *ZPD*. In order to evaluate the results, four points had been chosen in the university of Baghdad campus to be rover ones, with a fixed Base point. For each rover position a 155 day of coordinates measurements was collected to overcome the results. Many models and mathematic calculations were used to extract the ZPD using the Matlab environment. The result shows that the ZPD values in mm depend on the water vapor intensity in the atmosphere and the mean temperatures. Also, the mean temperature model can be generated to calculate the Water Vapor Intensity( WVI ) for 20 km highest.

**Keywords:** Zenith Path delay, RTK DGPS, Zenith Wet Delay.

# تقدير تأخير الخط السمتي في قراءات نظام التموضع التفاضلي العالمي

**ريام رحيم محمد، علاء سعود مهدي***
وحدة الاستشعار عن بعد، كلية العلوم، جامعة بغداد، العراق .

**الخلاصة**

في هذا البحث، تم تطبيق طريقة لتقدير التغير في تأخير الخط السمتي لقياسات نظام التنوضع التفاضلي العالمي باستخدام أسلوب الوقت الحقيقي الحركي. يمكن أن تعطي نظم التموضع العالمية تقديرا للمحتوى المائي للغلاف الجوي وبالتالي يمكن اعتبارها طريقة استشعار عن بعد لغرض دراسة حالة الطقس. ولغرض استخراج النتائج، تم اختيار أربع مواقع لقياس الإحداثيات ونقطة أساس واحدة (في مجمع جامعة بغداد – الجادرية) وتضمن العمل قياس الإحداثيات في فترة 155 يوم. تم استخدام حسابات رياضية وموديلات محددة لغرض حساب تأخير الخط السمتي وبمساعدة بيئة الماتلاب. كذلك في هذا البحث يمكن حساب معدل درجة الحرارة لغرض استخراج تركيز بخار الماء في الغلاف الجوي ولارتفاع 20 كيلومتر.

## 1. Introduction

The methods of estimating the variation of water vapor in the atmosphere will be illustrated and evaluate using Just Integrated Water Vapor model **(IWV)** with no underline. With In some researches IWV is known as **p**recipitable water vapor (PWV), **[1]**. If all the water in that column were precipitated as rain. At a depth, the precipitable water is measured in millimeters or inches. Often abbreviated as "TPW" = **T**otal **p**recipitable **w**ater". For this purpose, four rover stations were selected in the college of science, university of Baghdad, (in the study area) The measurements of the RTK-

*Email: dralaa_smahdi@yahoo.com

DGPS data were obtained in the period from 2-11-2016 to 26-4-2017 including the recording of all climatic parameters.

## 2. The DGPS Operation Modes

DGPS operation modes

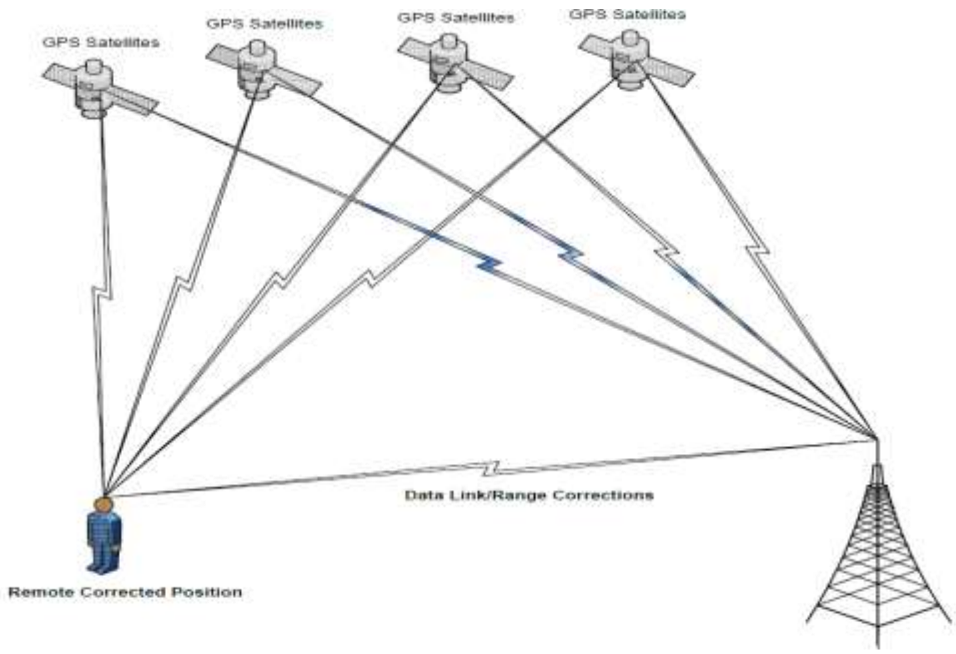


**Figure 1-The GPS System Simulation.**

is the basic concept of correcting and augmenting the GPS position solution. DGPS is based on the principle that all receivers in the same vicinity will simultaneously experience common errors [2] and [3]. There are three elements, where DGPS is composed of three elements, first, at a known location, an antenna or GPS receiver is present (base station), second , at an unknown location, another GPS receiver (user receiver) and finally, between these two receivers, a communication medium is present, as shown in Figure-1. In a known location, a reference station is present and comparing these known locations, a correction vector could be generated with the calculated measurements at the reference station and these signals in order to be integrated with its position solution are sent to the rover (mobile) receiver, [4].

## 3. The RTK, DGPS, and Climatic Data Collection Method

In all GPS applications of water vapor variation measurements, the use of GPS it self yield many errors in PWV due to the ground coordinates errors, for this reason, we select the differential global positioning system DGPS *Topcon Hyper-II* DGPS which belongs to remote sensing unit had been chosen to reduce the metrological errors as possible. . Also, for this type of research, the user must establish a network of GPS stations, this can not be reached in our work due to the security purposes in our country. So, the measurements of DGPS were collected near the center of the college of science as four Rover RTK DGPS points. The description of the four rover points is given in the Table-1 as well as the coordinates of Base Point, Figure-2 illustrate a satellite image for the base and four rover points in the Baghdad university campus / college of science buildings.

**Table 1-**The Rover Points Description and Coordinates of Base Point

| Rover Points | |
|---|---|
| **Description** | **Position No.** |
| **Above Computer Department, in front of the football stadium** | **1** |
| **Above Computer Department, in front of the woman's college of science** | **2** |
| **Above Geology Department, in front of the Computer Department** | **3** |
| **Above Physics Department, in front of the Chemistry Department** | **4** |
| **Base Point, Above Computer Department** | |
| **Easting, m** | **442239.179** |
| **Northing, m** | **3681735.544** |
| **Elevation, m** | **42.633** |

**Figure 2-**A Satellite Image for Base & Rover Points Locations.

The *Topcon Hyper-II* receivers collect the position of rover point as (Lat. Long. decimal degree), and the height above the sea level,m in each measurements day, the weathering parameters were collected in this region on that day systematically. The data were rearranged according to the station position. The Base coordinate was pickup through a duration of 3 hours in order to achieve high accuracy at 2-11-2016 Above Computer Department, Baghdad university camp. After 36 hours the base coordinates value has been corrected using the OPUS. These coordinates values are constant for all positions, i.e. the highest of Base receiver and its projection to the ground was denoted, so this position was used for all Rover task. Table-2 represent the data of base point, where, Table-3 show the data for station 1, (Above Computer Department, in front of the football stadium), Note, the duration of picking all Rover points is 60 second for all stations.

**Table 2-**The Base Point Parameters

| **Base Point** | |
|---|---|
| **Date** | **2 November, 2017** |
| **Duration** | **3 hr.** |
| **Easting, m** | **442239.179** |
| **Northing, m** | **3681735.544** |
| **Elevation, m** | **42.633** |
| **Description** | **Above Computer Department** |

**Table 3-** The Data of Station No. 1

| **Point** | **Elev (m)** | **Date** | **Temp. C̊** | **Humidity (%)** | **Wind Speed(KM/H)** | **Pressure (mbar)** | Lat. decimal degree | Long. decimal degree |
|---|---|---|---|---|---|---|---|---|
| Rov1 | 42.842 | 02-Nov | 24 | 42% | 11.3 NW | 1.023 | 33.273277 | 44.379429 |
| Rov5 | 42.833 | 03-Nov | 16 | 30% | 14.5 NW | 1.019 | 33.273278 | 44.379428 |
| Rov9 | 42.829 | 06-Nov | 17 | 53% | 13 W | 1.019 | 33.273278 | 44.379428 |
| Rov13 | 42.834 | 08- Nov | 23 | 45% | 6.4 WNW | 1.023 | 33.273278 | 44.379428 |
| Rov17 | 42.837 | 10- Nov | 21 | 44% | 11.3 WNW | 1.023 | 33.273277 | 44.379428 |
| Rov21 | 42.836 | 13- Nov | 24 | 31% | 11.3 WNW | 1.019 | 33.273277 | 44.379427 |
| Rov25 | 42.826 | 04-Dec | 13 | 64% | 11.3 NW | 1.029 | 33.273277 | 44.379428 |
| Rov29 | 42.827 | 06- Dec | 8 | 70% | 14.5 NWW | 1.023 | 33.273278 | 44.379429 |
| Rov33 | 42.829 | 08- Dec | 7 | 54% | 6.4 NW | 1.026 | 33.273278 | 44.379428 |
| Rov37 | 42.826 | 13- Dec | 13 | 55% | 11.3 SE | 1.019 | 33.273277 | 44.379427 |

**4. Calculation of Integrated Zenith Path Delay ZPD**

The (GPS) provides a relative method to remotely sense atmospheric water vapor in all weather conditions. The GPS signal delay in the atmosphere can be expressed as a zenith path delay (*ZPD).* the zenith path delay *ZPD (mm)* consist of the (*ZHD*) and the Zenith Wet Delay (*ZWD*), **[5]**, such as;

$$ZPD = ZHD + ZWD \qquad (1)$$

the zenith hydrostatic delay can be written as a function of the surface pressure $P_s$ in hPa. (In Equation. (2), a typing error included in the paper on **[6]** is corrected. The correct value is 2.279).

$$ZHD = (2.279 \pm 0.0024)\frac{P_s}{f(\lambda,h)} \qquad (2)$$

Where;

The Common multiple units of the Pascal are the hectopascal (1 hPa = 100 Pa) which is equal to one millibar, and the kilopascal (1 kPa = 1000 Pa) which is equal to one centibar.

$$f(\lambda,h) = 1 - 0.00266\cos(2\lambda\frac{\pi}{180}) - 2.8x10^{-4}h \quad (3)$$

Where;
$\lambda$, is the latitude of the GPS station, degree.
$h$, is the height $h$ in km,**[7]**.
According to, **[8]**, the *ZWD* can be expressed as;

$$ZWD = 0.002277*(0.005 + \frac{1255}{T_s})e_s \quad (4)$$

Where;
$T_s$ ($\mathring{K}$) is the surface temperature,
$e_s$ (hPa) is the surface water vapor pressure.
The surface water vapor pressure calculator Formula can give as;

$$e_s = 10^{A-B/(C+T)} \quad (5)$$

Where:
*P*: Vapor Pressure of Water
*T*: Water Temperature, in Celsius
*A,B,C*: Antoine Constants for Water. When water temperature in the range of 1 - 100 Celsius A=8.07131, B=1730.63, C= 233.426; when the temperature in the range of 99 - 374 degree Celsius, A=8.14019,
B=1810.94 and C=244.485.

**5. Result and Discussion**

All calculation of ZPD was evaluated using simple Matlab Subroutines, Table-4 illustrates the values of ZPD and its components for 10 rover points in position1. The result show that the ZPD depends on water vapor concentration in atmosphere, this was true with respect to the measured humidity values. Also, some ZPD values not obey the above criteria, this was picked due to m any errors in DGPS rover points. Therefore, as the water vapor increase in atmosphere, the ZPD will be also increase, this is true due to the DGPS microwave signal absorption by water molecules.

**Table 4-** The Calculation of some points in Position No. 1

| point | ZHD1(+) | ZHD2 (-) | ZHD(±) | ZWD | ZPD | % Humidity |
|---|---|---|---|---|---|---|
| Rov1 | 2.3647 | 2.3598 | 2.3623 | 3.2399 | 5.6022 | 42 |
| Rov5 | 2.3555 | 2.3505 | 2.353 | 2.9579 | 5.3109 | 30 |
| Rov9 | 2.3555 | 2.3505 | 2.353 | 2.9673 | 5.3203 | 53 |
| Rov13 | 2.3647 | 2.3598 | 2.3622 | 3.1827 | 5.5449 | 45 |
| Rov17 | 2.3647 | 2.3598 | 2.3623 | 3.085 | 5.4473 | 44 |
| Rov21 | 2.3555 | 2.3505 | 2.353 | 3.2399 | 5.5929 | 31 |
| Rov25 | 2.3786 | 2.3736 | 2.3761 | 2.997 | 5.3731 | 64 |
| Rov29 | 2.3647 | 2.3598 | 2.3622 | 3.4841 | 5.8463 | 70 |
| Rov33 | 2.3717 | 2.3667 | 2.3692 | 3.7176 | 6.0868 | 54 |
| Rov37 | 2.3555 | 2.3505 | 2.353 | 2.997 | 5.35 | 55 |

## 6. Conclusion

From the above result the conclusions can be given as;

1. The GPS signal interact with atmosphere compositions causing path delay known as Zenith Path Delay
2. The ZPD consist of *ZHD* , *ZWD* zenith hydrological and zenith wet delay.
3. The values of ZPD are depend on the water vapor concentration in the atmosphere with respect to mean temperature model. That is due to the DGPS microwave signal absorption by water molecules in the atmosphere.

## 7. Reference


1. Dong-Seob Song and Dorota A. Grejner-Brzezinska, **2009.** "Remote sensing of atmospheric water vapor variation from GPS measurements during a severe weather event" Satellite Positioning and Inertial Navigation (SPIN) Laboratory, The Ohio State University, Columbus, OH 43210, USA.
2. Peter Loomis, Len Sheynblatt, and Tysen Mueller, **1995.**" Differential GPS Network Design" *Proceedings of the 4th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GPS 1995)*, Albuquerque, NM, pp. 511-520, September.
3. Hossam-e-Haider, Mohammed, Qishan, Zhang, **2000.** "Comparative Study on OEM-Based Differential GPS," *Proceedings of the 13th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GPS 2000)*, Salt Lake City, UT, pp. 305-310, September.
4. Gérard Lachapelle, Paulo Alves, Luiz Paulo Fortes, M. Elizabeth **2000.** Cannon Department of Geomatics Engineering, University of Calgary Bryan Townsend "DGPS RTK Positioning Using a Reference Network " Presented at ION GPS-00 , Salt Lake City,UT, pp.1165-1171.
5. Bevis, M.S., Businger, S., Herring, T.A., Rocken, C. and Anthes, R.A. **1992.** Ware GPS meteorology: Remote sensing of atmospheric water vapor using the global positioning system, *J. Geophys. Res*. **97** :15787- 15801.
6. Yuan, L.Y., Anthes, R.A., Ware, R.H., Rocken, C., Bonner, W.D., Bevis, M.G. and Businger, S. 1993. Sensing climate change using the global positioning system, *J. Geophys. Res*. **98**:14925-14937.
7. Saastamoinen, J. 1972. Atmospheric correction for the troposphere and stratosphere in radio ranging of satellites, Ed.: S.W. Henriksen et al., The Use of Artificial Satellites for Geodesy, Geophys. Monogr. Ser. 15, AGU, Washington, D.C., 247-251.
8. Mauro Boccolari et.al**. 2002.** GPS Zenith Total Delays and Precipitable Water in comparison with special meteorological observations in Verona (Italy) during MAP-SOP ANNALS OF GEOPHYSICS, VOL. 45, N. 5, October.