# Improvement of Elipsoidal Heights with Athmospherical Data Calculated from GNSS Data

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Key words: GPS; TEMPERATURE; PRESSURE; HUMİDİTY

## SUMMARY

Signals released from GPS satellites proceed in the space before entering the atmosphere. The first layer that these signals pass through when they entered the atmosphere is ionosphere. The proceeding speed of signals in ionosphere depends on signal frequency. Therefore, the effects of ionosphere layer on GPS signals could be overcome with double-frequency measurements.

The signals that pass ionosphere go through mesosphere, stratosphere, and troposphere respectively.
Troposphere (neutral atmosphere) is the lowest layer where air touches the earth. Its thickness is around 8 km in poles and 18 km in equator.
 Meteorological events (weather conditions) are generally seen 3-4 km lower sides of troposphere. Unlike ionosphere layer, troposphere has the ability to disperse radio frequencies lower than 30 GHz since it does   not have electrical charge. For that reason, the dispersion of GPS signals in troposphere layer is not frequency depended. Therefore, the effect of troposphere on phase and code measurements is the same. That's why, it is not possible to overcome this effect using double frequency feature of GPS receivers.

The effect of neutral atmosphere on electromagnetic waves released at radio frequencies is called tropospheric delay effect (or tropospheric refraction, zenith tropospheric delay). Atmospheric parameters used for the calculation of tropospheric delay effect are obtained from meteorological data measured at observation points( pressure, dry thermometer temperature and wet thermometer temperature) or from water vapor radiometers and radiosonde data. Today, the most frequently used tropospheric effect models are
Saastamoinen, Hopfield and Niell models. In GPS calculation tropospheric effects carried out so far have generally been calculated by modeling. The results of this model were inconsistent with real atmosphere in some cases.

On the other hand, deriving high accuracy ellipsoidal heights using GPS is one of the problematic issue in surveying. The main reasons for this issue are the GPS geometry and the tropospheric modeling errors. Several scientific studies&researches have been performed until now on this subject. Hence, deriving high accuracy ellipsoidal heights using GPS observation and processing techniques will be investigated by this project.

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## 1. TROPOSPHERE EFFECT

Environmental effects are the most important accuracy limiting factors in both absolute and relative GPS positioning. Tropospheric effect mainly influences the accuracy of the calculated height differences. For example, this effect causes about 3 cm deviation on height differences in approximately 50 km long bases. Since tropospheric effects are not dependent (both frequencies are nearly in same size) deviations cannot be removed by using dual-frequency measurements as in ionospheric effects. Therefore, the effect in application is minimized by means of appropriate modelling. The most important part of tropospheric delay is due to the dry component of atmosphere. However, the dry component can be modelled in a few cm accuracy in absolute positioning and in 0,1 ppm accuracy in relative positioning.

Tropospheric effect should be considered in studies which determination of the height differences is important. This has a great importance on short-sided networks where the height differences between the points are too much

The projects where height information is very important (for example, determining the level of the sea, observing the movement of earth's crust in three dimensions, etc.) in order to keep the tropospheric effect below 1 cm, it is useful to make long term GPS observations including different atmospheric conditions. It is taught to provide the conditions that the terms should be between 16-24 hours and repeated several days for measurement session. Determination of height information by means of satellite geometry can be taught the best way in these projects. In other words, it is the ideal way for the receiver to observe all the monitors in the sky as many as it can. The best results are expected to get on the condition that the measurement campaign method above is applied in order to improve the ellipsoid heights calculated with GNSS data by atmospheric data.

In this method, the sensitive tool is to buy which measures temperature, pressure and humidity to minimize troposferic effect will connect to the GPS via a cable and will measure air temperature, pressure, and humidity during the static measurement in:

- – different seasons
- – different land shapes
- – short-sided networks (< 20 km),

The collected data can be stored on the recording media and processed in a data format to be able to use on GAMIT software program. The method mentioned above is expected to get more sensitive results that couldn't be obtained by Modelling method which was used so far For the studies that require high accuracy (to determine the sea level, to observe the movement of earth's crust in three dimensions, etc.).

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When the suggested experiments performed, the closest results to reality for the GPS observations made in the conditions of Turkey will be able to obtain.

## 2. LITERATURE

Knowing the distribution of water vapour in the atmosphere is an important issue in the studies of weather forecasting and climate studies, However, the information on the real humidity area remains missing because of the inadequate number of observations and being not able to use moisture information effectively on data fusion (assimilation) systems. GPS (Global Position System) signals are very sensitive to water vapour. Although GPS does not provide information about the vertical distribution of water vapour, it is more economical, more accurate, more reliable system and it can be used in all weather conditions when compared with radiosonde observations. Especially the real-time observations obtained from many stations consists fixed GPS networks contains valuable information for many scientific studies. On the other hand, as can be seen from the studies in the literature, it is thought that the rate of consistency on model estimations will rise in the case of assimilation of the GPS IPWV (IPWV; Integrated Perceptible Water Vapour) data. The use of Meteorological purpose of the water vapour information obtained from using geodetic methods will contribute the sciences of geodesy and geophysics. Because height information is the lowest accuracy, coordinate component obtained from geodesy and geophysics studies that aiming the prediction of earthquakes and establishment of high-precision GPS network. ($\approx$ 3-5 cm). One of the reasons of why GPS height information has low accuracy than horizontal coordinates is tropospheric model error used in calculations.
However, the atmospheric parameters obtained from NWP (Numerical Prediction Model) can help to get high accuracy ($\approx$1-2 cm) coordinate (height) information with the help of parameters (temperature, humidity and pressure). By this way, it will provide important contribution in geodetic and geophysical studies besides real-time navigation applications.

Studies on this topic have been carried out intensively for 10 years as part of a project by the meteorological agencies of Japan, Europe, Australia and the United States. The studies that can only be carried out by GPS satellites which are under the control of USA will gain an advanced dimension after the satellite system GALILEO of Europe which will ready by 2012 and Russian Satellite System GLONASS of that modernization is continuing. In other words, the studies will reach further levels by means of the GNSS receivers that records the real-time data of GPS/GALILEO/GLONASS and meteorological data that will be taken from the satellites placed into space for meteorological purpose.

The institutions / organizations dealing with meteorology and related departments of the universities in Turkey should consider the following proposals not to stay away from the issue.
a. The studies on using the GPS data on weather forecasting and climate should be done and appropriate models for conditions in Turkey should be developed.
b. The opportunities of using GPS data on Numerical Weather Prediction Models (preparation of approximate real-time and continuous IPWV IWV maps) should be investigated in detail.

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c. The study of 4-dimensional data assimilation and GPS tomography should be done in Modelling studies by taking into consideration the resolution of the GPS data related to time.
d. The usability of GPS data on other meteorological studies (ionospheric modelling, and climate modelling) should be investigated.

## 3. ORIGINAL VALUE

The aim of this study, unlike that done so far, going backwards and measure very sensitive atmospheric parameters (temperature, humidity, pressure), and to obtain highly accurate ellipsoid heights for using GNSS calculations. The biggest factor affecting the accuracy obtained from GPS measurements is the tropospheric effect.

Tropospheric effect influences mainly the accuracy of the calculated height differences. For example, this effect causes about 3 cm deviation on height differences in approximately 50 km long bases. These information is not sensitive enough for the projects where height information is very important (for example, determining the level of the sea, observing the movement of earth's crust in three dimensions, etc.) in order to keep the tropospheric effect below 1 cm.

To achieve this goal 4 different fixed GPS stations will be established in the field within the project. Meteorological measurements in real-time high precision with GPS observations will be done by means of Meteorological Sensors (measures temperature, humidity and pressure) that is to be bought within the project, and the model will take the place of the calculations used in tropospheric effect and the better method showing the real situation will be applied. If the results to be obtained reach us to satisfactorily fine level, instead of using modelling method in Tropospheric Effect which is known the most dangerous error source on GPS positioning determination, more accurate positioning data will be obtained by using the calculation of heat, pressure and humidity as first in Turkey.

## 4. METHOD

The number of the Meteorological Sensors are planned to increase four by purchasing two new sensors with two present sensors within the project. Supplier Company of the sensors will give training service after providing them in the project.

4 points will be chosen around Konya Selcuk University Campus of which distances will not be more than 20 km and with small height difference.
The GPS device will be installed in one of the main fixed point; four mobile devices will collect data; Meteorological Sensors will be connected to mobile devices via cable.

While GPS devices are real-time measuring in four different locations, Meteorological Sensors will measure the value of the air temperature pressure and humidity. The collected data will be recorded on disks or flash disks.

The measurement time periods will be repeated monthly and in various weather conditions. For example, when a measurement campaign is held in hot weather, another measurement

campaign will be held in rainy weather.

The collected data obtained from every measurement will be transferred into a computer.

The raw data will be processed in GAMIT software program.

As it is known, the accuracy of Ellipsoidal Height coordinate is not as sensitive as X, Y coordinate data. The reason is while the Ellipsoidal Height data is being obtained, "Tropospheric Effect" the main factor affected the accuracy of Ellipsoidal Height, which is the main issue of the thesis, the modelling method of Tropospheric Effect was used and the correction of the result was brought due to the fixed table values. In fact whether it is like that or not is not known. Because no study has been done so far except improving the Modelling Methods used in calculation of Tropospheric Effect. In this study, the data obtained from measurement instead of modelling will be used and the accuracy will be calculated after the result of measurement was corrected, finally the result will be compared to accuracy value obtained from modelling.

If the results are satisfied, in other words if the accuracy of ellipsoidal height can be increased in this way, this issue will open new horizons in GPS Meteorology.

## 5. BACKGROUND

The aim of the study that is thought to be done differently and first in Turkey is to obtain high accuracy ellipsoid heights to use in GNNS calculations by going reverse i.e., measuring the atmospheric parameters (temperature, humidity, pressure) very sensitively. To achieve this goal 4 different fixed GPS stations will be established in the field within the project. Meteorological measurements (temperature, humidity and pressure) in real-time high precision with GPS observations will be done, and the model will take the place of the calculations used in tropospheric effect and the better method showing the real situation will be applied.

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