Concept in Determining the Height of Mount Everest (Sagarmatha)

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KEYWORDS

Height determination, sea level, gravimetric geoid, Mount Everest

ABSTRACT

In this paper we describe the concepts in determining the height of the Mt. Everest and elucidate the method of height measured relative to sea level. The current height determination procedure is limited by the accuracy of the calculation of height of the sea, (less than +/- 2m) or its mathematical approximation the geoid. Although Nepal has been recognizing 8848m as the official height of the Everest, many climbing team and scientific explorations from different countries in different time have been conducted and achieved different numerical values of height of the Everest. The challenging issue is defining the elusive sea level with or without nearby shoreline. Through some recognized media it has been made public that the Government of Nepal have plan to ascertain the height of Mt. Everest and if it is so this would be the first attempt by Nepal government to determine the height on its own. Survey Department under the Ministry of Land Reform and Management is the authoritative organization to translate Government's decision into action. Depending on the nature of the work; in order to accomplish the measurement, the complete task is divided into five parts such as Precise leveling survey, Determination gravimetric geoid, Trigonometrical leveling, Global Positioning System (GPS) Survey and Data processing. Survey Department, lacks in enough resources and infrastructures for completing this project in the complex environment of the most rugged High Himalayas therefore some other potential International Scientific organization can be expected to join hands in the process of height determination.

Background:

Mount Everest, situated along the border of Nepal and China, has been regarded as the highest point on the earth. Mt. Everest lies in the collision zone along the boundary of Eurasian and Indian plates, As the impact of Earthquakes, regular crustal movement and melting of the snow through global warming the variation in the height of Everest has been one prime concern in community of geosciences.

During the Great Trigonometric Surveys around 1840 and 1850s started measuring the height in jumble of northern Himalayan peaks. The calculation started in 1850 and completed in 1855 for all Himalayan peaks. Long before the announcement of its height attempts were initiated to find the local name of Peak XV given during observation. Since the mountain lies deep inside the Nepalese territory and half in Tibet its local name cannot be ascertained. In 9 August

1856 the Peak was named Mount Everest in the recognition of special contribution of Colonel Sir George Everest, Surveyor General of the then British India of Great Triangulation Survey (GTS). A year latter it was changed to Mount Everest. The height was announced 29002 ft. Nearly for 50 years this became the official height.

Height determination by SOI in 1954:

The new height 29028 +/- 10 feet was reported by G.L. Gulatee in 1954. During this time series of measurements were made by survey of India specially to determine the height of the Mount Everest. Trigometrical leveling was conducted by sighting the mountain form series of points of the triangulation network extended for the height measurement within 40 miles from the summit. This highly reduced the refraction errors. Deflections of verticals were also measured in series of points from the plain area to northernmost points. The points considered for the observation were linked to the extensive leveling network of India. This made possible to estimate the sea level height of the Mt. Everest but the uncertainty in sea level remained the largest contribution to the error in the Gulatee's height determination.

Although it was not extensively known the preparation of the height of the Mt. Everest from northern side (China) commenced in 1966. The Chinese triangulation network and leveling network was extended to the Rongbuk Glacier during this year and the measurement published the ice summit height 8849.75m with and uncertainnity +/- 2m. The result very much resembled with the height measured by Washburn in the year 2000.

Height determination by Chinese expedition in 1975:

In 1975 Chinese expedition was set out for redetermination of the height of the Mt. Everest. This time vertical triangulation was undertaken towards a summit at a distance ranging from 8.5 km to 21.2 km. These measurements can be considered as the closest ever taken measurements from the summit anticipating the smallest refraction correction in the vertical angle observation. For meteorological measurement balloons were lunched close to the optical sight line to minimize the refraction error.

Gravity measurements were carried out at points throughout the region including the point less than 1.9 km from the summit. The height was ascertained 29029 ft with and uncertainty of +/- 1 ft. (8848.13 m +/- 0.35m). The height was very effectively identical to the height calculated by Survey of India (SOI) in 1954 by G.L. Gulatee (29028 +/- 10 ft). However the noted difference were only the uncertainties which is much smaller. For the very first time this measurement was tied up with the rock height of Mt. Everest. In the report of this 1975 expedition it was reported that the depth of the snow is 0.92 m. The thickness of the snow was probed only by pole so it is possible to speculated that penetration stopped after reaching the hard ice.

Height determination by Italian/ Chinese expedition in 1992:

The joint exploration of Italian/Chinese took place in 1992. During this exploration comprehensive new measurement with adopting the new technology was undertaken in determining the height of the Mount Everest. Its mission was organized by Ardito Desio together with Italian geodesist Giorgio Poretti. This was the first time GPS receivers were operated on the Summit. It was also the first time that laser distance and theodolite measurement were used simultaneously to sight target placed on the top of the summit from north and south of the mountain. Three points in the China side and three points in the Nepal side concurrently targeted the reflector combined with GPS antenna placed on the top. Deflection of verticals were also measured in several points. By using vertical triangulation method the leveling lines were extended close to the base of the mountain in order to complement Chinese leveling carried from north (Datum based on Yellow Sea).

One of the important achievement in this 1992 Italian/Chinese exploration was to determine refined gravimetric geoid from the Chinese side to better estimate the sea level height.

The ellipsoidal height obtained was 8823.51 +/- 0.05m. The geoid adjustment used in 1992 derived the new height of 29031.0 ft +/- 6 ft given adopted geoid – 82.5 ft. ie elevation (8848.65 m) and geoid undulation of -25.15 m.

Height determination by National Geographic expedition in 1999:

The expedition was organized by Brad Washburn in 1999 in cooperation with National Geographic Society. The expedition decided simply to measure the height of the ice summit and also because of the difficulty in obtaining detailed gravimetric and leveling data of the region along with its laboriousness in computing the regional gravimetric geoid it was decided to use Earth Gravity Model (EGM96) a global geoid in the process of height determination. The height ascertained after GPS measurement and using the global geoid EGM96 was 29034.52 +/- 6 ft ie (8849.72 +/- 2m).

The ellipsoidal height determined was 8820.98 +/- 0.05m. The geoid undulation computed using EGM96 was – 28.74m +/- 2m.

Relevance of New Height Determination:

The comparison of the 1992 and 1999 measurements of the height of the Mount Everest the difference in the ellipsoidal height shows that we have a decrease in elevation by 2.5 m in 7 years difference. This indicates that ice summit have decreased. In 1999 revised geoid correction -26.2m was published from the Chinese side. The difference is 1.06 m. The negative sign indicates that geoid is below WGS84 ellipsoid. Gulatee pointed out that the height varied because of the thickness of the snow and ice on the top of the summit. And in the course of learning from scientific article on determining the height of Mount Everest the problematic quantity has become geoidal height beneath the mountain. Therefore precise geoid determination can give the new estimate of height of the Mount Everest. This is the further improvement in the geodetic history. The thickness of ice is next impediment in the accurate height measurement. The mapping of the rock summit using radar profiling can solve this problem. The Gorkha earthquake moved the Kathmandu valley 1.8m in south west direction and rise of the ellipsoidal elevation about 1m. which the observation elucidated just after the earthquake occurred in April 2015. It is one of the strong region why new measurement is necessary.

Procedure for the height determination:

Different technologies and methodologies are in practice to determine the altitude of any point above MSL depending upon the availability of the instruments, human resources and affordability of the organization. This measurement, being associated with the world's highest peak, is the concern of the world's researchers, scientists, geographical communities, and general people as well. Hence Survey Department will try to adopt the highly accurate methodology and precise instruments to determine the height of the Mt. Everest so far available and affordable. Following activities will be carried out during the project period.

Phase I: Precise Leveling

Phase II: Refinement of Geoid

1. Gravity Measurement
2. GPS Observation in the Bench Mark (Leveling Point)

Phase III: GPS Observation at the existing Network and the Base Points

Phase IV: Observation to the Summit

1. Expedition to the Summit
2. Trigonometric Leveling
3. GPS Observation at the Summit and the Base Points
4. Observation for Snow Depth

Phase V: Meteorological Data Collection

Phase VI: Data Processing and Release of the Report

Phase I: Precise Leveling

Geodetic Survey Branch has already established a leveling profile along the major roads throughout the country by geometrical leveling (spirit leveling). But the branch has not worked in the area where the road is not metallic or motorable. As the project area is mountainous and all the roads in this region are not motorable, GSB has not established the leveling profile in this project area. Thus the precise leveling work should be started from Katari of Udayapur District, which is about 250 km from the base of Mt. Everest, the Kalaptthar, up to which the precise leveling will be carried out. The MSL height of the bench marks of the leveling network of the country is derived from the Fundamental Benchmark at Nagarkot which is connected to the MSL at Indian Ocean.

Phase II: Refinement of Geoid

Survey Department has already established the geoid which fits best with the ground surface of the country with the help of Technical University of Denmark (DTU) and International Association of Geodesy (IAG) by airborne gravity method. Due to the lack of sufficient surface gravity data, the accuracy of the geoid is not satisfactory in the Himalayan region to determine the altitude of Peaks. Thus surface gravity observation needs to be carried out in the project area to refine the existing geoid of Nepal and GPS observation will be carried out at bench marks after every 4 km in the leveling profile to assess the quality and accuracy of the refined geoid. After the computation of highly accurate geoid GPS technology can be used to determine the orthometric height (MSL height) of any place.

Phase III: GPS Observation at the existing Network and the Base Points

Before the advent of GPS technology, triangulation and traverse methods were used to determine the horizontal position of any point. In Nepal, triangulation method was used to establish the higher order control points for the horizontal positioning. Geodetic Network of first and second order control points was established in the hilly region of Nepal by triangulation method. A number of first and second order trigonometric points are located in the project area. So to connect the new surveyed points with the existing geodetic network, GPS observations will be carried out at some of the triangulation points, newly established control points for the horizontal position of the peak of Mt. Everest and other points.

Phase IV: Observation to the Summit

As the main goal of this project is to determine the altitude of the Mt. Everest, a number of observations will be carried out at the summit of Mt. Everest. It is not an easy task to climb the Mt. Everest frequently and stay at the summit for a longer time, so all the necessary observations will be carried out at the same time. The followings tasks will be carried out for the observation at the summit.

1. Expedition to the Summit

By this time it cannot be guaranteed that the adequate number of Nepalese surveyors can reach the summit of Mt. Everest. Therefore a team of Sherpa, professional climbers, possibly accompanied by Nepalese surveyors, will be prepared for setting up the instrument at the summit. Before the expedition to the Mt. Everest each members of the team will be trained for setting out the instruments and carrying out the necessary observations.

2. Trigonometric Levelling

Geometric leveling cannot be carried out up to the peak of Mt. Everest so trigonometric leveling method will be resorted at the peak from the control points around the base of the Mountain. The control points are so selected that the peak of the Mt. Everest is visible from all of those points. The signal for the trigonometric leveling will be erected by the Mount Everest expedition team.

3. GPS Observation at the Summit and the Base Points

After joining the newly established base control points, from which the observations to the summit are made, with the existing geodetic network GPS observation at the summit, the base control points, and some other selected points is carried out. After the refinement of geoid of Nepal, GPS can be used to compute the altitude of any point above MSL. Specially designed GPS receiver and other accessories are used for this purpose because the GPS instruments that GSB is currently using may not work in the high mountain. Also the GPS receiver will be designed in such a way that it can work as a target signal for the trigonometric levelling. These instruments are operated by trained expedition team.

4. Observation for Snow Depth

This kind of project is very costly and it is difficult to conduct such project repeatedly. Sometime it may be the matter of depth of snow because the snow cover is not always the same. Thus, grabbing this opportunity, the depth of snow at the top of the Mt. Everest is calculated with the help of specially designed RADAR instrument so that it could be possible to find the position of rock at the top.

Phase V: Meteorological Data Collection

The trigonometric leveling is carried out from the points which are about 80 km from the peak of the Mt. Everest. Thus this line of sight needs to be corrected with the help of atmospheric data. Thus the data of temperature, pressure, humidity etc. are collected along the line of sight during the observation period.

Phase VI: Data Processing and Release of the Report

All the surveyed data in the field are processed in the Survey Department, Nepal jointly by the Nepalese Surveyors and the technical experts from the collaborating agencies. All the newly established control points are joined with the existing network of the country. Vertical controls are based on the fundamental bench mark at Nagarkot and the horizontal controls are also based on the fundamental point at Nagarkot. Nepalese surveyors are trained for advanced processing techniques in-house or abroad collaborating agencies.

Challenges of the Project:

This project is an ambitious task to accomplish. Followings are the challenges during the implementation of the project.

1. Training to the Mountaineers

All the project area contains high mountains including Mt. Everest. The first challenge for Nepalese surveyors is to climb the Mt. Everest. First attempt will be to prepare the interested Nepalese surveyors to climb the Mt. Everest. If not, all the necessary tasks done at the summit of Mt. Everest is accomplished by the expert mountain climbers. But again the problem is that they are not acquainted with the survey techniques. Thus to train the mountaineers for handling the survey equipments is also the challenge of this project.

2. Managing Specific Instruments

Another challenge of this project is the survey equipments. The instruments used by GSB may not be appropriate in high Himalayas. Also for the summit, it requires specially designed instruments which occupies less space, can be used as a multipurpose such as GPS receiver, target for the trigonometric levelling etc and can be handled in very low temperature and pressure. Managing such kind of equipments is not, at this moment, an easy task for GSB.

Conclusion:

Also, as almost all the project area is mountainous, it is not convenient to travel such area frequently. So the necessary observations should be accomplished as soon as possible. For this purpose adequate numbers of survey equipments are required and the existing number of instruments that GSB currently have may not be sufficient for this project. Further, most of the instruments are analogue (especially for levelling) which is time consuming and demand high costs. So, managing efficient instruments is also the challenge of this project.

Use of advanced instruments and processing of the field data with high accuracy requires trained and expert manpower. Thus the Nepalese survey team involved in this project needs some training for handling the new instruments and processing the surveyed data.

Another most important challenge of this project is the international recognition of the result obtained from this project. This project is of great interest to all the researchers, scientists, geographers and other communities, so the equipments used and the methodology adopted in this project should be worldwide accepted and accurate. Thus we should not forget these facts during the implementation of this project.

Bibliography of Height Determination:

Angus-Leppan P. V, (1982) The height of Mount Everest, Survey Review, 26, 206, 367-385

ChenJ-Y, G. Chang Y.L. Lee and Z.L. Zhen, (1999) An improved local geoid in Mt. Everest area, *Osterreichiche Zeitschrift furVermessungswesen und Photogrammetrie, 11 362-363.*

Chen J-Y Everest Height Determination (1995), GPS world 6, 12

DeGraaaff-Hunter, J., (1928) Height of the Mount Everest and other Peaks, Survey of India, Geodetic Report 1922-1925, 1, 287-229.

Gulatee, B. L. The Height of Mount Everest: A new determination(1952-54) Technical Paper, 8, Survey of India, Dehradun.

Poretti G., C. Marchesini, A. Beinat (1994) On the top of the World: GPS survey of Mount Everest, GPS world, 10, 33-62.

Washburn B., A new official height of Mount Everest, National Geographic, 11, 76.

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