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# Orthometric Height Determination Using GPS in East Antarctica

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## Abstract

GPS observations were made in East Antarctica during the X Indian Scientific Expedition for providing geographical controls. Heights above MSL, i.e. the geoid, is an essential parameter in geographical coordinates for mapping and other Survey application. The Global Positioning System (GPS) provides three dimensional coordinates—latitude, longitude and height—with reference to the World Geodetic System 84 (WGS 84) ellipsoid. This paper describes a method by which the heights above the Instantaneous Mean Sea Level (IMSL) can be obtained in an inaccessible area where classical techniques for determination of MSL cannot be adopted. The main drawback in this method is that sufficient observation over a long period and from more sites have to be collected.

## Introduction

Global Positioning System (GPS) is an all weather positioning system, which can provide the relative positions of points that are separated by tens of kilometres. Additionally, the GPS system can provide the required level of precision in position with one to two hours observation, without requiring the intervisibilities of stations. The relative positions are obtained with reference to a geocentric reference system. The difference of heights between the two ends of a baseline gives us the height of the Antenna positions located on the control points.

For all mapping and other allied purposes, including geophysical researches, one needs orthometric height of all the control points and not the height above the

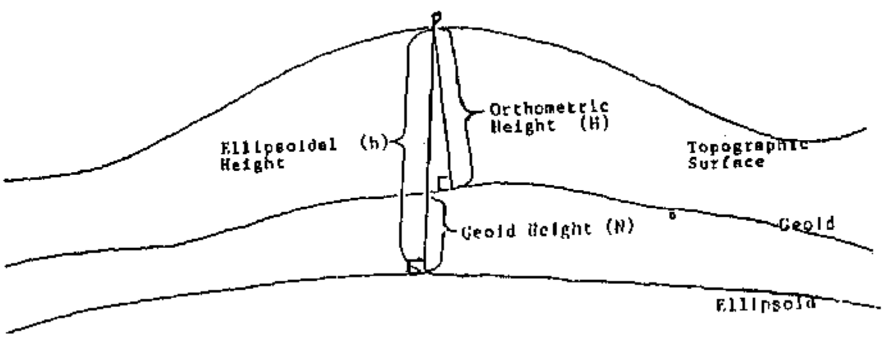



*Fig. 1. Relationship between orthometric and ellipsoidal height.*

ellipsoid. The orthometric height of a point is defined as the vertical distance recorded along the plumb line between a point on the earth's surface and the geoid. In most cases the orthometric height is also considered the mean sea level elevation of the point. Fig. 1 gives the relationship between the ellipsoidal height, h, the geoid separation, N, and orthometric height, H, which are related by the following equation:

$$H = h - N$$

By using this equation, we may easily determine the orthometric height (Liddle, 1989). In the present report, geoidal undulation (N) of the area was not known, but for a small area, we may consider an average geoid undulation.

When locating one or more points relative to another known point the relationship between the difference in orthometric height, $\Delta H$, and difference in the ellipsoid height, $\Delta h$, (Gilliland, 1984) may be represented by :

$$\Delta H = \Delta h - \Delta N \quad ...(2)$$

Where $\Delta N$ is the difference in the geoid separation.

This is generally the approach used when applying GPS techniques for geodetic purposes. The practical application of equation (2) has the advantage that any systematic error in h and N will have minimal or no effect on the determination of the orthometric height difference, provided these errors have the same or similar magnitude at each point (Gilliland, 1986).

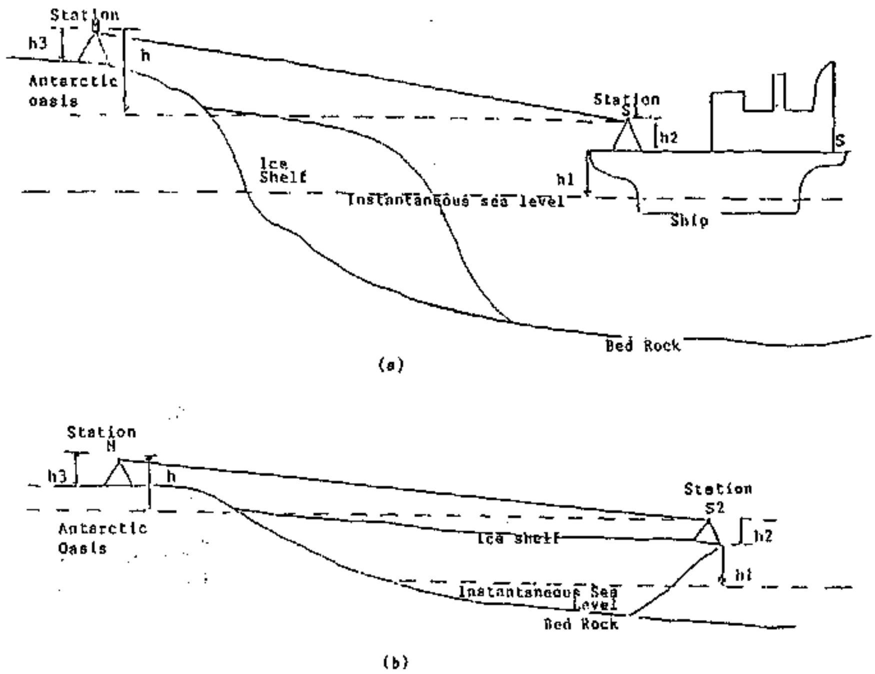
## Principle

Fig. 2 schematically illustrates the principle of orthometric height determination.

During the X Scientific Expedition to Antarctica, the ship was anchored onto the ice shelf of East Antarctica. GPS observations were made between station S1, which was situated at the corner of the ship's deck and station M on the Schirmacher oasis. The distance between the two points was about 90 km.

The height difference between the Antenna position and the instantaneous sea level was measured paripasu with GPS observation.

A similar technique was adopted by selecting station S2 on the edge of the ice shelf. The distance between stations S2 & M was about 89 km. The height of station M was estimated from the observations on S1 & S2 stations. The height above the instantaneous sea level for station M was estimated using the equation, given in Fig. 2.




Instantaneous Mean Sea Level (IMSL) = $h_1 + h_2 + h - h_3$

Where $h_1$ is the height from IMSL to the ship.

$h_2$ is the height of the antenna phase centre.

$h$ is the differential height between station M and S.

$h_3$ is the height of the antenna phase centre.

*Fig, 2, Schematic illustration of instantaneous mean sea level (IMSL) determination in Antarctica using GPS.*

## Observation and Processing

To establish the accurate height of station M from the sea level, observations were made on two dates and at two different places at an interval of 50 days using GPS receivers.

The data was collected for about 1 hour for each vector at a time when the satellite configuration was better in geometry. Temperature and pressure were recorded for applying tropospheric corrections. Special care was taken for centering the GPS receivers over the point and for the measurement of antenna height. The vertical distance from the instantaneous sea level to the antenna site was used for reduction of height of antenna at stations S1 & S2.

Baselines were processed using the post processing software POPS 3.

## Results

Table 1 gives the results obtained after final computation.

The above data has been corrected for height of antenna above instantaneous sea level and the heights above IMSL was reduced for the station. The height obtained using the two vectors is given in Table 2.

The mean orthometric height of station M, obtained from two independent sites in a span of 50 days is 117 m.

GPS interferometric surveying and NNSS positioning was done in 1986 for installation of geoid height control station on Antarctica during the 28th Japanese Antarctica Research Expedition. The team has established the height of a station near 70°S, 40°E and has drawn the geoidal undulation chart of the area (Fig. 3).

Interpolating the geoidal height (N) from Fig.3 at latitude 70°S and longitude 11°E, we get a geoidal undulation estimate as 13 m.

Taking into consideration the maximum accuracy deterioration of ±4 metres (White, *et al.,* 1989) we get an ellipsoid height of station M as (from equation 1):

Ellipsoid height of station M = orthometric height + geoidal height

= 117 + (13 ±4)

= 130 ±4 metres ..(a)

Independent ellipsoid height of station M obtained by GPS single point positioning technique using observations of 14 epochs is 124 metres i.e.

Ellipsoid height (GPS) of station M = 124 metres .. .(b)

The variation of 2 to 10 metres in ellipsoid height in (a) and (b) is mainly due to the deterioration in GPS heights because of the application of selective availability.

Table: 1

| | Station Name | (Height wrt WGS 84) Differential mode | Sigma |
|---|---|---|---|
| | M | 157.3697 | 0 (Fixed Station) |
| I | S 1 | 55.0460 | .0451 |
| | M | 115.0551 | 0 (Fixed Station) |
| II | S2 | 06.9926 | .0691 |

Table: 2

| Epoch | Station | Height |
|---|---|---|
| I | M | 117.2437 |
| II | M | 116.8992 |

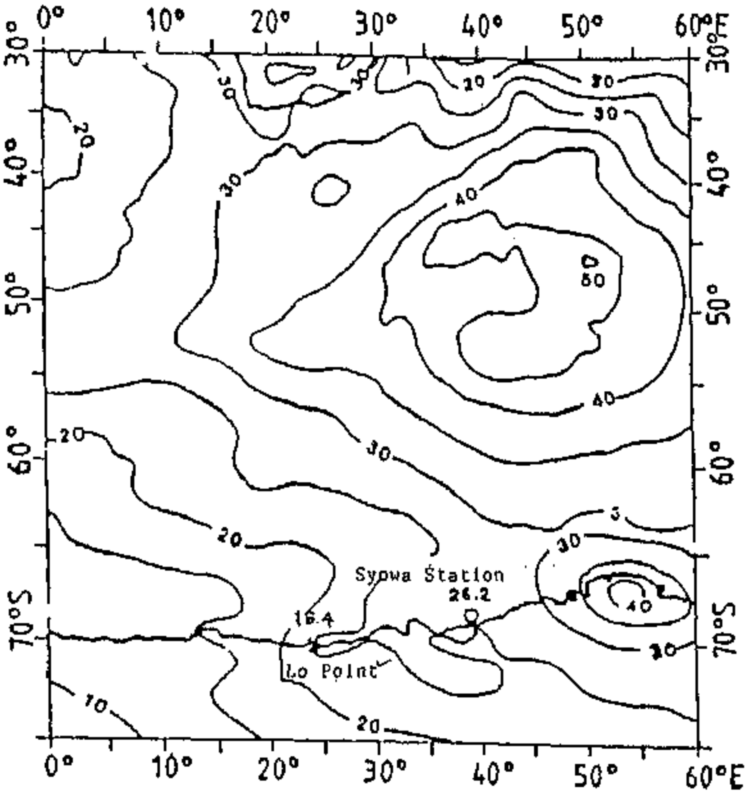



*Fig. 3. Geoid height data at Syowa station and Lo Point on the 0SU-S6D geoidal undulation.*

This, according to conservative estimates can vary approximately 150 m, 99% of the time, and beyond that during the remaining 1 % of the time.

## Conclusion

The orthometric height determination of station M appears to be the best estimate as all other classical techniques in the ice continent cannot give a better accuracy due to the harsh and difficult conditions prevailing there. Moreover, the heights provided by the barometers are generally used in exploratory surveys in which a height estimation of 40 to 50 metres is adequate.

Future endeavours of Antarctica Expedition envisage a better estimation of the orthometric height by gravimetric techniques. Possibilities of tide gauges will also be seen for a better estimation of sea level over a continuous period of time. These efforts will lead to a more accurate estimation of orthometric height of station M.

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