EDM HEIGHT TRAVERSING ON THE NULLARBOR

by

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ABSTRACT

The use of electronic distance measuring equipment (EDM) for surface height traversing would appear ideal for use on the Nullarbor where distances are long and unobstructed and the weather dry and clear. However, it is these long distances and the climatic conditions that can produce apparent errors if corrections for both the earth's curvature and refraction are not correctly accounted for. The experience on a recent expedition indicates that refraction is a most significant phenomenon and care must be taken to include its effects on the height elevation of survey points.

INTRODUCTION

As part of the 1991 Australian Nullarbor Caving Expedition, it was decided to carry out an accurate detailed survey of the surface features of the area surrounding the entrance to Old Homestead Cave. This included establishing the surface positions (easting, northing and elevation) of RDF stations, other and additional survey reference points, entrances to blowholes and other surface features. In addition, a topographic map was to be established with accurate contours to determine the drainage patterns between the low ridges.

As a large area was to be surveyed, a total station incorporating electronic distance measurement (EDM) and an electronic data recorder was employed. The equipment used was a Sokkisha Set3 total station with an SDR2 Electronic Field Book, essentially a data logger/computer. This instrument has infra-red EDM and a resolution of 1mm for distances and 1 second of arc for angles. In terms of accuracy, the standard deviation was +/-(5mm+3ppm) for distance measurement and +/-4 seconds for angles. The target is a corner prism that reflects the light emitted from the theodolite back along the same path to the theodolite for processing. Depending on weather conditions, distances exceeding one kilometre can be measured.

Once a known reference point and an azimuth was determined, a traverse line was established using control stations. The SDR2 records the horizontal angle measurement θ, the vertical zenith angle measurement zd and the slope distance s at each target point. From the height of the theodolite h_{th}, the height of the target h_t, the known coordinates (easting, northing and elevation) at the theodolite station and the known azimuth (direction relative to North between control stations), the SDR2 calculates the coordinates at each target point. Back in the office, the data from the SDR2 can be downloaded to a computer for further processing. The contour plots for the Nullarbor survey were generated using SDRMAP software.

The EDM distances can be corrected for temperature and barometric pressure using the program in the SDR2. This requires regular monitoring over the day with a thermometer and a barometer. A small portable barometer was calibrated to measurements taken at the nearby weather station at Forrest.

Determining accurate eastings and northings is not generally problem. For example, over the initial closed traverse of approximately four kilometres with six intermediate stations from Station AZ at the entrance to Old Homestead Cave and back again, the closing error was only 11 mm in easting and 60 mm in northing.

However, the apparent initial closing error in elevation was over 1 metre, an apparent gross error considering the highest ridge was only 10.7 metres above the surface at the cave entrance. This apparent error is the result of two factors; the curvature of the earth's surface; and refraction, the latter being by far the more significant for the topography and climate of the Nullarbor. Corrections for curvature can be made simply, either directly with the SDR2 or with computer software in subsequent processing. Corrections for refraction are more difficult and require procedures and measurements to be made in the field from which coefficient of refraction k (a parameter which varies with time and the climatic conditions) can be deduced.

CURVATURE CORRECTION

In geodetic reference systems, a commonly used datum is an ellipsoid to approximate the shape of the earth. Mean sea level is conventionally adopted for the vertical component in an ellipsoidal reference system. In Fig. 1, the ellipsoid has a radius of curvature R at the location where the surveying measurements are being taken.

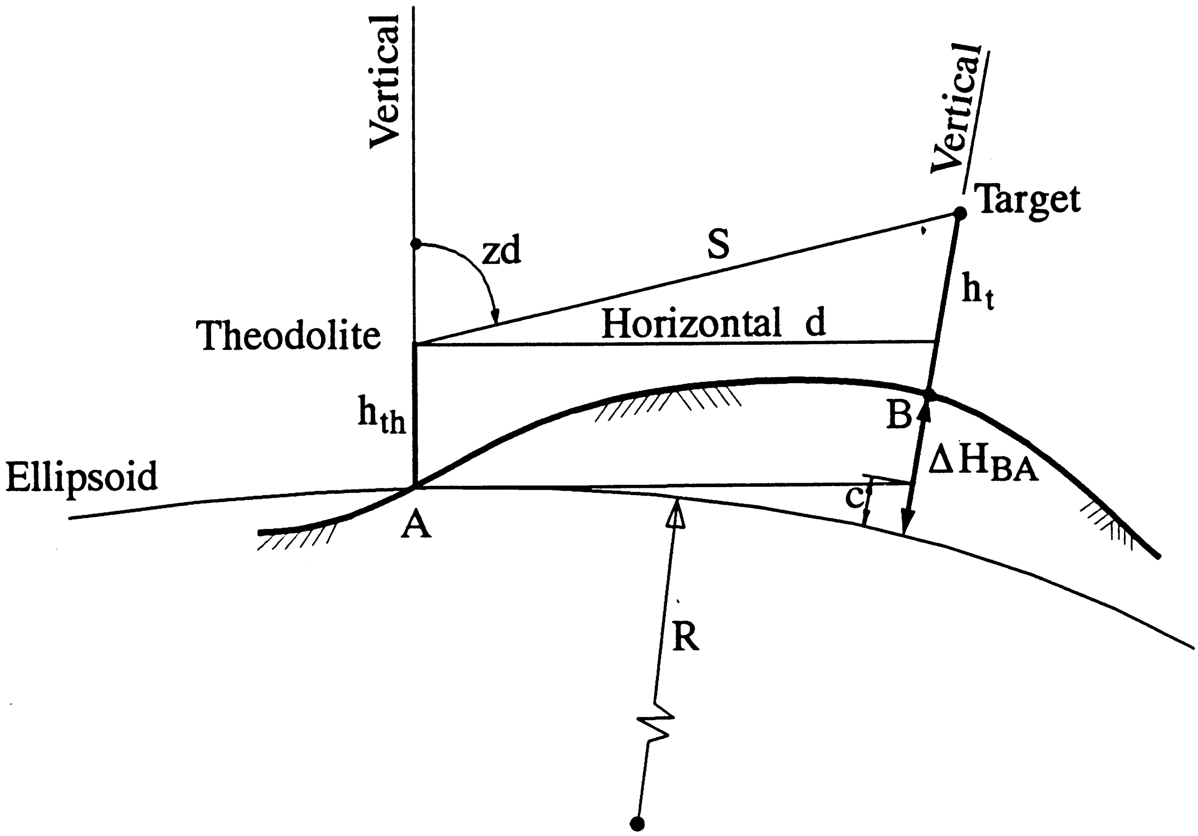


FIG.1

A theodolite of height h_{th} is set over point A on the earth's surface. A target of height h_t is set over point B. The theodolite measures the slope distance S and the zenith angle zd to the target. The horizontal distance d is given by

$$d = S \sin(zd) \tag{1}$$

The orthometric height difference between stations A and B relative to the reference ellipsoid is given by

$$\Delta_{AB} = h_{th} + d \cot(zd) - h_t + c \tag{2}$$

where c is the curvature correction and

$$c = \frac{1}{2R} d^2 \tag{3}$$

Assuming a typical value of 6,370,000 m for the radius of curvature R, the correction c for a horizontal distance d of 1000 m (not uncommon for the SET3) would be 78 mm. If there were a number of such legs in a traverse (say 6), the accumulated error would be quite large (468 mm). However, if the horizontal distance d was only 100 m, the correction c would be only 0.78 mm. For an equivalent 60 legs, the accumulated error would be only 46.8 mm. It can be seen that the correction for curvature is very important for height traverse where EDM equipment is used to measure large distance between stations.

REFRACTION CORRECTION

This correction is similar to the correction for curvature. Refraction causes the light ray to bend (shown as a dotted line in Fig. 2) with a curvature of unknown radius taken as concave down. The theodolite therefore measures a zenith angle zd to an apparent point above the target.

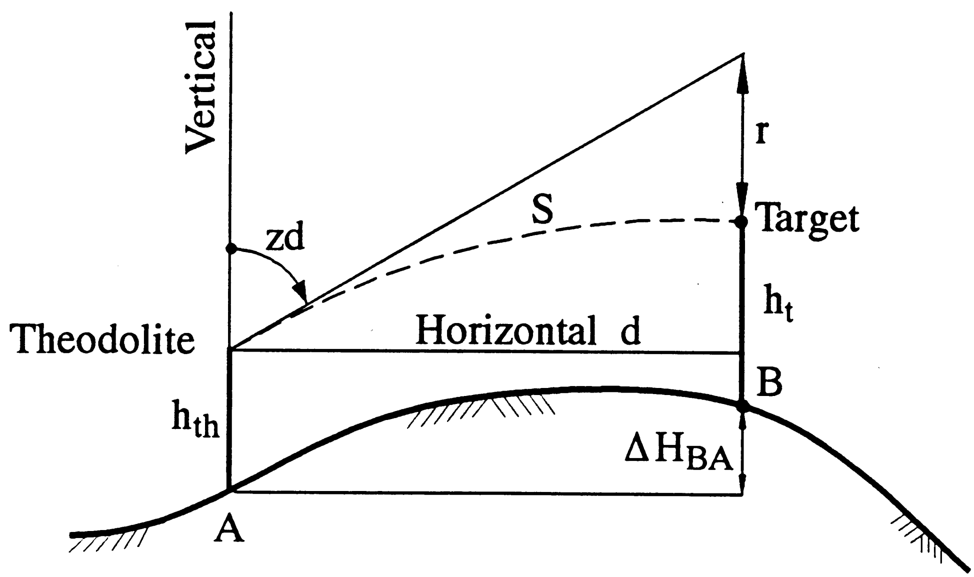


FIG.2

The apparent height difference measured by the theodolite between stations A and B relative to the horizontal is given by

$$\delta_{BA} = h_{th} + d\cot(zd) - h_t \tag{4}$$

The actual orthometric height difference between stations A and B relative to the horizontal is given by

$$\begin{aligned}\Delta_{BA} &= h_{th} + d\cot(zd) - h_t - r \\ &= \delta_{BA} - r\end{aligned} \tag{5}$$

where r is the refraction correction and

$$r = \frac{k}{2R} d^2 \tag{6}$$

and k is the coefficient of refraction and R is a reference curvature, usually taken as the radius of curvature of the reference ellipsoid at the location where the measurements are taken.

A typical value of k quoted in surveying texts is +0.13. For the Nullarbor survey, this is grossly in error!

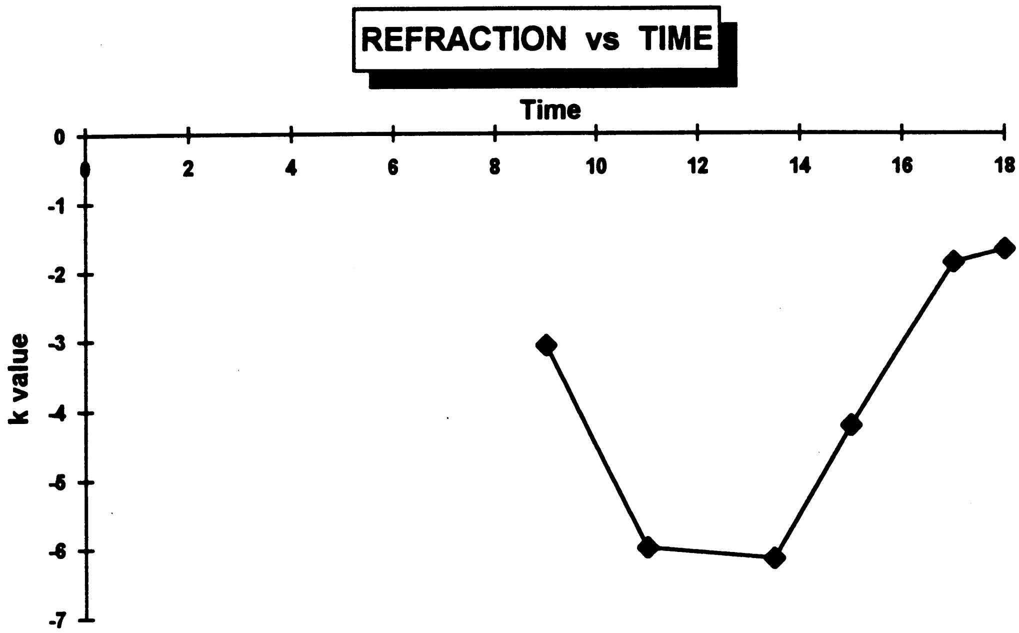
To determine a value for k, it is necessary to measure both the apparent height difference δ_{BA} between A and B with the theodolite at A and then to measure the apparent height difference δ_{AB} between B and A with the theodolite at B. The total orthometric height difference must be zero hence

$$\delta_{BA} + \delta_{AB} - 2r = 0 \tag{7}$$

from which the value of k can be deduced. This must be done regularly during the day as the value of k is obviously temperature and hence time dependent. At each station, all intermediate points measured from that station must be corrected for refraction.

The results for a typical October day at Old Homestead are shown in the following graph. The absolute values of k increase to a maximum during the middle of the day and decrease in the cool of the evening or the morning.

Typical temperatures ranged from 15°C to 32°C. It can be seen that a value of k of -6 is not uncommon, a long way from the suggested value of +0.13, based on European experience. This also indicates that refraction can be up to six times more significant than curvature.



CONCLUSIONS

Surface surveying on the Nullarbor is difficult at the best of times; long distances, lack of features, heat, flies, no water, and staked tyres. Even when using EDM techniques to cover distances quickly, care has to be taken that corrections for curvature and, more importantly, refraction are not neglected. Where curvature is not accounted for directly, both curvature and refraction can be combined where

$$c\text{-}r = \frac{1-k}{2R} d^2 \qquad (8)$$

Values of k can be deduced directly from the total apparent forward and backward height differences between stations. Regular readings should be taken during the day as the value of k can have a wide range of values depending on the topography and the climatic conditions