Surveys of Meall Gaineimh

27 May 2015

The Team:-

Surveyors – John Barnard, Graham Jackson and Myrddyn Phillips

TMS Volunteers – David Batty, Alan Brook, Anne Butler, Iain Robertson, John Rogerson, Bill Wheeler and Peter Willimott.

SMC Guest – Rab Anderson

1) Introduction

Over the past several years The Munro Society (TMS) has been carrying out a programme to measure accurately the heights of Scottish hills that were close to 3000feet. The programme for this project was initiated and coordinated by Iain Robertson, a TMS member and former president of the society. The first two surveys in this programme were carried out by a commercial company called CMCR. Subsequently CMCR was replaced by us, G & J Surveys, and we have continued the work. Essentially now this programme has been completed and has resulted in the reclassification of Beinn a'Chlaidheimh and Sgurr nan Ceannaichean from the official list of Munros maintained by the Scottish Mountaineering Club (SMC). Unfortunately no hills were found that could be reclassified to Munro status.

As appreciation for TMS choosing G&J Surveys for this work, we asked Iain to choose any hill that he would like us to survey. After some discussion the choice was made to survey the Corbett Top Meall Gaineimh (Hill Number 592, Grid reference NJ166051, OS 1:50000 scale map 36 and OS 1:25000 scale map 404). This hill has a spot height of 912m marked on OS maps adjacent to where a cairn appears on the ground, but the summit is crowned by a rock tor which was estimated to be at least 2m higher than the base of this cairn and therefore Meall Gaineimh had a reasonable possibility of exceeding 914.4m (3000 feet). With a drop of about 70m, if Meall Gaineimh were to exceed 3000 feet, then the SMC might choose to promote this hill to either a new Munro or Munro Top.

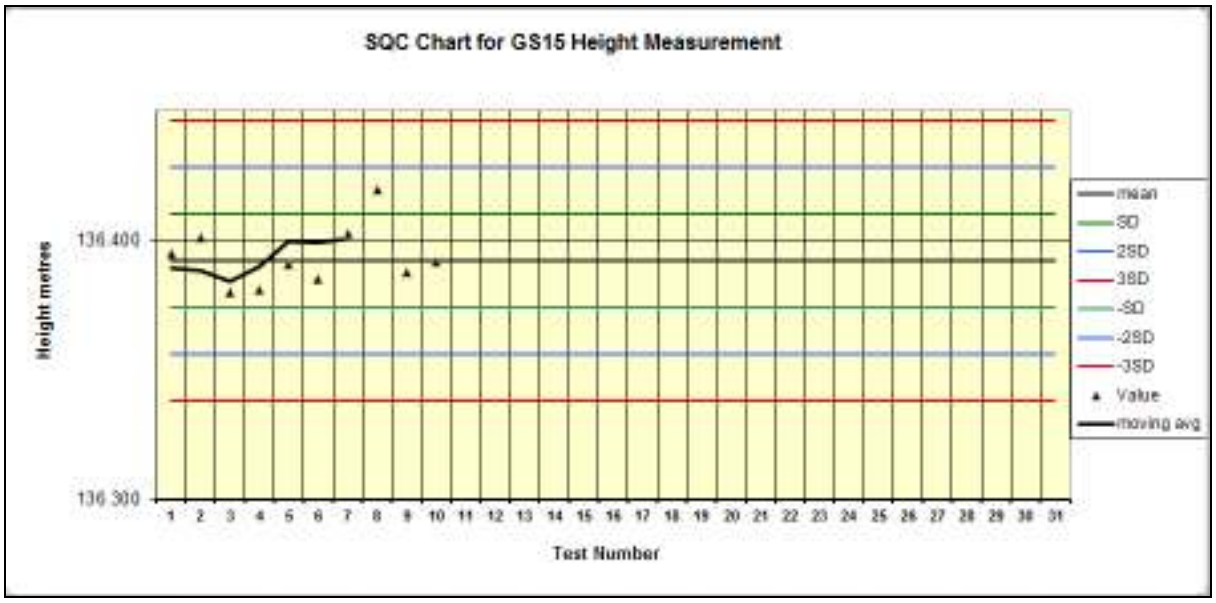
2) Equipment used and Conditions for Survey

The summit position was identified using a Leica NA730 Professional Automatic level (X30 telescopic system)/tripod system and a "1m" **E**-staff extendable to 5m.

Absolute heights were measured using a Leica Geosystems Viva GS15 Professional receiver. This instrument is dual-frequency and multi-channel, which means it is capable of locking on to a maximum of 12 GPS and 8 GLONASS satellites as availability dictates, and receiving two signals (at different frequencies) from each of these satellites. The latter feature reduces inaccuracies that result from atmospheric degradation of the satellite signals. As a stand-alone instrument it is capable of giving position and height to an accuracy of about two metres and five metres respectively. Note that small hand-held GPS receivers used for general navigation can only receive up to 12 GPS satellites and each at a single frequency and therefore these instruments have a poorer positional accuracy of +/-5metres and a height accuracy of no better than +/-10 metres. Some recently produced hand held GPS Garmin receivers can also receive signals from GLONASS satellites which greatly improve the speed at which these units can achieve a satellite "fix". Despite the on-board features of the Viva GS15 receiver, there are still sources that create residual errors.

To obtain accurate positions and heights, corrections were made to the GNSS (Global Navigation Satellite System) data via imported RINEX data from the Ordnance Survey and this dataset was post-processed using Leica Geo Office 8.3 software. Confirmation of heights was carried out by Mark Greaves of Ordnance Survey.

The Leica NA730 level is routinely checked to make sure that the line of sight is correct when the instrument is set up horizontally; there is a standard surveying method to do this described in the users' manual for these instruments. We also regularly check the functioning of the Leica Viva GS15 GNSS receiver against Statistical Quality Control (SQC) charts generated for a marked position. The chart associated with height measurement is shown below. The mean height above sea level for a fixed point (measured on 20 different occasions for 30mins of data collection at each time) was calculated to be 136.392m. Further height measurements have been made on separate occasions over a period of 18 months using the same process parameters. The last and penultimate measurements were carried out after and before the mountain surveys described in this report. The results shown on the graph are all within a range of +/- two SD (Standard Deviation), in this case one SD is +/-0.018m. This demonstrates that our Leica Viva GS15 GNSS receiver is giving consistently precise results within the expected errors for the measurements.



In addition, we check the instrument periodically by taking measurements on an Ordnance Survey Fundamental Bench Mark, processing the data and comparing it with the OS derived value. Heights should agree within about 0.02-0.03m.

Checks were carried out on 19 June 2015 at the Daresbury Fundamental Bench Mark and the results in the table below show excellent agreement between the Ordnance Survey measurement and our own.

Processing	Date	Height(m)
OS measurement		73.24
JB/GVJ GeoOffice 8.3	19-06-2015	73.23

Conditions for the survey of Meall Gaineimh, which took place between 11.00hr and 15.00hr BST, were satisfactory. The temperature was about 10 degrees Celsius on the summit and the wind speed was about 20mph. Although the sky was overcast visibility was good for all the required optical measurements.

3) The Survey of Meall Gaineimh

3.1) Character of Mountain

Meall Gaineimh lies in the North Eastern Cairngorms about 14km South of the village of Tomintoul and about 5km North East of the summit of the Munro Ben Avon. The hills in this region appear barren with flanks of stony ground covered sparsely with short grass and heather and they are often topped with rocky tors and outcrops. This region is a large area of high land in Scotland and large distances are often involved in ascending these hills. The high altitude also leads to poorer weather conditions and snow often lingers long after it has disappeared from other parts of Scotland.

Access to Meall Gaineimh can be either made from the North or from the East. From the North one can start at the small car park at NJ165176 below Queen Victoria's viewpoint and follow the track South along Glen Avon for approximately 10km until the Estate House of Inchory is reached. Just under 1km after Inchory at the Linn of Avon, one can turn off the main track and follow a path South of the crags of Carn Fiaclach and then onto the summit of Meall Gaineimh 1.5km further making a total distance of about 13km. For this survey we chose access to Meall Gaineimh from the East. This area up to a point about 2km East of Inchory is owned by the Balmoral Estate. There is a car park for Corgarff Castle just off the A939 at the entrance to the Estate road that runs West to Delnadamph Lodge. However, the Balmoral Estate was contacted prior to this survey and gave us permission to take cars as far as Inchmore thereby saving several km of walking with the surveying equipment. In addition Anne Butler from the Munro Society kindly carried the survey equipment in her Landrover up the unsurfaced track to the boundary between the Balmoral and Inchory Estates. The route then followed the track West to Inchory where the route as described above was followed to the summit of Meall Gaineimh.

An extract from the OS 1:25000 map for the summit area of Meall Gaineimh is shown above. The map shows a cairn marked with a spot height of 912m. 70m to the South West of this cairn there is a broad rock tor, also shown on the map, the top of which is clearly higher than the base of the cairn. The critical bealach lies about 400m to the West of the hill and is quite well defined. From the map contours one can judge its height to be between 840m and 850m giving a drop from the summit of Meall Gaineimh of approximately 70m.

3.2) Summary of Survey

Fortunately the rock tor on the summit of Meall Gaineimh is easily accessible and flat enough to be able to place a tripod to carry out optical measurements. The first task was to identify the highest point on the rock tor. Having set up the Leica NA730 automatic level at a suitable point, staff readings were taken until the highest point had been located which was very close to the edge of the rock tor. At this point it was evident that we would not be able to set up the Leica GS15 over the highest point as it was too near the precipitous edge, so a convenient point was chosen and marked, and then a staff reading taken from it. A staff reading was also taken from a point next to the large cairn 70m North East which is the position of the 912m spot height on OS maps.

Staff reading at cairn = 3.24m

Staff reading at highest point on rock tor = 0.471m

Staff reading at GS15 setup position = 0.695m

Therefore the base of the cairn (912m spot height) is 2.8m LOWER than the highest point on the rock tor.

The Leica GS15 receiver was set up with the "short tripod" assembly over the allocated point and GNSS data were collected for 2hours and 20 minutes with an epoch time of 15 seconds. Photographs of this and the tape offset are shown in the Appendix.

3.3) Results for Meall Gaineimh

The ten-figure grid references for the summit recorded with hand-held GPS units were:-

Garmin Montana 600	NJ 16684 05106	Height = 916m
Garmin Etrex 20	NJ 16686 05105	Height = 915m
Garmin Oregon 450	NJ 16685 05106	Height = 918m

The GNSS data were processed with Leica GeoOffice Version 8.3 Software. RINEX correction data were imported from the Ordnance Survey Website for the 7 nearest Active Base Stations (Braemar – BRAE 14km, Inverness – INVR 64km, Kintore – KINT 66km, Buckie – BUCK 66km, Fort Augustus – FAUG 79km, Dundee – DUDE 80km, and Killin - KILN 94km). We used Broadcast Ephemeris data received by the GPS during the survey rather than Precise Ephemeris data, since we have found this makes little difference to the height results. The computed Tropospheric model was chosen for the calculations to suit the data collection times and the wide difference in height between the base stations and the summit of the mountain.

The following corrections were made to establish the height of the GS15 antenna above the summit position:-

Height of GS15 setup position BELOW summit 0.695 – 0.471 = 0.224m

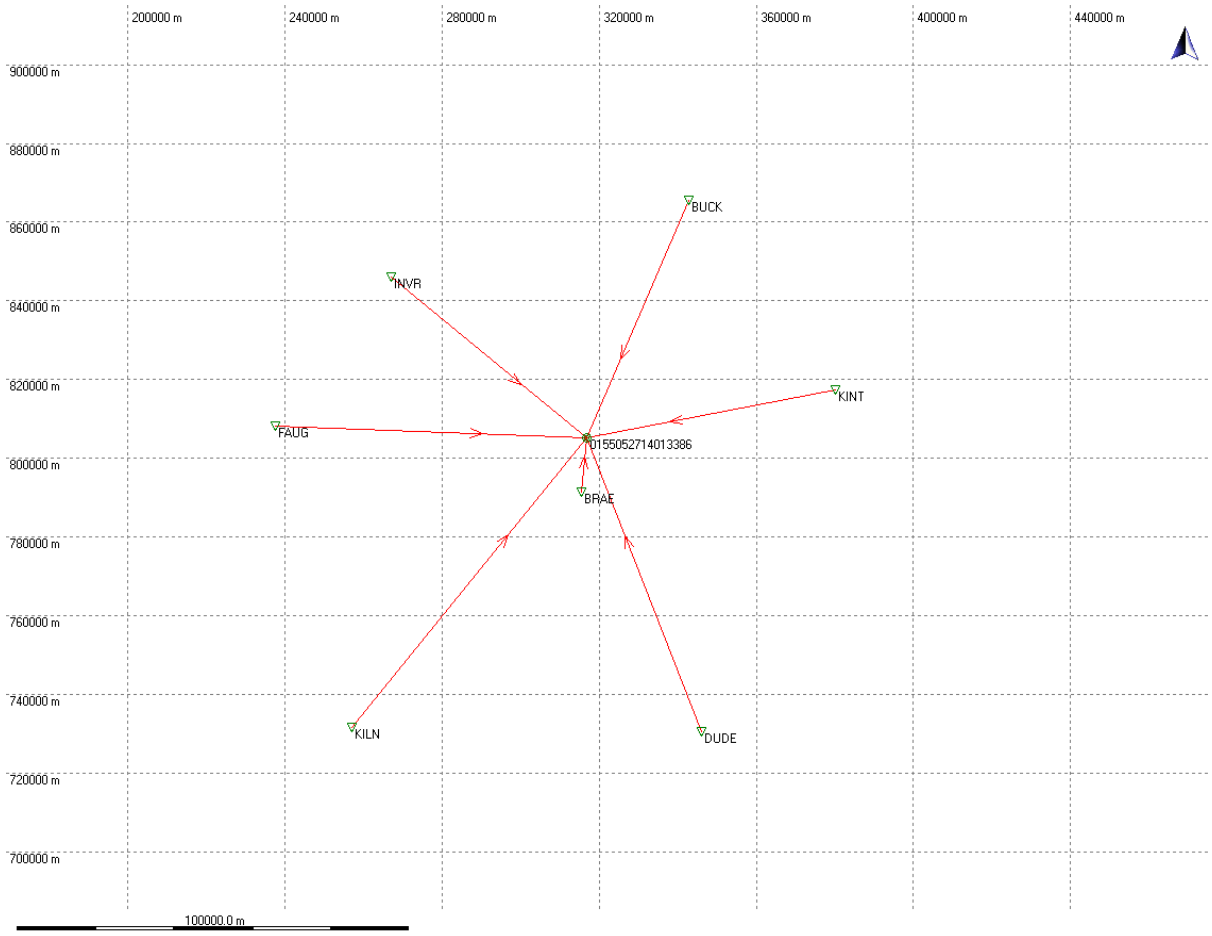
Tape reading for GS15 set up (see photo in Appendix) = 0.458m

Additional height correction for GS15 (fixed for “short tripod” setup) = 0.255m

Vertical offset for GS15 above set up position 0.255 + 0.458 = 0.713m

Vertical offset for GS15 above summit position 0.713 – 0.224 = 0.489m (used in GeoOffice calculations)

The distances and directions of the base stations from Meall Gaineimh are shown in the scaled diagram below. As far as is possible, the base stations are evenly distributed around the survey point with heights measured from each base station within +/-0.01m of the mean result.



The results for the GS15 measurements are presented in the table below:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	316681.956	0.001	805112.960	0.001	913.635	0.002

Since our measurement for the height of Meall Gaineimh was over 0.7m below 914.4m (3000.0 feet), there is no question of reclassification to Munro/Munro Top status. However the result does indicate that a change to OS maps is needed and therefore we sought verification of the result from Mark Greaves at Ordnance Survey.

4) Coordinate Recovery Analysis

In order to verify the accuracy and consistency of a GNSS dataset, Ordnance Survey recommends a procedure called Coordinate Recovery Analysis. Instead of processing the data with reference to all the nearest OS Base Stations under 100km distance, as used in this report, the data is first processed with reference to only the nearest Base Station. The data is then reprocessed with the survey point taken as a Reference Point and all the remaining Base stations under 100km distance taken as survey points. These measured values for the OS Base Stations can then be compared directly with the actual OS values for Position and Height. (This has been carried out via an Excel Spreadsheet supplied to us by OS).

Although the spreadsheet calculates a number of different parameters, two important ones are presented in the tables below. "Height Difference **U** metres**"** is the vertical height difference between the height of the Base Station as measured in this survey compared with the actual OS value. "Separation $\mathbf{D_{ij}}$ metres" is the distance in 3-d space between the measured and actual OS values for each Base Station.

The results are presented below.

Base Station	Code	Distance to Survey Point km.	Height Difference **U** metres	Separation $\mathbf{D_{ij}}$ metres
Braemar	BRAE	14		
Inverness	INVR	64	0.007	0.008
Kintore	KINT	66	0.028	0.028
Buckie	BUCK	66	-0.016	0.022
Fort Augustus	FAUG	79	-0.010	0.016
Dundee	DUDE	80	0.004	0.012
Killin	KILN	94	-0.007	0.008

The results for the Meall Gaineimh show a consistent dataset as all measured OS Base stations are within 0.03m distance and height of the OS actual values.

5) Discussion of Results

The measured height for Meall Gaineimh is 913.64m, and is 1.6 metres HIGHER that the spot height of 912m that currently appears on the Ordnance Survey 1:25k & 1:50k maps. The measured height is below 914.4m (3000.0 feet) and therefore there is no reclassification for this hill.

The GNSS data and the Coordnate Recovery analysis were presented to Mark Greaves at the OS for analysis. He has confirmed OS agreement with the result and has requested the Cartography Department at the OS to make the required map changes.

For a 2 hour GNSS dataset we would estimate the uncertainty for the height measurement to be within +/-0.05m. This is confirmed with the Coordinate recovery analysis where our measured heights for six OS Base Stations were within 0.03m. Since the highest point was on a stable rock

tor, the height uncertainty in the location of its position is estimated to be better than +/-0.005m and therefore is insignificant in the overall uncertainty.

6) Summary of Heighting Results

Meall Gaineimh was measured to be **913.64m +/-0.05m,** the summit being a rock tor at NJ 16685 05106.

The height **is below 914.4m (3000.0 feet)** and therefore Meall Gaineimh remains a Corbett Top.

7) Acknowledgements

Many people contributed to the success of this survey.

We would like to thank Mark Greaves of the Ordnance Survey, who verified the height for Meall Gaineimh and has arranged for the necessary changes to be made to OS maps.

We would also like to thank Richard Gledson, the Resident Factor, and David Scrimgeour of the Balmoral Estate for allowing us vehicular access onto the Estate roads and tracks to help with the logistics of the survey and also for their keen interest shown in this survey work.

Finally, we would like to thank members of The Munro Society and Scottish Mountaineering Club who assisted with this survey and in particular, Iain Robertson, who coordinated the Heightings Project for The Munro Society and has continued to choose us to carry out the required survey work, and Anne Butler with her Landrover for providing transport on the Estate tracks.

John Barnard, Graham Jackson and Myrddyn Phillips, 29 October 2015.

Appendix

Leica GS15 set up on the Summit Tor of Meall Gaineimh

Tape Reading for Vertical Offset for summit measurement of Meall Gaineimh