

Survey of Meikle Millyea

23 October 2015

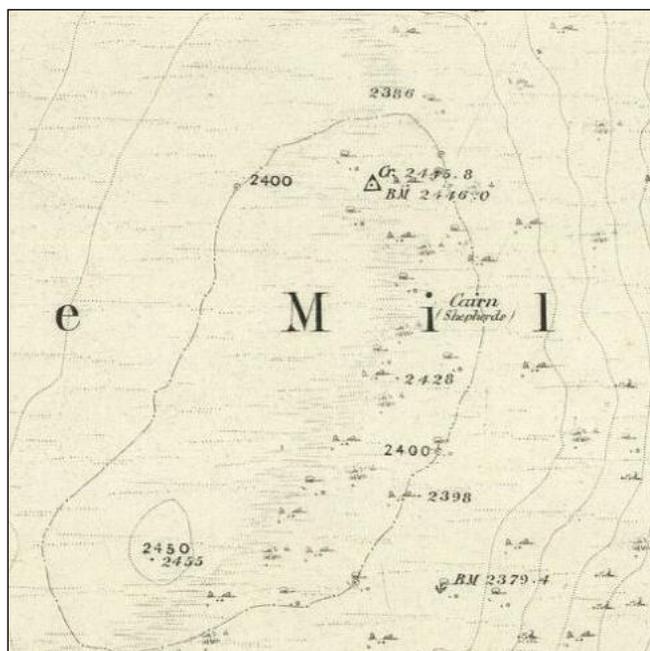
The Team:-

Surveyors – John Barnard and Graham Jackson of G&J Surveys.

Assisted by – Richard Cooper, Laurence Rudkin and John Russam

1) Introduction

G&J Surveys has agreed a project with the Scottish Mountaineering Club (SMC) to measure accurate heights for several Scottish mountains. The aim of the project is the resolution of anomalies that currently exist in several lists of hills that are of interest to the SMC. One such list is the Donalds, mountains of 2000ft or over in the Scottish Lowlands. The list was compiled by Percy Donald who grouped the hills into Tops and Hills using a complicated formula. Whether a summit was a Hill or Top was dependent on drop, distance from the next higher hill and topographical merit. The full definition is given in the recently published SMC Hillwalkers' Guide: The Grahams and The Donalds and also in previous publications of Munro's Tables. Meikle Millyea (hill numbers 1693 & 1694 in the Database of British and Irish Hills) is classified as a Donald. Historically, the accepted summit is the NE summit (hill 1694) bearing a very large cairn and a trig point. This position is given a 746m spot height on modern 1:50k Ordnance Survey (OS) maps, but old OS maps show higher ground about 400m to the SW (hill 1693). For example the 1853 map shows a 2455ft (748m) spot within a 2450ft (747m) contour on the SW top, while the NE top has a 2446ft (746m) BM. The 1:40k Harvey map also gives a 749m spot height on the SW top.



Consequently, there has been much confusion as to just where the summit of Meikle Millyea lies.

The aim of this survey was to resolve the confusion and obtain accurate heights for the summits of the SW and NE tops of Meikle Millyea using a survey grade GNSS (Global Navigation Satellite System) receiver and submitting the data sets collected to OS for verification.

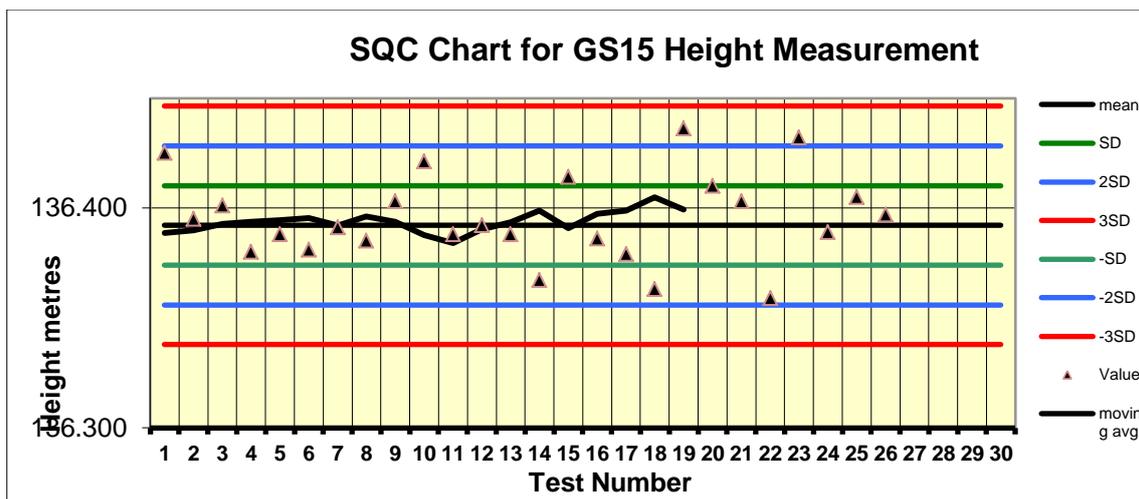
2) Equipment used and Conditions for Survey

The summit positions were 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. Despite the on-board features of the Viva GS15 receiver, there are still sources that create residual errors. To obtain accurate positions ($\pm 0.01\text{m}$) and heights ($\pm 0.05\text{m}$), corrections were made to the GNSS (Global Navigation Satellite System) data via imported RINEX data from Ordnance Survey and this dataset was post-processed using Leica Geo Office 8.3 software. Confirmation of heights was carried out by Mark Greaves, Geodetic Analyst of Ordnance Survey.

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 $\pm 5\text{metres}$ and a height accuracy of no better than $\pm 10\text{metres}$. 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”.

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. A few weeks prior to this survey this level was checked by M&P Surveys, who are Leica agents, and its accuracy was verified and certificated. 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 ODN (Ordnance Datum Newlyn) 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 \pm three SD (Standard Deviation), in this case one SD is $\pm 0.018\text{m}$ and the moving average is within 1SD. This demonstrates that our Leica Viva GS15 GNSS receiver is giving consistently precise results within the expected errors for the measurements (all points are within a range of 0.07m of one another).



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 values. Height should agree within about 0.02-0.03m.

Checks were carried out on 26 August 2015 and 12 November 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	26-08-2015	73.22
JB/GVJ GeoOffice 8.3	12-11-2015	73.21

Conditions for the survey of Meikle Millyea, which took place between 11.00hr and 16.00hr BST, were satisfactory. The temperature was about 10 degrees Celsius on the summit and the wind speed was about 30mph. Visibility was intermittent as low cloud and light rain frequently swept over the summit. Towards the end of the survey, a previously forecast front arrived bringing heavy rain and increased wind speeds to 40mph.

3) **Character of the Mountain**

Meikle Millyea (Hill Numbers 1693 & 1694, Hill Section 0a (SMC Guide), OS 1:50000 Map 77, OS 1:25000 Map 318, Grid Refs NX516825 & NX518829) lies at the southern end of a 12km ridge which stretches to Coran of Portmark in the North. The highest point along the ridge is the Corbett Corserine (814m).

The easiest approach to Meikle Millyea is from a forestry car park (NX552862) at the end of the minor road to Forrest Lodge. This narrow road starts from Polharrow Bridge on the A713 and winds for 6km through a mixture of wooded and open countryside. From the car park a forest road, named Prof Hans Heiberg Road, leads SW, steadily climbing to 330m. Although the map shows forestry for the whole of its length, large areas of woodland have been cut and the road is in fact very open and gives good views of the lower slopes of Meikle Millyea on the approach. Care should be taken to maintain a SW line as there are a couple of new tracks which were not marked on our maps. After about 2.7km the forestry begins to close in on the road and after a further 300m or so, a narrow ride is reached with a stile at its end that gives access to the open fell. From here there is a stiff climb of about 100m on a well-defined walker's path before the gradient eases. By continuing on this path a wall is soon reached which then leads all the way up Meikle Lump and thence to within about 200m of the trig point on the NE top of Meikle Millyea. From here it is just 400m to the SW top over grass and heather, the drop between the two summits being of the order of just a few metres. The SW top is marked by a cairn and nearby is a smaller cairn and within this area are several large embedded rocks.

The view from this top is extensive. Just to the South lies Clatteringshaws Loch, while further to the SE is the finger-like outline of Loch Ken and beyond this Criffel and the Solway Firth, although the latter was only glimpsed occasionally between showers on our visit. To the West are the Corbetts Merrick and Shalloch on Minnoch and the complex terrain that includes the Grahams Mullwharchar and Craignaw. To the North the view is dominated by the bulk of Corserine and its SE ridge.

4) Summary of Survey

The survey started on the SW top where the highest point was identified using the level and staff. Prior to setting up the Leica Viva GS15 over the identified summit position, the level was also turned towards the NE top which was clearly seen to be lower. A photograph was taken of the view through the level (see Appendix) and from this a semi-quantitative determination of the height difference could be calculated. Once GNSS data had been collected, attention was next turned to the NE top. Once again the level and staff was used to identify the summit position before setting up the Leica Viva GS15 receiver over it to collect GNSS data.

4.1) Survey of SW Top

The first task was to identify the exact highest point using the level and staff which was set up a few metres away from the larger cairn. Ground by the larger cairn and smaller cairn along with several embedded rocks and small outcrops were examined and the highest point was found to be an embedded rock 20m NE of the larger cairn. A second embedded rock 10m East of this was found to be just 0.03m lower.

Next the tripod was set-up over the highest rock and the Leica Viva GS15 was then fixed to it with a clamp and tribrach (the “short tripod” configuration). The height of the receiver above the ground was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.165m (see photograph in Appendix) plus 0.255m for the tribrach/hook system. GNSS data were collected for 2hr with an epoch time of 15 seconds.

4.2) Results for Meikle Millvea SW Top

The Leica Viva GS15 was used only to collect data on the Summit rock. Consequently, the locations of the other major summit features were recorded with hand-held GPS receivers. These were:-

Summit rock

Garmin Oregon 450	NX 51617 82556	Accuracy 3m	Height = 754m
Garmin Montana 600	NX 51617 82555	averaged	Height = 751m
Garmin Etrex 20	NX 51617 82556	averaged	Height = 753m

Second rock

Garmin Oregon 450	NX 51617 82556	Accuracy 3m	Height = 754m
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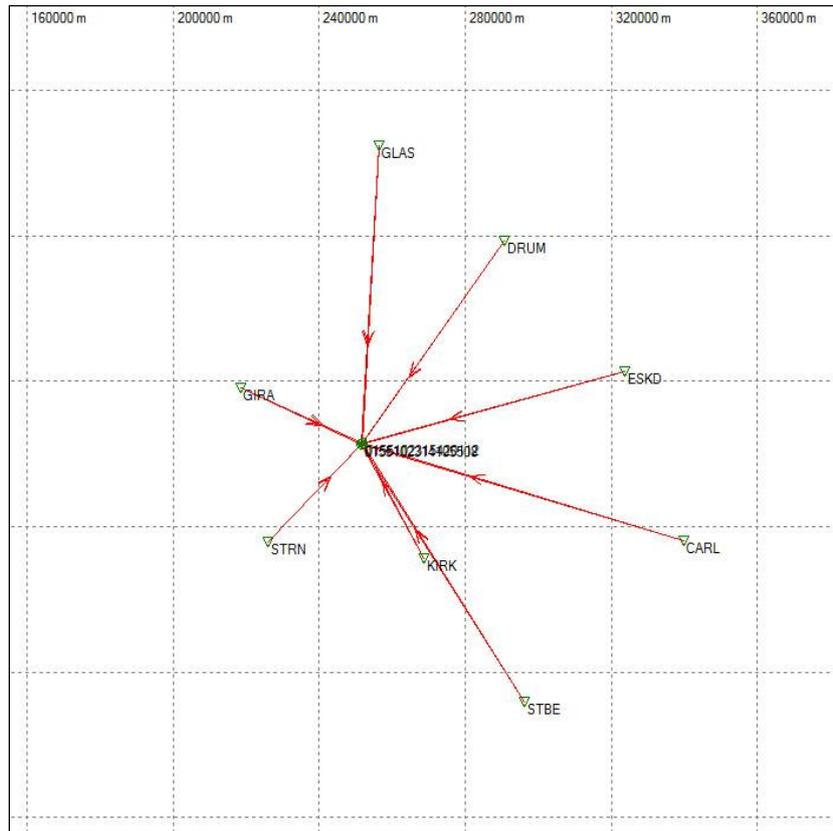
Larger cairn

Garmin Oregon 450	NX 51607 82538	Accuracy 3m	Height = 756m
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The data for the Leica Viva GS15 were processed in Leica GeoOffice 8.3 using the eight nearest base stations: (Kirkcudbright– KIRK 35km, Stranraer – STRN 36km, Girvan - GIRA 36km, Drumalbin – DRUM 69km, Eskdalemuir– ESKD 75km, Glasgow- GLAS 83km, St Bees – STBE 84km and Carlisle – CARL 93km). 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 distances and directions of the base stations from Meikle Millyea are shown in the scaled diagram below. As far as is possible, the base stations are evenly distributed around the survey point

and heights measured from each base station were within +/-0.03m of the mean result for the SW Top.



The results are tabulated below:

Processing	Feature	Easting	Northing	Height(m)
Leica GeoOffice 8.3	Embedded rock	251612.832	582557.877	748.644

The height of Meikle Millyea SW Top is 748.64m. The data file was also sent to Ordnance Survey for confirmation of the result.

The height difference between the SW top and the NE top may be calculated from the photograph taken through the level of the NE top from the SW top. The small horizontal stadia lines at the top and bottom of the photograph represent 1/100th of the distance between the SW top and the NE top (the continuous central line is the level line). This distance is measured from the GNSS position readings and is 380m. The distance between the highest point of the ground and the level line is 0.58 of the distance between the two stadia lines.

Therefore the height difference between the level as set up on the SW top and the ground on the NE top is: $0.58 \times 380 / 100 = 2.20\text{m}$. The height difference between the level and the summit of the rock on the SW top was 0.35m which must be subtracted from this value.

Therefore the height difference is $2.20 - 0.35 = 1.85\text{m}$ with the SW top being the higher. Earth curvature is negligible (0.01m) over the distance between the two tops. The precision of this

technique is about +/-0.2m, but serves as good guide for our expectation of the more accurate GNSS determination.

4.3) Survey of Meikle Millvea NE Top

Attention next switched to the NE Top where once again the level was set up at a convenient position. The summit area is adorned with a very large cairn, a trig point and several embedded rocks. It was quickly established that the cairn and the trig point were not at the summit which was in an area of ground a few tens of metres South of the trig point. This area was next investigated more intensively and one of several candidate rocks was found to be the highest point.

A staff reading was taken both for the summit rock and the flush bracket on the trig point in order to determine the height difference between them. Subtraction of this height difference from the final summit height measurement determined by the Leica GS15 then yields a value for the flush bracket height which can be compared with the OS value.

Next the tripod was set-up over this position and the Leica Viva GS15 was then fixed to it with a clamp and tribrach (the “short tripod” configuration). The height of the receiver above the ground was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.304m (see photograph in Appendix) plus 0.255m for the tribrach/hook system. GNSS data were collected for 1hr with an epoch time of 15 seconds.

4.4) Results for Meikle Millvea NE Top

The Leica Viva GS15 was used only to collect data on the Summit rock. Consequently, the locations of the other major summit features were recorded with hand-held GPS receivers. These were:-

Summit rock

Garmin Oregon 450	NX 51832 82871	Accuracy 3m	Height = 754m
Garmin Montana 600	NX 51830 82872	averaged	Height = 748m
Garmin Etrex 20	NX 51830 82871	averaged	Height = 754m

Trig Point

Garmin Oregon 450	NX 51843 82881	Accuracy 3m	Height = 756m
Garmin Montana 600	NX 51841 82882	averaged	Height = 750m
Garmin Etrex 20	NX 51844 82881	averaged	Height = 753m

Large cairn

Garmin Oregon 450	NX 51841 82899	Accuracy 3m	Height = 756m
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The data for the Leica Viva GS15 were processed in Leica GeoOffice 8.3 using the same eight nearest base stations as above and a Broadcast Ephemeris and a computed Tropospheric model. The results are tabulated below:

Processing	Feature	Easting	Northing	Height(m)
Leica GeoOffice 8.3	Embedded rock	251826.710	582875.037	746.726

The height of Meikle Millyea NE Top is 746.73m. The data file was also sent to Ordnance Survey for confirmation of the result.

Flush Bracket height

Staff Reading for Flush Bracket of trig point = 0.896m

Staff reading for summit rock = 0.598m

Flush Bracket height = $746.73 + 0.598 - 0.896 = 746.43\text{m}$

The OS value for the Flush Bracket is 746.46m

The agreement to 0.03m is excellent.

Height difference between the SW Top and the NE Top

The height difference between the two tops as measured by the Leica Viva GS15 is:

$748.64\text{m} - 746.73\text{m} = 1.91\text{m}$ with the SW top being the higher.

5) Summary of Operating Conditions

Variable	GS15 on SW Top	GS15 on NE Top
Data collection summit (min)	120	62
Number of Base Stations used in Processing for all points	8	8
Epoch Time (sec)	15	15
Tropospheric Model	Computed	Computed
Cut off Angle (degs)	15	15

6) Discussion of Results

The summit positions of both tops were rocks and consequently the height uncertainty associated with locating the tops is no more than 0.005m. The height uncertainty associated with the GNSS measurement from a 2hr dataset has been measured by us and is +/-0.05m for data processed in propriety software. The measurement uncertainty for the height difference between the two tops is therefore:

$$(0.05^2 + 0.05^2 + 0.005^2 + 0.005^2)^{0.5} = 0.07\text{m}$$

The measured height for Meikle Millyea SW Top is 748.64m which is in good agreement with the spot heights on the 1853 OS map (2455ft (748.3m)) and Harvey’s map (749m). The measured height for the NE top is 746.73m which is also in good agreement with the 1853 map (2446ft (745.5m)) and the modern OS map (746m). The height difference between the two summits is 1.91+/-0.07m. Note that the less accurate optical determination of 1.85m is just 0.06m different.

The GNSS measured height of the trig point flush bracket of 746.43m is just 0.03m different from the OS value again emphasising the self-consistency of the measurements.

7) 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 **D_{ij}** metres” is the distance in 3-d space between the measured and actual OS values for each Base Station.

The results for the two surveys are presented below.

Meikle Millyea SW Top:-

Base Station	Code	Distance to Survey Point km.	Height Difference U metres	Separation D_{ij} metres
Kirkcudbright	KIRK	35		
Stranraer	STRN	36	-0.016	0.018
Girvan	GIRA	36	0.009	0.015
Drumalbin	DRUM	69	0.000	0.006
Eskdalemuir	ESKD	75	-0.002	0.007
Glasgow	GLAS	83	-0.019	0.024
St Bees	STBE	84	0.001	0.013
Carlisle	CARL	93	0.030	0.032

Meikle Millyea NE Top:-

Base Station	Code	Distance to Survey Point km.	Height Difference U metres	Separation D_{ij} metres
Kirkcudbright	KIRK	35		
Stranraer	STRN	36	-0.001	0.021
Girvan	GIRA	36	-0.005	0.017
Drumalbin	DRUM	69	-0.034	0.040
Eskdalemuir	ESKD	75	-0.002	0.017
Glasgow	GLAS	83	-0.022	0.029
St Bees	STBE	84	-0.005	0.023
Carlisle	CARL	93	-0.005	0.022

The results for both Meikle Millyea SW Top and NE Top show consistent datasets as all measured OS Base stations are within 0.04m distance and height of the OS actual values.

8) **Summary of Heighting Results**

Meikle Millyea SW Top was measured to be **748.6 +/-0.05m**, the summit being an embedded rock at NX 51617 82556*.

Meikle Millyea NE Top was measured to be **746.7 +/-0.05m**, the summit also being an embedded rock at NX 51831 82871*.

The height difference between the two summits is 1.9 +/-0.07m

The results have been accepted by Ordnance Survey and forwarded to OS Cartography for map changes.

9) **Acknowledgements**

Many people contributed to the success of these two surveys.

We would especially like to thank the Scottish Mountaineering Trust for generously supporting the work and Rab Anderson and Andy Nisbet of the Scottish Mountaineering Club for their guidance and encouragement.

We also wish to thank Mark Greaves of the Ordnance Survey, who accepted the data and forwarded the results to OS Cartography for map changes. We also thank Mark for his support and advice that has helped us carry out our mountain heighting work over the past seven years.

*grid references for use with Garmin hand-held receivers

John Barnard, Graham Jackson and Myrddyn Phillips, 30 October 2015

Appendix



Meikle Millyea NE Top as viewed through the level from Meikle Millyea SW Top



Measuring the offset for the Leica Viva GS15 on the summit of Meikle Millyea SW Top



Leica Viva GS15 collecting data on the summit of Meikle Millyea SW Top



Setting up the Leica Viva GS15 on Meikle Millyea NE Top: the large cairn is just off the picture to the left of the trig point



Measuring the offset for the Leica Viva GS15 on the summit of Meikle Millyea NE Top