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VALUE OF GRAVITY AT DEHRA DUN

By

Mr B. L. Gulatee, M. A. (Cantab).

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VALUE OF GRAVITY AT DEHRA DUN

Perhaps the situation as regards the value of gravity at Dehra Dun is more unsatisfactory than at any other national base station in the world. This is particularly unfortunate as it occupies a pride of place, controlling as it does stations distributed over a vast region which is of considerable geodetic and tectonic interest. Starting from the year 1904, Dehra Dun has been connected directly and indirectly with the various European stations about a dozen times and each time a different value has been obtained. The stations of reference used have been Potsdam, Genoa, Kew and Cambridge, the results being tabulated below :-

Date of observation.	Observer	European station of reference.	Instrument used.	g gals
1. 1904	Lenox Conyngham	Kew	Potsdam pendulums	979.063
2. 1906	Allessio	Potsdam	,,	979.059 (value obtained via Indian station Colaba, observed by Survey of India in 1904).
3. 1905	Hecker	,,	,,	979.065 (value obtained via Indian station Jalpaiguri).
4. 1913	Allessio	Genoa	Italian pendulums	979.079
5. 1924	Cowie	Kew	Potsdam pendulums	979.054
6. 1927	Glennie	Cambridge	Cambridge apparatus	979.072
7. 1929	Glennie Cowie	Kew	Potsdam pendulums	979.068
8. 1929	Spoleto	Genoa	Italian pendulums	979.069

Date of observation.	Observer	European station of reference.	Instrument used.	g gals
9. 1929	V-Meinesz	De Bilt		979.075 (via Colombo, observed by Survey of India in 1934).
10. 1932	Lejoy	Potsdam		979.085 (via Colombo, observed by Survey of India in 1934).
11. 1939	Browne Glennie	Cambridge		979.056

The range is 31 mgals which is considerable and is not in accordance with the accuracy expected of pendulum observations. Some portions of it may be due to errors in the European reference stations but this will be comparatively negligible. The major portion must be ascribed to defects of observation and the vagaries of the pendulum apparatus and its ancillaries whose misdeeds are so well known.

The value accepted at Dehra Dun is the first one viz: 979.063 which was carried out by Von Sterneck's brass pendulums swung at Kew and Dehra Dun in October 1903 and February 1904 respectively. The apparatus was new and the observations both at Kew and Dehra Dun were not regarded as very satisfactory-at Kew on account of clock trouble and at Dehra Dun on account of the room in which pendulums were swung being too large and high with an iron roofing, producing very unsatisfactory temperature conditions during the day time.

Borrass in his well known 1907 adjustment of the fundamental gravity stations of the world remarked that this determination was unsatisfactory in that observations were not closed at Kew after Dehra Dun but that it received strong confirmation from the independent connection of Indian station Jalpaiguri with Potsdam by Hecker in 1905. He accepted the value $g = 979.065$ obtained by Hecker's observations for Dehra Dun via Jalpaiguri and after adjustment in the circuit Hongkong-Jalpaiguri-Dehra Dun-Zikawei-Tokyo-Washington-Munich-Vienna obtained final adjusted value as 979.066.

The subject of gravimetry has expanded considerably now and several studies have been made recently to adjust the national base stations of the world as the earliest adjustment carried out by Borrass in 1907 has been rendered obsolete by recent accurate connections between the various stations. One such study is that by Hirvonen, details of which have not yet been published, but Heiskanen in Publication No.5 of the Isost. Institute of Geodesy, Helsinki has given his final results in the form of a table. The value of g at Dehra Dun according to him is as follows :-

	Borrass (1907)	Hirvonen (1939)	Survey of India (accepted value)
Dehra Dun	979.066	979.078	979.063

In deriving the above value of 979.078 Hirvonen appears to have given considerable weight to the value obtained indirectly from Alessio's observations at Colaba, practically ignoring the evidence of other connections. The International

Isostatic Institute at Helsinki has accepted Hirvonen's value at Dehra Dun for their study of the geoid from gravity values.[1]

Morelli[2] has derived the value of 979.073 ± 0.004 by taking weighted mean of the three determinations (1), (2) and (4) but in doing so he has used the value of (1) wrong by 3 mgals. He has mentioned the 1939 connection with modern Cambridge apparatus but the value quoted by him for this determination is 979.072 instead of the correct figure of 979.056. If he had taken into account this very low value of 979.056, he would probably have revised his estimate considerably.

It was expected that the 1939 determination, which was made with great care with modern Cambridge Pendulum apparatus, would give a value in the neighbourhood of 979.072, and if this had happened we would have accepted this value as final, rejecting all previous determinations or assigning them such weights as to give a weighted mean value not differing widely from it. However, in his above determination Morelli has correctly placed more reliance on the value 979.079 ± 0.0014 obtained by de Fillipi Expedition. This value deserves a special mention since it was not only the result of a direct connection between Dehra Dun and Genoa carefully executed with eight pendulums but this expedition also

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1. "The geoid study of the International Isostatic Institute" by W. Heiskanen.

   Trans. American Geophysical Union, Vol.28, June 1947.

2. Carlo Morelli: Compensazione della rete Intern: delle Stazioni di Rifermento per le misure di gravita Relativa Pub. No 221, Instituto Geofisico-Trieste, 1946.

connected the Russian work to the Indian by observations at Dehra Dun, Srinagar and Tashkent. The Russian value at Tashkent was found to be higher than even de Fillipi's by 8 mgals. affording further indubitable evidence that the accepted value of Dehra Dun is too low. None of de Fillipi's eight pendulums gave such a low value as 979.063. The value for Dehra Dun in terms of Tashkent is 979.087, which is 24 mgals more than the present accepted value. In view of the above and the fact that the 1904 Kew-Dehra connection was weak (as already mentioned) and Alessio's determination of 1906 via Colaba was of an indirect nature one cannot do better than accept provisionally for Dehra Dun de Fillipi's value of 979.079 obtained by Italian pendulums.

Closely bound up with the choice of gravity values at the base station of a country is the magnitude of the gravity anomalies there. The isostatic anomalies $g-\gamma_{c1}$ in India computed on the International gravity formula are predominantly negative. There is no special reason for India being a heavily deficient area. A spurious negative anomaly at a station can be produced by either the normal value γ_0 being too high or the observed value of g derived with respect to Dehra Dun being too low. Evidence is now accumulating that the predominance of negative anomalies are due to both these causes. The value of equatorial gravity G_E employed in the International formula was derived in such a way as to secure the best agreement with the observed values of gravity in the world. The world station of reference is

Potsdam at which the value of gravity adopted is 981.274 ± 0.003. This value is the result of an elaborate absolute determination by Kuhnen and Furtwangler, made in the beginning of this century. Recent work[3] has shown that this value is about 15 mgals too high, and the adoption of a revised lower value for it would reduce γ_0 by about this amount. The introduction of a suitable longitude term in the formula, for a reliable determination of which sufficient data is not yet available, would further modify the derived values of normal gravity. De Fillipi's value of 979.079 for Dehra Dun appears at present to be the most reasonable figure and if due account is taken of the error in the value of Potsdam, this figure is reduced to 979.064, which is in good agreement with the present adopted value of 979.063 for Dehra Dun. This means that the isostatic gravity anomalies in India need increasing by about 15 mgals, which incidentally will result in the areas of negative and positive anomalies being well balanced.

A point that might be mentioned here is that the site of the Base station for Pendulums was altered in 1913, from the Walker Observatory to the Burrard Observatory. The difference in the elevations of the two sites was 9 feet but no comparative observations with the pendulums were taken and the same value of gravity viz. 979.063 was adopted for the new station. The difference of gravity between the two sites has now been accurately

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3. "A re-examination of the Potsdam Absolute determination of gravity" by H.L. Dryden.

U.S. Department of Commerce, Research Paper R.P. 1502.

measured with a Frost Gravimeter and is 0.4 mgals. Since the results of pendulums are not of such a high accuracy, this difference is not of much importance at the moment. The greater need is to effect a reliable connection to some European station in terms of the revised Potsdam value as the body of data now at hand appears to be grossly inconsistent and does not permit of a value being adopted which can be regarded as final. As regards the details of how to accomplish this connection, the three possible methods are :-

(a) By absolute observations. These are notoriously difficult and laborious.

(b) Relative measures by pendulums. Our past experience has shown that the scheme of relative observations between stations so far apart as Dehra Dun and some European station is beset with considerable uncertainties.

(c) With the help of gravimeters. These now dominate the domain of gravimetry and have been carried to such a high pitch of accuracy that they appear to be the best solution.

The Survey of India have acquired a Frost Gravimeter but it is inapplicable to this geodetic problem on account of its small range and other limitations. News has now been received by the writer from Dr. G.P. Woollard of the Wood Hole Oceanographic Institution that he is hoping shortly to connect the principal gravity stations of the world with a temperature compensated meter having a range of 5000 mgals and a sensitivity of 0.6 mgals. Three stations in India and Pakistan are in his programme. The Survey of India will afford active co-operation, and it is hoped that results of his observations will enable us to settle the vexed and unsolved question of the value of gravity to be adopted for our base station.

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