SIMULTANEOUS DETERMINATIONS OF LONGITUDE AND LATITUDE IN AFRICA WITH THE PRISMATIC ASTROLABE

by Gunther ZIMMERMANN
Institut für Angewandte Geodäsie, Frankfurt/M.

Paper submitted by the Government of the Federal Republic of Germany to the Second United Nations Regional Cartographic Conference for Africa, Tunis (Tunisia) 12-24 September 1966.

In this paper the author describes astronomical determinations of control points which he carried out some years ago in connection with technical aid projects in Liberia. The purpose of the work was to establish by means of astronomical observations the homogeneous systems of control points required for the photogrammetric preparation of large-scale planning maps of the regions not yet surveyed.

The execution of this work revealed that the observation and evaluation procedures, as well as the instruments, involved certain requirements which are fairly typical for astronomic controls in the regions of developing countries that are either not yet surveyed or else isolated geodetically. For this reason some further details on this subject will be given.

The following circumstances characterise the situation :

(1) The astronomical observations had to be planned, prepared, performed and evaluated within a relatively short period of time, i.e. within the interval between the photogrammetic flight over the area to be mapped and the aerotriangulation.

(2) Due to the difficult operational conditions (i.e. the flight to the work site, the use of bad roads during field work, and the frequent transport of equipment by carriers) the instruments should be light, small and sturdy, but they should nevertheless guarantee very accurate astronomical determinations of position.

(3) As the planning, preparation and computation of the observations had to be performed far from the actual site of work — namely in Germany — it was necessary to determine, during the stay on each station, whether or not the observations of the stars really supplied the required accuracy for the coordinates. This check had not only to be rigorous, but also so easy that it could be performed quickly under the difficult operational conditions in virgin forests under tropical rain and without

special auxiliary means, and by a person still inexperienced in astronomical computations.

These requirements led to the decision that longitudes and latitudes of the control points should be simultaneously determined by means of a prismatic astrolabe by the method of equal altitudes of stars. The observations, however, could not be evaluated by the usual direct position-line method because it was impracticable to compute the individual position-lines on the spot with the required accuracy, due to lack of time and the necessary auxiliary means. Thus we had recourse to the indirect method; i.e. we had to pre-calculate the times of transit of selected stars at the known zenith distance of the astrolabe used, using the approximate values of the station's coordinates. By using this method it was possible to process the observations in the field with simple auxiliary means so as to able to judge the accuracy obtained for the coordinates very quickly.

The special economy of the observation and evaluation procedures, as developed and tested by the author, may be found in the fact that for all the stars in question the exact ephemerides of the transit times at the instrument's zenith distance of 30°00′40″ have been computed in advance by an electronic computer for each observation station. Thus the evaluation could be based on the differences between the computed times — referred to the Greenwich meridian — and the times determined by chronometer and stop watch.

The ephemerides had been computed at 10-day intervals, so that the transit times corresponding to the approximate values of longitude, latitude and zenith distance could be quickly determined by interpolation for the various observation days, which, naturally, were not known in advance. Thus the rigorous evaluation, up to the observation equations, could be performed in the field itself and provided approximate values of clock correction and of latitude. The setting up of the normal equations, the determination of the corrections in latitude and longitude, as well as the computation of errors, were all performed after the termination of field work. It is worth mentioning that the pre-calculation of an ephemeris by a Zuse Z 23 electronic computer (including the printing) took approximately one hour per station, whereas the evaluation of the observations resulting in the final coordinate values, and performed after the return from Africa, took approximately 40 minutes per station.

Two examples will serve to demonstrate the scope of the work connected with the aforementioned procedure. The first example concerns the photogrammetic preparations for producing planning maps at scale of 1/10 000 for the exploitation of an extensive deposit of iron ore situated approximately 80 km northeast of Monrovia, the Liberian capital.

For the execution of this project six astronomical stations, a mean reciprocal distance of approximately 4.5 km apart, have been established in order to fix the area of mining geographically and to control the aerotriangulation. Due to the beginning of the rainy season the weather conditions were extremely bad, since each evening the dew-point was already reached two hours after nightfall at the latest. The astronomical observations had therefore to be carried out within these few evening hours before a heavy ground fog set in, followed shortly after by complete cloudiness.

Although the stay in Liberia totalled 40 days, the measurements could only be made during 13 nights, with an usable observation time of 35 hours, in the course of which 394 star transits were registered by means of a Wild Astrolabe with a mercury horizon. The results of the aerotriangulation disclosed that, with an average of 66 stars per station, a mean accuracy of ± 15 m for the coordinates was obtained. For further details see the recent publication mentioned in reference [1].

The second example concerns the production of 11 sheets of the Topographic Map of Liberia, at a scale of 1/20 000, which were published in 1963 by the Republic of Liberia in cooperation with the Federal Republic of Germany, as a basis for the town planning of Monrovia. In this case seven astronomical stations were established which (together with the nine baselines whose directions were determined by astronomical measurements) served as a basis for orientation and scale checking of an aerial block triangulation. This stay in Liberia lasted only 20 days out of which 16 nights could be used for measurements, with an usable observation time of 44 hours, in the course of which 853 star transits were registered by means of a Zeiss Ni2 Astrolabe. With an average of 122 stars per station a mean accuracy of ± 9 m for the coordinates was obtained.

In the following table the characteristic data for both projects are listed by way of comparison.

Year	1961	1962/63
Project	Bong-Mining	Town planning of Monrovia
Map scale	1/10 000	1/20 000
Mean distance between control stations (km)	4.5	18
Type of astrolabe	Wild-T3	Zeiss-Ni2
Number of observation nights	14	16
Number of observation hours	34.9	44.1
Numbers of stars	376	853
Number of stars per hour	10.8	19.4
Mean number of stars per station	66	122
Mean accuracy of coordinates (m)	± 15	± 9

In conclusion it should be mentioned that the dispersion of the evening values of longitude and latitude, compared with the mean values resulting from the whole adjustment, is of exactly that order of magnitude which should be theoretically expected. As the instruments had to be mounted and demounted before and after each observation it may be concluded that the results do not contain any noticeable errors due to the transport of instruments.

REFERENCE

[1] ZIMMERMANN, G. : Astronomisch-geodätische Arbeiten in Liberia. *Dt. Geod. Kommission, Veröffentlichung* R. B, H. 117, Frankfurt/M, 1965.