Computer Evaluation of Double-Theodolite Data^{1,2,3}

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The basic approaches to evaluating double-theodolite data have been: (1) numerically to calculate the position of the balloon in space and time, and then to plot it on a winds-aloft plotting board to determine wind speed and direction; or (2) to use graphical methods throughout to determine wind speed and direction. Either of these methods requires the use of winds-aloft plotting boards and both methods are laborious and time consuming. When a large number of observations are to be evaluated, a high speed electronic digital computer offers a much more convenient and rapid technique of analysis.

The following method of analysis requires no plotting of data. The only man-hours involved are in the conversion of the data from tabular form to punched cards (or any other convenient form of computer input). The output is in the desired form of the horizontal wind vector and the altitude of the balloon for each reading.

The standard equations as presented by Middleton and Spilhaus (1953) are used to describe the position in space of the balloon. This gives the position in cylindrical coordinates (r, θ, z) which need to be converted into a Cartesian coordinate system (x, y, z) for the following approach. The Cartesian coordinate system is set up by requiring that the x -axis coincide with the baseline used for the two theodolites and that the origin be at the theodolite where the balloon is released. The baseline was located on an east-west line thus making the y -axis on a north-south line (Fig. 1).

The position of the balloon in the x, y plane is designated as x_0, y_0 for the release position; x_1, y_1 as the first position, etc., to x_n, y_n as the n th position; then in order to find the distance the balloon traveled in going from x_i, y_i to x_{i+1}, y_{i+1} the following formulas are used: $r = [(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2]^{1/2}$; $\theta = \tan^{-1} [(y_{i+1} - y_i) / (x_{i+1} - x_i)]$. Thus, knowing r , the distance traveled, and t , the time between successive readings (for this program it was every 10 sec), the average wind speed $\bar{U}$ is simply r/t . The height of the balloon was previously calculated by the computer in order to describe its position in space.

When the computer comes to a missing point, the average is formed by using the next point. This is also true if two consecutive points are missing. However, if three or more consecutive points are missing, then an average is not taken and the computer continues to

FIG. 1. Diagram showing coordinate system used in equations.

test for missing data until points are again found, and the averaging process starts again. Thus a segment of the run is considered missing only if three or more consecutive readings are missing.

A problem also arises when the balloon crosses the baseline or travels along it. Middleton and Spilhaus (1953) present equations for these cases using the elevation angles to compute the position of the balloon in space. Once the position of the balloon in space is computed, the wind speed and direction may be computed using the same method as previously described.

A test set of data was used as a comparison and was hand-calculated using a graphical analysis. The results of the comparison showed a maximum difference in wind speed of only 1 ft per sec and a maximum difference in wind direction of only 6 deg (all the rest being 2 deg or less).

The merit of the program is the great speed with which a large number of data can be analyzed. One program consisted of 10 pibal soundings, each 10 min long and readings taken every 10 sec for a total of 600 points to evaluate. The computer time involved was less than 3 min for the IBM 704. The time involved for punching the data on cards was about 40 min. This is to be compared to the method as presented by Weedfall and Jagodzinski (1961) which required about 25 min to complete one 30-interval run and the U. S. Weather Bureau Circular "O" method of 70 min.

The details of the computer program used have been published in a technical report through the Great Lakes Research Division, Institute of Science and

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² Contribution No. 15 of the Great Lakes Research Division, Institute of Science and Technology, The University of Michigan.

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Technology, The University of Michigan⁴. The program was written in the MAD⁵ language.

⁴ Biggs, W. G., 1962: Computer evaluation of double-theodolite data. The University of Michigan ORA Report 03632-4-T, Great Lakes Research Special Report No. 13, Ann Arbor, Mich.

⁵ Michigan Algorithm Decoder.

REFERENCES

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- Weedfall, R. O., and W. M. Jagodzinski, 1961: Comments on double-theodolite evaluations. *Bull. Amer. meteor. Soc.*, **42**, 322-324.