LIMITATIONS ON TREE HEIGHT MEASUREMENTS BY PARALLAX

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AS AERIAL photographs are being used to an ever increasing extent in obtaining estimates of timber volume, and since these estimates are in many cases based on height measurements of individual trees or stands, it becomes increasingly important to know what precision can be obtained in taking differential parallax readings to obtain tree or stand heights. The values obtained for this variable directly affect the volume. It has been stated that a difference of five feet in the height of a mature tree will in some instances double the calculated volume of the tree. A rough check on volume tables giving merchantable volume for different values of DBH and total height indicates that for a group of eastern hardwoods and softwoods a difference of five feet in height will modify the volumes of the smaller trees (about 9 inches DBH) by about 13% and mature trees by about half of this. No calculations were made on fully matured trees to which the above statement could be directly applied. However, the rough percentages do show that a significant volume change takes place with a change of 5 feet in height. These facts point to the desirability of finding what the limitations of consistency are of height values obtained from differential parallax measurements.

The data available for this study were obtained by Joseph Zaremba in connection with a problem in which he showed that positive transparencies were superior to positive semimatte prints for differential parallax measurements for heights. This study was made by only the one operator and is highly indicative of the superiority of transparencies though not entirely conclusive. The above study and also the one at hand are based on the consistency of values as developed by the standard deviations of repeated measurements. The basic equipment and materials used and other information were:

Ryker mirror stereoscope with 4× binoculars.
Fairchild parallax bar.
Photographs taken in late June in Massachusetts and of excellent quality.
Focal length of camera, 12 inches.
Flying height, 9,600 feet.
Film—infra red with a No. 25 (red) filter
Measurements—960 completely randomized, ten taken on each of 48 trees on both semimatte prints and positive transparencies.

Ten differential parallax determinations were obtained on each of 48 tree images on both transparencies and semimatte prints—a total of 960 determinations. The standard deviation was obtained for each group of ten measurements (in other words, each tree) and these were plotted over the mean differential parallax for that particular tree. This latter figure represented the height of the tree as it was desirable to find whether or not standard deviation varied with the height of the tree. This procedure was followed for both transparencies and semimatte prints with the results shown in the lower part of Figure 1.

It is interesting to note in Figure 1 that there is a definite slope to the lines of about 10% and that they are almost identical in this respect. This is contrary to what was expected. Unless some factors have been overlooked there seems to be three possible avenues to the approach in analyzing this upward trend. These are, first, placing the floating dot on the ground at the base of the tree; second, placing the dot at the top of the tree; and third, the increased number of revolutions of the micrometer in measuring a tall tree over the number in measuring a short tree.

It is thought that the only difference in placing the dot on the ground at the tree base would involve the difference that might be caused by the smaller tree having branches closer to the ground and thereby obscuring the tree base. With respect to the tree top, it is thought that the top of the larger tree would be better defined on the photograph as mature trees have a tendency to acquire a flattened top in contrast to the spire shape of the younger trees. This would make the parallax reading at the top more consistent. This would increase the precision of the top measurement on the larger trees but as pointed out

RELATIONSHIP OF COEFFICIENT OF VARIATION AND STANDARD DEVIATION TO MEAN DIFFERENTIAL PARALLAX

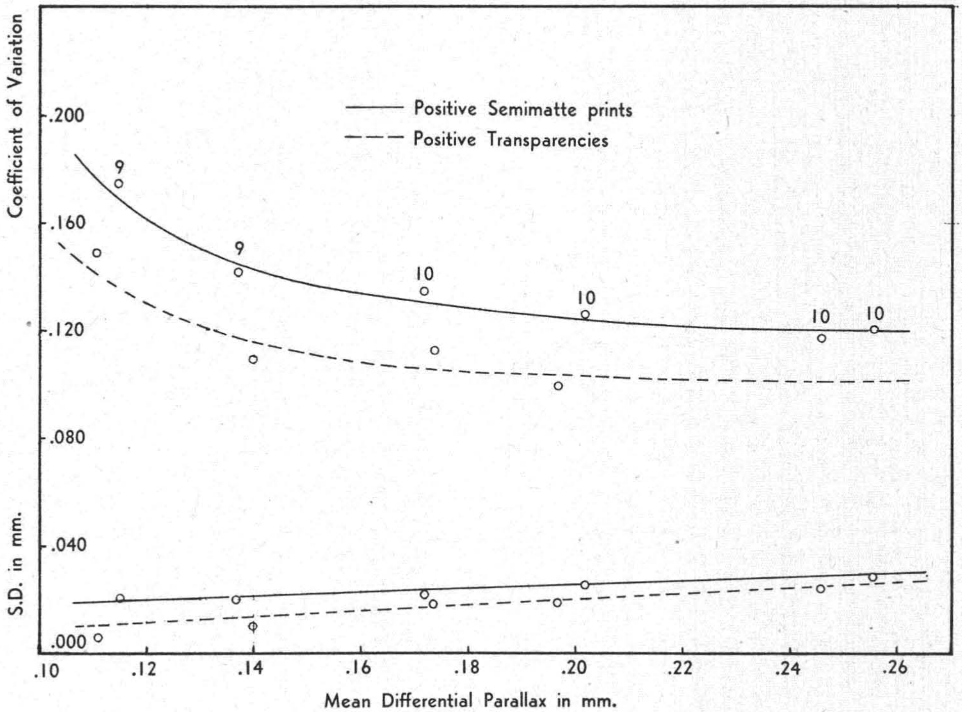

FIG. 1

above, the precision decreases with height. A third possibility is that more turns of the micrometer must be made for a large parallax value (a tall tree) than for a small one. There is a bare possibility that this may cause the variation.

The reason for this small though persistent up trend is not clear. Any suggestions will be appreciated.

The lower limit of the graph would tend to indicate that the standard deviation of the differential parallax values will not get much below .020 mm. for the semimatte prints nor .015 mm. for the transparencies. The percentage of variation as measured by the standard deviation with respect to the average tree height (coefficient of variation) while large for small size trees does not greatly affect the total volume as it would be developed for a cruise. The per cent associated with the larger trees, while smaller, has a very decided effect on volume. From the upper graph it can be seen that this is apparently tapering off to a horizontal line at about 12 per cent. To carry this further, if a five per cent limit of error were set with a probability of staying within this limit for 95 per cent or approximately two standard errors, then the number of measurements required to determine height within these limits on a particular forest type or other sub-classification would be

$$N = (2\,C/.05)^2 = [(2)(.12)/.05]^2 = 25$$

in which C is the coefficient of variation. This means that if the probability limit were set at the five per cent level, the most that could be said is that individual tree height measurements are being obtained to within a consistency of ± 24 per cent. While this large limit of error may be satisfactory for some cruising purposes, it limits the use of height determination by differential parallax as a method of volume determination in cruises that demand a higher degree of accuracy. The values for the transparencies would decrease these percentages by two to four per cent.

This information should not be considered a conclusive proof of anything, but it most assuredly should raise the question as to whether individual tree heights as obtained from differential parallax measurements on aerial photographs can be depended upon to furnish a desired accuracy in timber volume estimates. Of course, the average of repeated measurements on the same trees, or from a practical standpoint on say 25 different trees in the stand for the purpose of obtaining the *stand* height, would yield a figure that would be within the range of accuracy and probability mentioned above. The findings are based on the measurements of one man, using one set of instruments on photographs taken on infra red film with a red filter by a camera with a 12 inch focal length and at a flying height of about 9,600 feet over an area of mixed hardwoods and softwoods in Massachusetts. Any factors other than these could cause a variation in the findings.

As can be realized need exists for a great quantity of basic information. Any suggestions regarding the reasons for the increase in the standard deviation with the height of the tree, or other means of approach, will be greatly appreciated.

THE HOTSPOT IN WIDE-ANGLE PHOTOGRAPHS

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Abstract

The phenomenon known as "hotspot," "no-shadow-area," or "hazy spot" in wide-angle vertical aerial photographs contributes greatly to increased mapping costs and lower map accuracy. The spot is caused by absence of shadows and by halation near the prolongation of a line from the sun through the exposure station. Its major effect is the destruction of fine image detail over a considerable portion of the wide-angle photograph. It is not a serious problem in normal or narrow angle photographs in the temperate zones. The most practical method of overcoming the hotspot is to avoid it. The position of the hotspot on the photograph at any given time may be accurately predicted and flights may be planned to avoid it.

I. Introduction

The "hotspot" in wide-angle photographs is a phenomenon which, in the author's opinion, may increase the cost of some mapping projects 30 per cent or even more. Little, if anything, has ever been published with regard to the hotspot, and the author has found that many leading photogrammetrists were unaware of its existence or of its economic effect. Ryker is known to have referred to its hindrance to forest interpretations in the 1930's, but no subsequent reference has come to the author's attention until December, 1952, when Beltman[1] and Spurr[2] mentioned it briefly during discussion of shadows on aerial photographs.

The phenomenon has been referred to as the "point-of-no-shadows," "no-shadow-area," and "hazy spot," among other things; but among the author's associates the term "hotspot" has been adopted as a handy expression and is sufficiently explicit for practical purposes.

It is believed that some of today's leaders in photogrammetry may be unfamiliar with the hotspot because they transferred from direct everyday contact with photographs to administrative positions at about the time normal-angle photography was supplanted by wide-angle for topographic mapping. The effect of the hotspot is rarely noticed in $8\frac{1}{4}$ inch and 12 inch focal length photographs in the latitudes of the United States. Stereoplotter operators of today are aware of the spot, but apparently few know the cause or what can be done about it.

II. Cause of the Phenomenon

The hotspot is caused by that portion of the sun's rays which is directed back toward its source by diffuse reflection from objects on or near the prolongation of a line from the sun through the exposure station of the photograph (Figure 1A and 1B). The shadow of the aircraft always

[1] Beltman, B. J., "Shadows on Aerial Photographs," Photogrammetric Engineering, Dec., 1952, Vol. XVIII, No. 5, p. 831.

[2] Spurr, S. H., "A Further Note Concerning Shadows on Aerial Photographs," *loc. cit.*, p. 833.