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DEPARTMENT OF TRANSPORT
METEOROLOGICAL BRANCH

THE DIURNAL VARIATION OF WIND IN THE LOWEST 5000 FEET

BY
DAVID SEALE

U.D.C. 551.557.31

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ABSTRACT

The variation of wind with height up to 5000 ft above terrain for morning and afternoon observations is discussed. The wind profiles of five days were averaged and compared to the wind at 5000 ft. The depth of the layer of frictional influence was found to be about 2000 ft in the morning and 3000 ft in the afternoon. A pronounced maximum in the ratio of morning to afternoon wind speeds was noted at about 1000 ft.

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1. INTRODUCTION

Wind variations with respect to height and time of day in the lowest few thousand feet have often been observed and have been partially explained. Ekman (4) was the first to provide a valid theoretical explanation. However, his theory neither explains the pronounced maximum in the wind speed occasionally observed at the top of a nocturnal inversion nor the observed variation of wind (Anonymous (1)) at levels above what is normally considered the top of the friction layer. Blackadar (2) has proposed a theory for explaining wind variations above the top of the nocturnal inversion.

Attempts have been made (e.g.), Frost (5)) to express the momentum diffusivity as proportional to a power of the height, but this parameter was found to vary widely under different circumstances. Frost also attempted to account for the diurnal variation in stability. His theory predicts that, with an increase in lapse rate, there will be an accompanying decrease in the geostrophic departure in the lowest levels.

The variation of wind with height in the lowest 5000 ft and during cases of marked diurnal temperature rise is studied here.

2. EXPERIMENTAL AND ANALYTICAL PROCEDURE

Selection of Data

The data used in these calculations were obtained by two-theodolite observations taken near Camp Shilo, Manitoba, in October and November of 1963 (Danard (3)). Observations were taken simultaneously at five stations (see Fig. 1), four of which were located approximately in the form of a square, the fifth being in the center, with the length of the semi-diagonal being about fifteen miles. Winds were computed at 500-ft intervals above terrain.

The observations of five days were chosen on the basis of marked morning to afternoon heating (averaging 18°F and ranging from 10° to

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* This study was undertaken while the author, an undergraduate student of the University of Laval, was employed by the Meteorological Branch as a Summer Student Assistant.

24°) and the condition that the maximum difference in direction between the wind at any height below 5000 ft and the wind at 5000 ft not exceed 100°. This latter criterion excluded cases of marked thermal advection. All the morning observations were taken between 0800 and 1000 LST and those of the afternoon between 1100 and 1600 LST. To reduce the effects of observational error, the winds over the five stations for each observation time, were averaged vectorially thus giving ten sets of data involving the mornings and afternoons of the five days.

Comparison with the 5000-ft Wind

With the 5000-ft wind vectors of each day on a common axis, the winds at each height for morning and afternoon were averaged vectorially. The ratio of the wind speed at each height to that at 5000 ft above terrain (Fig. 2) and the angle between the two winds (Fig. 3) was calculated for both morning and afternoon observations. In Fig. 2, the ratio of the wind speed at each height for the morning to that at the same height for the afternoon is given. The averaging technique, besides minimizing the effects of vertical variations of the horizontal pressure gradient by considering several days, attaches little importance to light surface winds, whose directions are too much dependent on small scale topography to be of much significance in the scale of motion considered here.

3. DISCUSSION

The results of these computations must be carefully interpreted because of the small amount of data used. Only five days' observations met the specifications and consequently, the effects of observational error and variations of the pressure gradient are by no means eliminated.

The tops of the layers of frictional influence for morning and afternoon are quite easily distinguished from Figs. 2 and 3. At 3000 ft the afternoon curves of both the speed ratio and the angle attain a fairly constant value. The morning curves do not correlate quite as well but the height at which frictional influence becomes small is estimated at 2000 ft.

The curve of the ratio of the speed at a given height in the morning to that at the same height in the afternoon (dotted curve in Fig. 2) has a distinct maximum near 1000 ft. A contributing factor to this may be the persistence of nocturnal wind maxima in the morning observations. It will be noted that, at all heights, the morning wind speed is greater than that of the afternoon. For example, at 5000 ft, the speeds were 21 and 14 kt respectively. The corresponding surface geostrophic wind speeds were 25 and 18 kt. This unusual variation undoubtedly arose merely by chance because of the small sample (five days' observations) used. Therefore, differences between morning and afternoon curves cannot be ascribed entirely to diurnal influences.

For comparison, the Ekman theory curves are given in Figs. 4 and 5. The depths of the friction layers were taken as 2000 ft and 3000 ft corresponding to the morning and afternoon values estimated from Figs. 2 and 3. It will be noted that the Ekman speed ratio curves approach unity much more rapidly than the observational counterparts.

4. ACKNOWLEDGEMENT

The author wishes to express his gratitude to Dr. M. B. Danard who supervised this study and provided many helpful suggestions.

APPROVED,

J. R. H. Noble,
Director.

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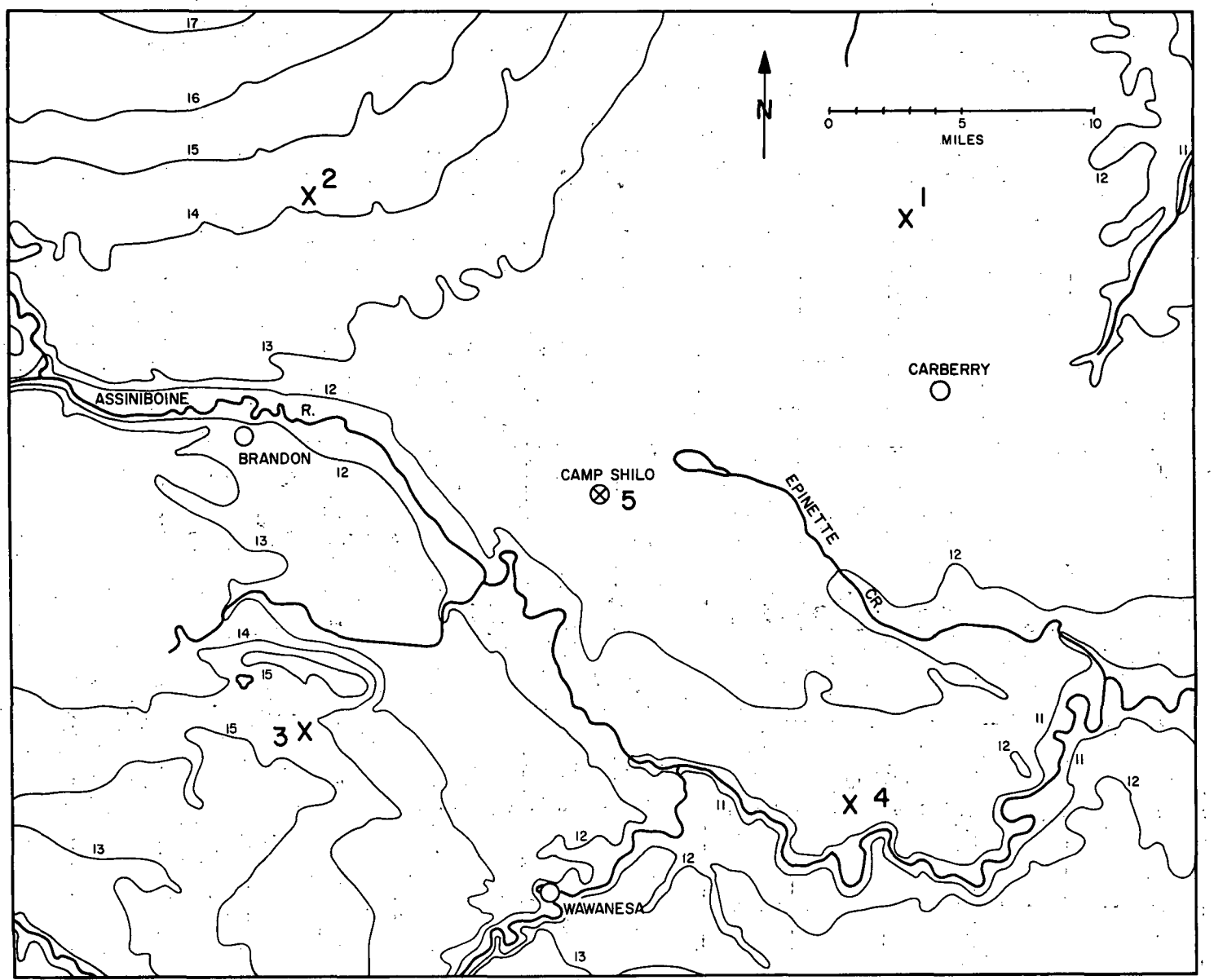

Figure 1
Topographical Map Showing the Five Stations (Numbered Crosses) at Which Observations were Made and the Surrounding Region. Thin Lines are Height Contours in Hundreds of Feet.

CIR-4126
TEC-541
13 Oct. 64.

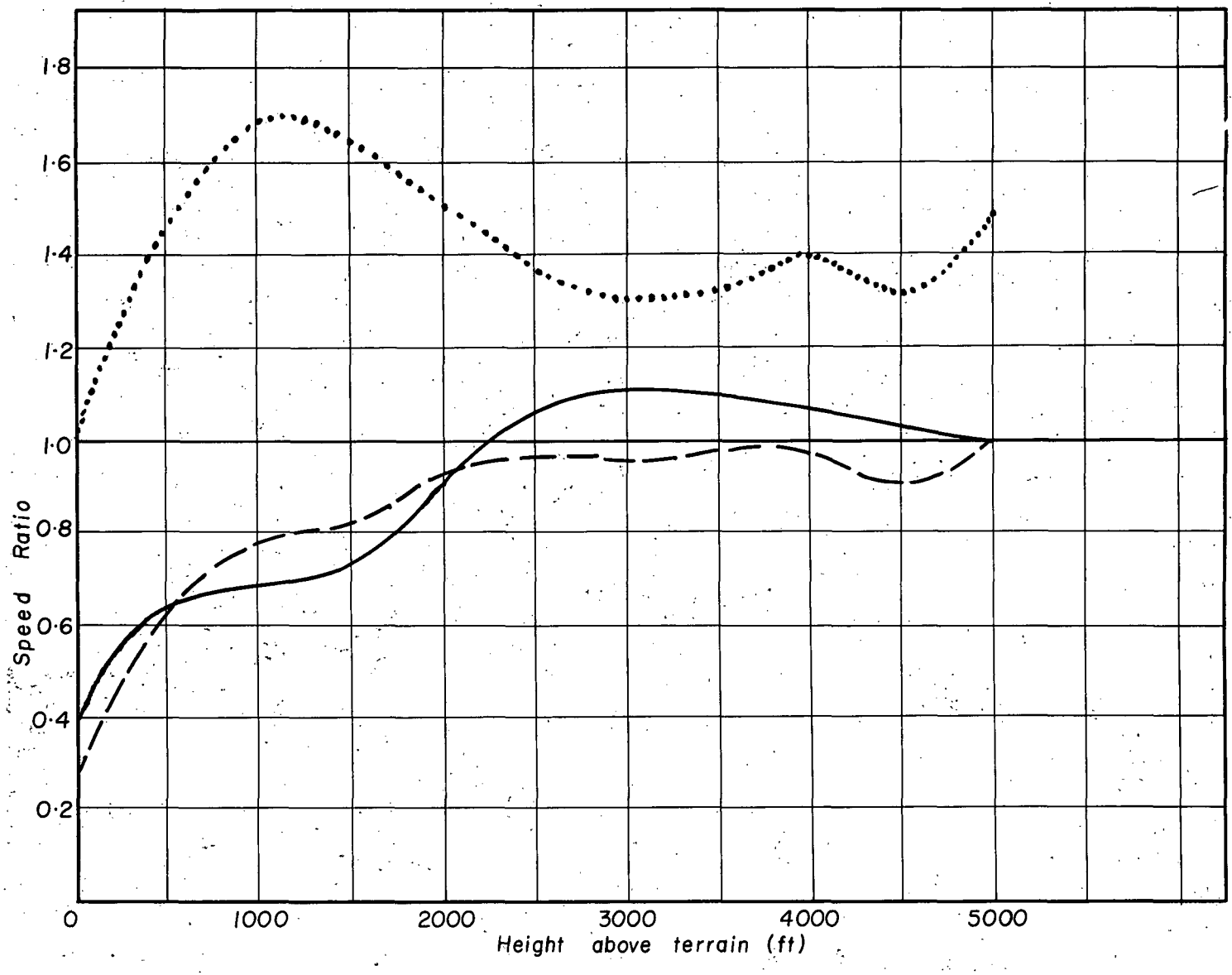

Figure 2
Ratios of the Wind Speed at a Given Height to that at 5000 ft Above Terrain for Morning (Dashed Curve) and Afternoon (Solid Curve) Observations. The Dotted Curve is the Ratio of the Morning Speed at a Given Height to the Afternoon Speed at the Same Height.

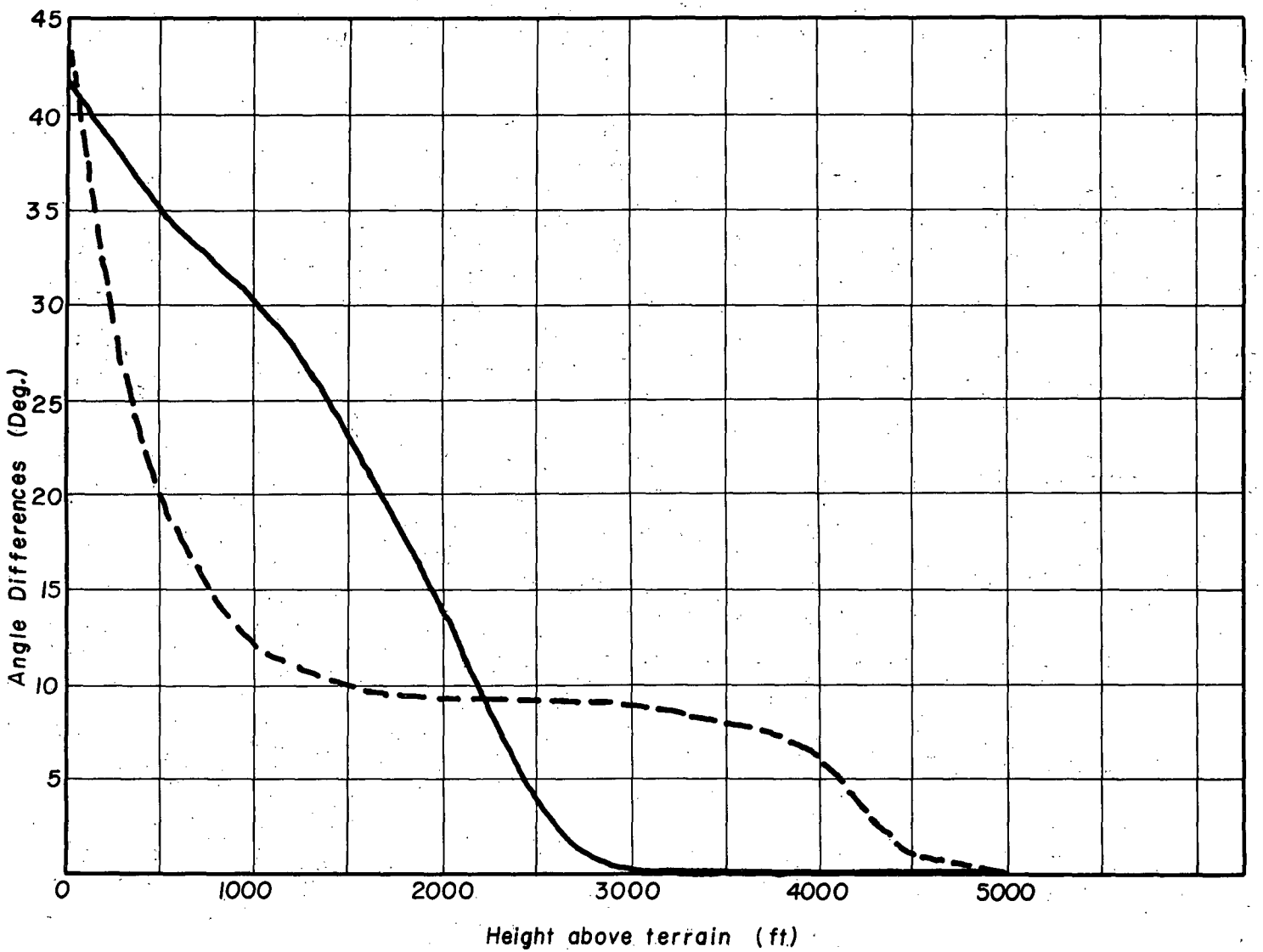

Figure 3
Angle Measured in a Clockwise Direction Between the Wind Vector at a Given Height and That at 5000 ft for Morning (Dashed Curve) and Afternoon (Solid Curve) Observations.

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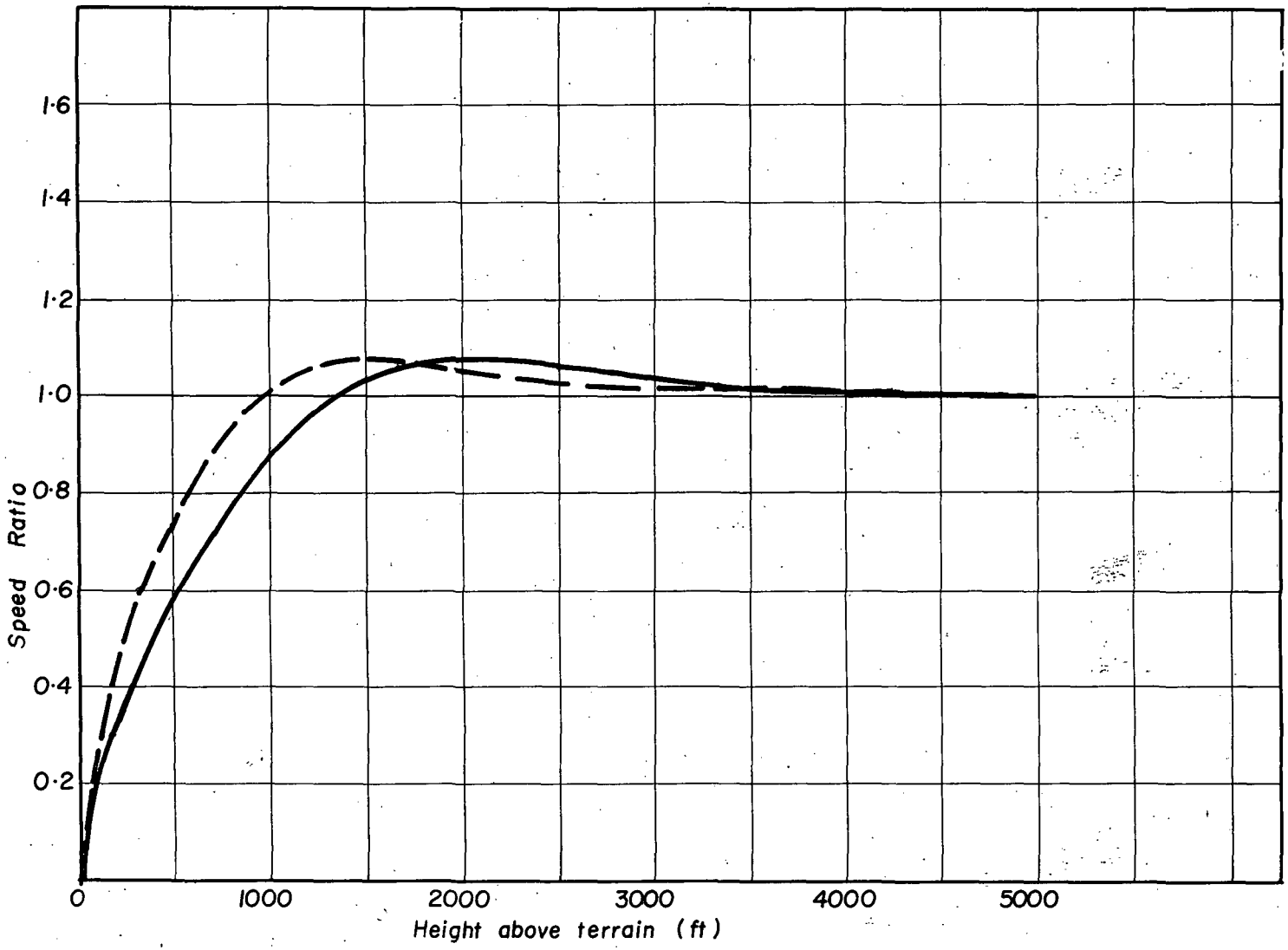

Figure 4
Ratio of the Wind Speed at a Given Height to That at 5000 ft From Ekman's Theory for Depths of the Friction Layers of 2000 ft (Dashed Curve) and 3000 ft (Solid Curve).

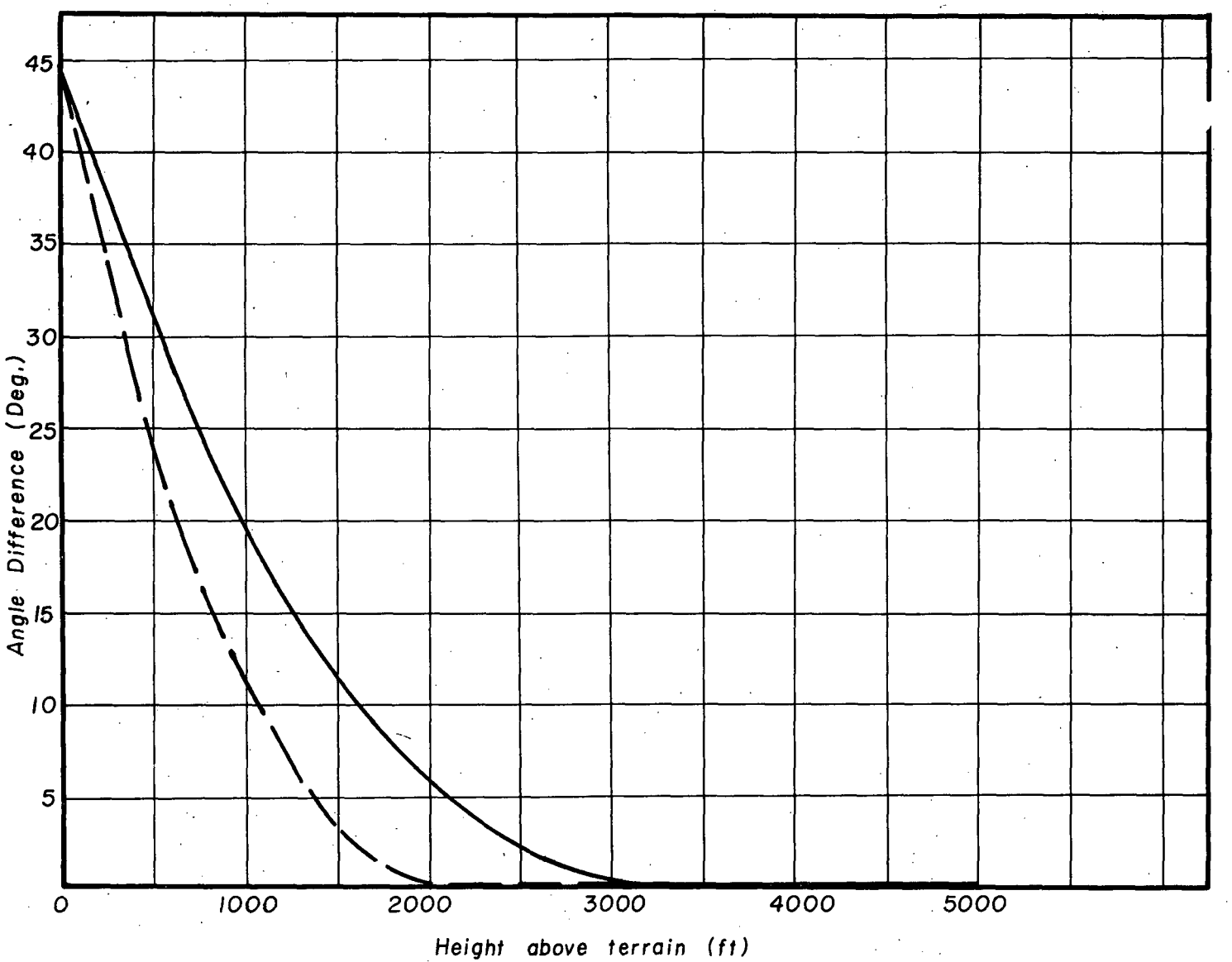

Figure 5
Angle Measured in a Clockwise Direction Between the Wind Vector at a Given Height and That at 5000 ft From Ekman's Theory for Depths of the Friction Layers of 2000 ft (Dashed Curve) and 3000 ft (Solid Curve).

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