Title

Atmospheric optical measurements during high altitude balloon flight, Part III, Sky radiances in the 400 to 500 millimicron region

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ATMOSPHERIC OPTICAL MEASUREMENTS
DURING HIGH ALTITUDE BALOON FLIGHT,
PART III, SKY RADIANCES IN THE 400 to 500 MILLIMICRON REGION

Almerian R. Boileau

July 1961

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Roger Revelle

Roger Revelle, Director
Scripps Institution of Oceanography

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Atmospheric Optical Measurements during High Altitude Balloon Flight, Part III, Sky Radiances in the 400 to 500 Millimicron Region.*

by

Almerian R. Boileau

1. INTRODUCTION AND SUMMARY

Certain optical measurements of the atmosphere were made by the Visibility Laboratory of the University of California, San Diego, 21 June 1958 over central Minnesota. Data were recorded from daybreak to midmorning during the time four balloons carrying optical instrumentation from the Geophysics Research Directorate, Air Force Research Division, Bedford, Massachusetts, were floating at higher altitudes.

Part I of the report[1] presented the recorded optical measurements, with the exception of sky luminance and radiance distributions, as they varied with altitude, time of day, azimuth with respect to the sun, and meteorological conditions.

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* This report is a result of research which has been supported by the Geophysics Research Directorate, Air Force Research Division, Bedford, Massachusetts, and the U.S. Navy Bureau of Ships.

1. Almerian R. Boileau, "Atmospheric Optical Measurements During High Altitude Balloon Flight, Part I," SIO Reference 59-32-(1) Scripps Institution of Oceanography, University of California, La Jolla Campus, December 1959.

Part II of the report[2] presented the sky luminance distribution as it varied with altitude, zenith angle, and azimuth with respect to the sun. This part of the report, Part III, presents in a similar manner the sky radiance distribution as measured by a filter-phototube combination having a spectral sensitivity of from approximately 400 millimicrons (mμ) to approximately 500 mμ.

Part IV of the report will present the sky radiance distribution as measured by a filter-phototube combination having a spectral sensitivity range of from approximately 580 mμ to approximately 700 mμ.

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2. Almerian R. Boileau, "Atmospheric Optical Measurement during High Altitude Balloon Flight, Part II, Sky Luminances," SIO Reference 61-1, Scripps Institution of Oceanography, University of California, San Diego, July 1961.

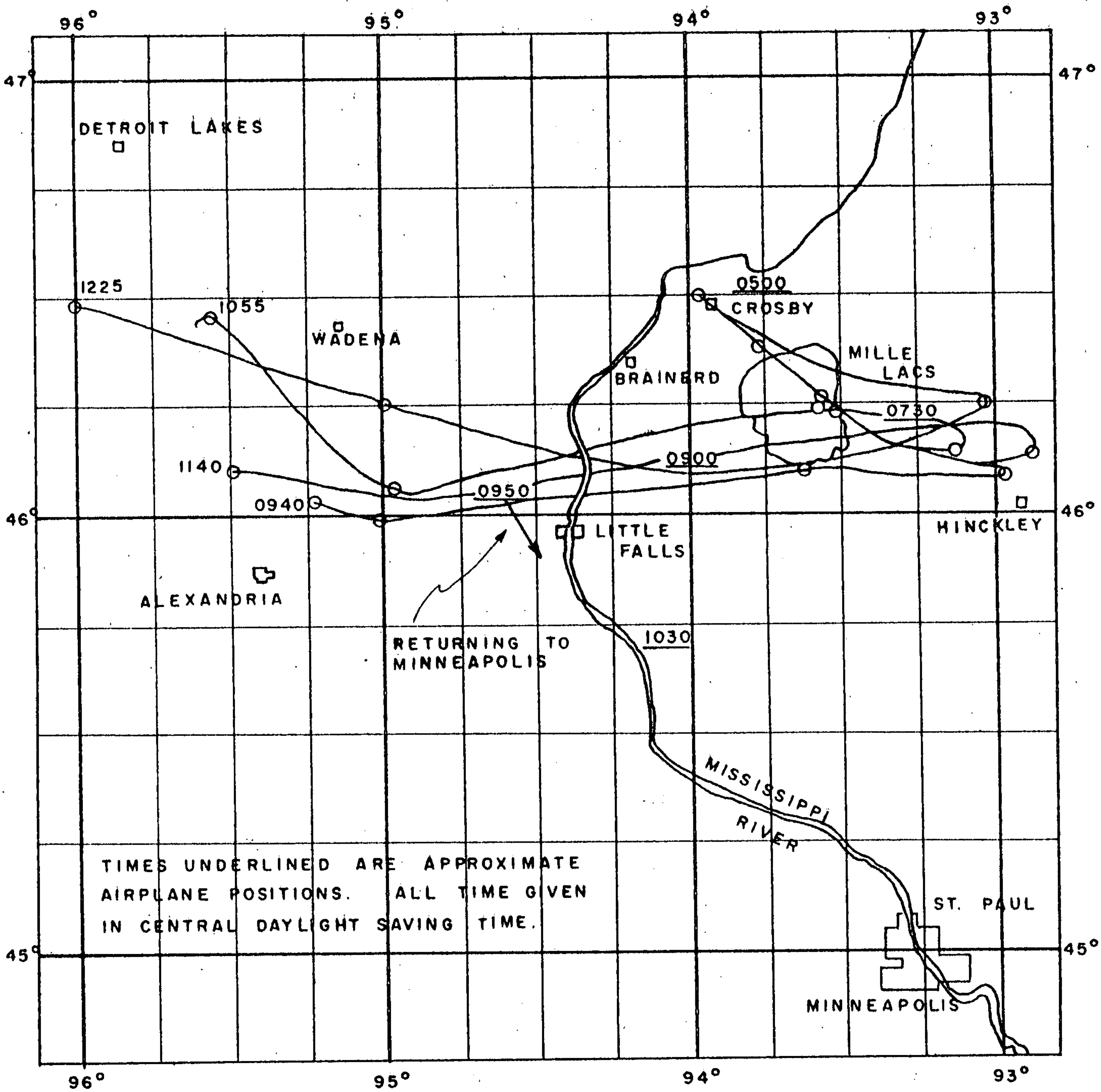
2. PROCEDURE

2.1 Introduction

U.S. Air Force XB-29 No. 4224725 took off for Flight 120 from the Air Force Base at Wold-Chamberlain Airport serving the Minneapolis-St. Paul area at 0415 21 June 1958 and proceeded to Crosby, Minnesota. The airplane carried optical and meteorological instruments from the Visibility Laboratory of the University of California, San Diego. Two of these instruments were sky scanning telephotometers by means of which the sky luminance and radiance distributions were to be measured. When the airplane arrived above Crosby, before sunrise, it was at an altitude of 20 000 feet.

2.2 Purpose of Flight

The flight was being made in the vicinity of Crosby to permit atmospheric optical measurements to be made by air borne Visibility Laboratory equipments at the same time that similar measurements were being made by balloon borne equipment. The balloons, four in number, were to be launched by Winzen Research, Inc., under the direction of Dr. V.J. Stakutis of the Thermal Radiation Laboratory, Geophysics Research Directorate, Air Force Research Division, Bedford, Massachusetts. The launchings proceeded on schedule, the balloons being launched, as observed from the XB-29, at 0500, 0521, 0536, and 0551. These times and all times given subsequently in this report are Central Daylight Saving Time.



Balloon tracks are shown in solid lines. The time of release of each instrumented package from the balloon which carried it is indicated by the time at the end of each track. The underlined times are approximate airplane positions.

FIGURE 1
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA

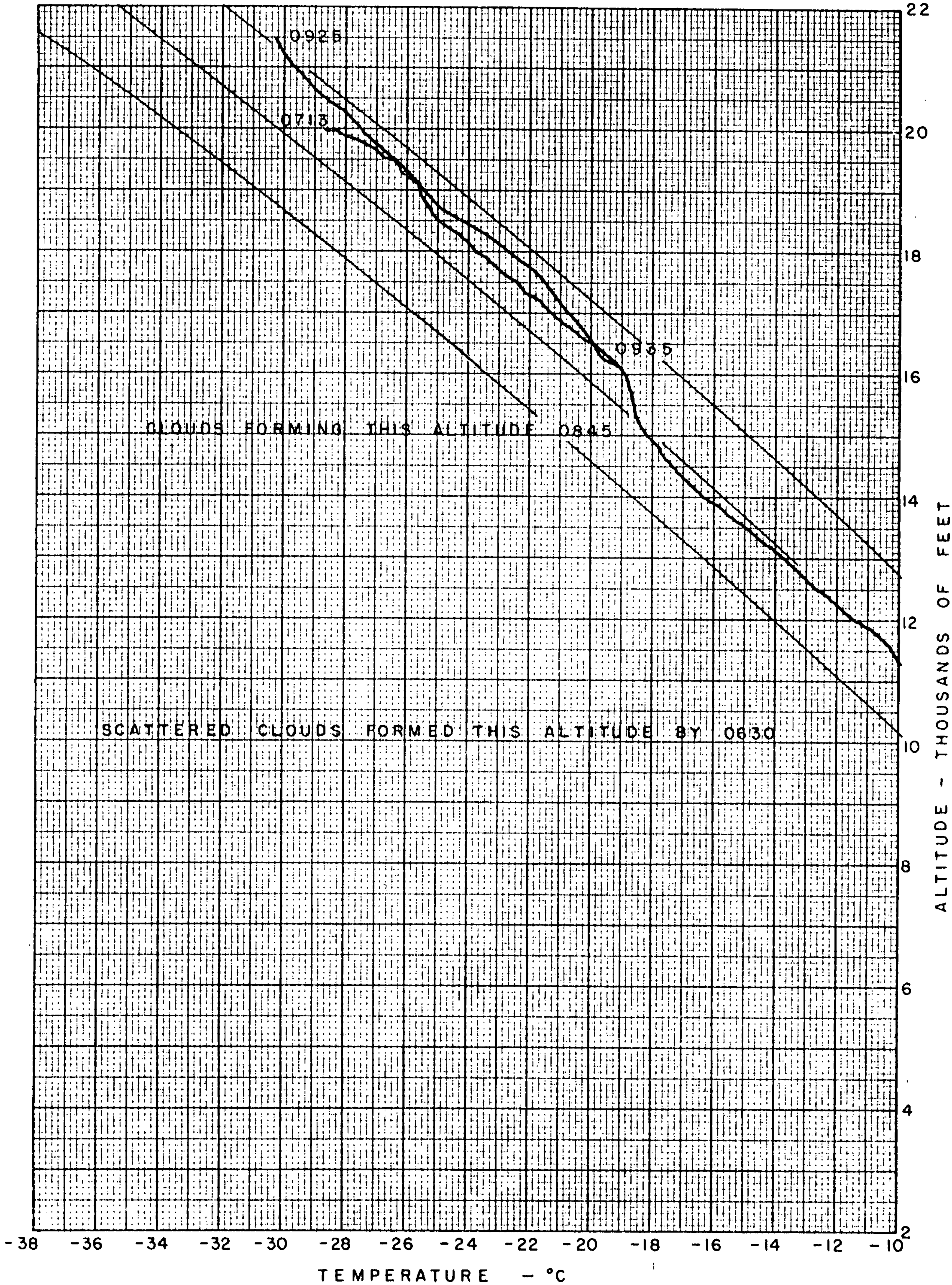
2.3 Data Gathering

The data-gathering operation was started as soon as there was enough light to cause all of the optical measuring instruments to respond. The XB-29 remained at altitude and in the general vicinity of the balloons until the start of the data-gathering runs at which time it became necessary to fly the airplane on prescribed courses and at different altitudes. At the conclusion of a data-gathering run the pilot returned to the vicinity of the balloons before starting another run. The balloons first drifted southeast until they were over the south shore of Mille Lacs Lake, then westward. The balloon tracks are shown in Fig. 1. The approximate positions of the XB-29 are also shown in Fig. 1 by the underlined times.

At the start of the data-gathering runs the lower scanning telephotometer became inoperative with the result that no lower sky distributions were recorded.

2.3.1 Recording Schedule. The upper sky luminance and radiance distribution data were recorded as follows:

Central Daylight Saving Time	Altitude
0635-0655	21 000 feet
0738-0751	11 000 feet
0813-0819	2 000 feet
0907-0915	22 000 feet
0938-0940	16 500 feet
0942-0945	17 200 feet
1033-1037	2 000 feet en route Minneapolis


0925
0713
0835
CLOUDS FORMING THIS ALTITUDE 0845
SCATTERED CLOUDS FORMED THIS ALTITUDE BY 0630
ALTITUDE - THOUSANDS OF FEET
22
20
18
16
14
12
10
8
6
4
2
-38 -36 -34 -32 -30 -28 -26 -24 -22 -20 -18 -16 -14 -12 -10
TEMPERATURE - °C

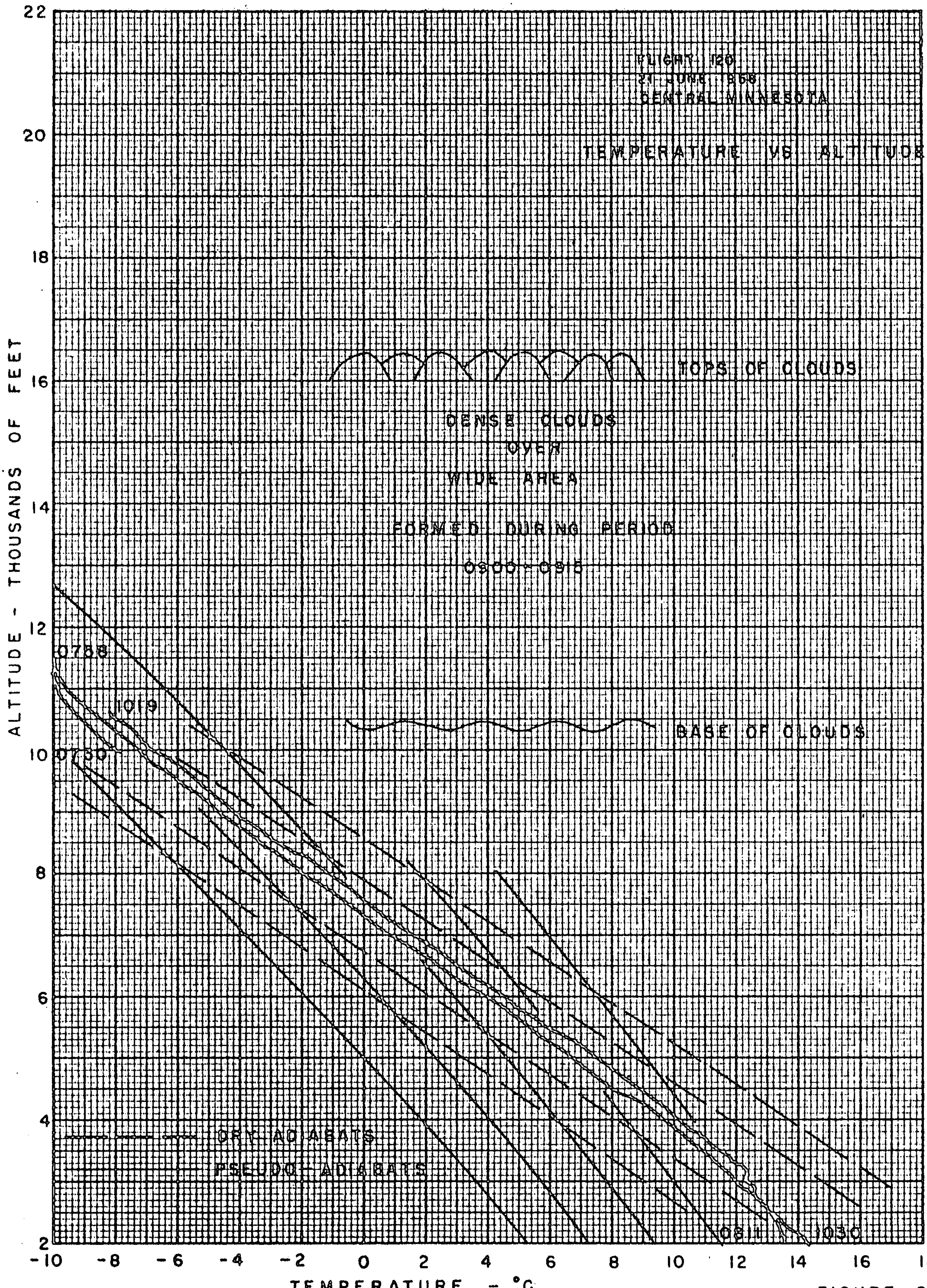
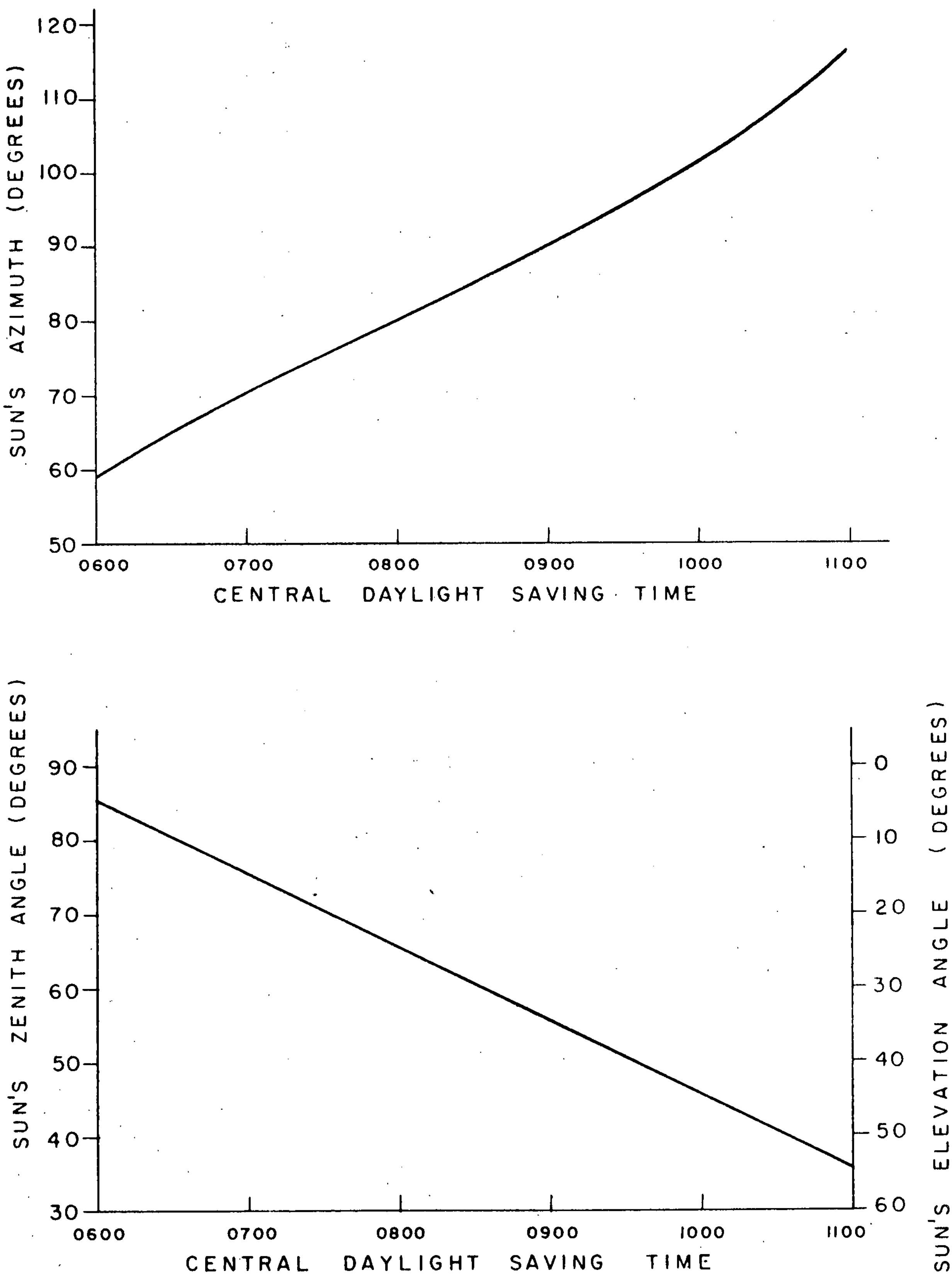

FLIGHT 120
21 JUNE 1958
CENTRAL MINNESOTA
TEMPERATURE VS ALTITUDE
TOPS OF CLOUDS
DENSE CLOUDS
OVER
WIDE AREA
FORMED DURING PERIOD
0900-0915
BASE OF CLOUDS
0758
1019
0730
0811
1030
DRY ADIABATS
PSEUDO-ADIABATS
ALTITUDE - THOUSANDS OF FEET
TEMPERATURE - °C
22
20
18
16
14
12
10
8
6
4
2
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
16
18

FIGURE 2

2.3.2 Weather. Data were recorded during the time that the airplane was flown at the several selected altitudes listed in the Recording Schedule and also during the time that the airplane was losing altitude at approximately 1000 feet per minute. Temperature of the ambient air was recorded during these descending runs as registered by an ML-471/AMQ-8 indicating resistance thermometers. A plot of temperature as it varied with altitude and time is shown in Fig. 2 preceding this page. In this Figure there are observations of cloud conditions noted at the time indicated. Lines representing dry adiabats and pseudo-adiabats are plotted in this figure near the temperature profiles.

Photographs (Kodachrome transparencies) from which color prints were made show the scattered clouds which were present at 0700, 0753, and 0945. The color prints are presented in Part I of this report.

2.3.3 Position of Sun. The zenith angle and azimuth of the sun computed for 46° North Latitude and 94° West Longitude are shown in Fig. 3. These coordinates were selected because the balloons ranged from approximately 93° to 95° West Longitude in the vicinity of 46° North Latitude. The angles are plotted for the time period from 0600 to 1100 Central Daylight Saving Time. The ordinates of the lower graph are shown as zenith angle values on the left side of the graph and as elevation angle values on the right side of the graph, these angles being complementary.



AZIMUTH AND ZENITH ANGLE OF SUN DURING FLIGHT 120, COMPUTED FOR POSITION 46° N. LAT., 94° W. LONG.

FIGURE 3
FLIGHT NO. 120
JUNE 21, 1958
CENTRAL MINNESOTA

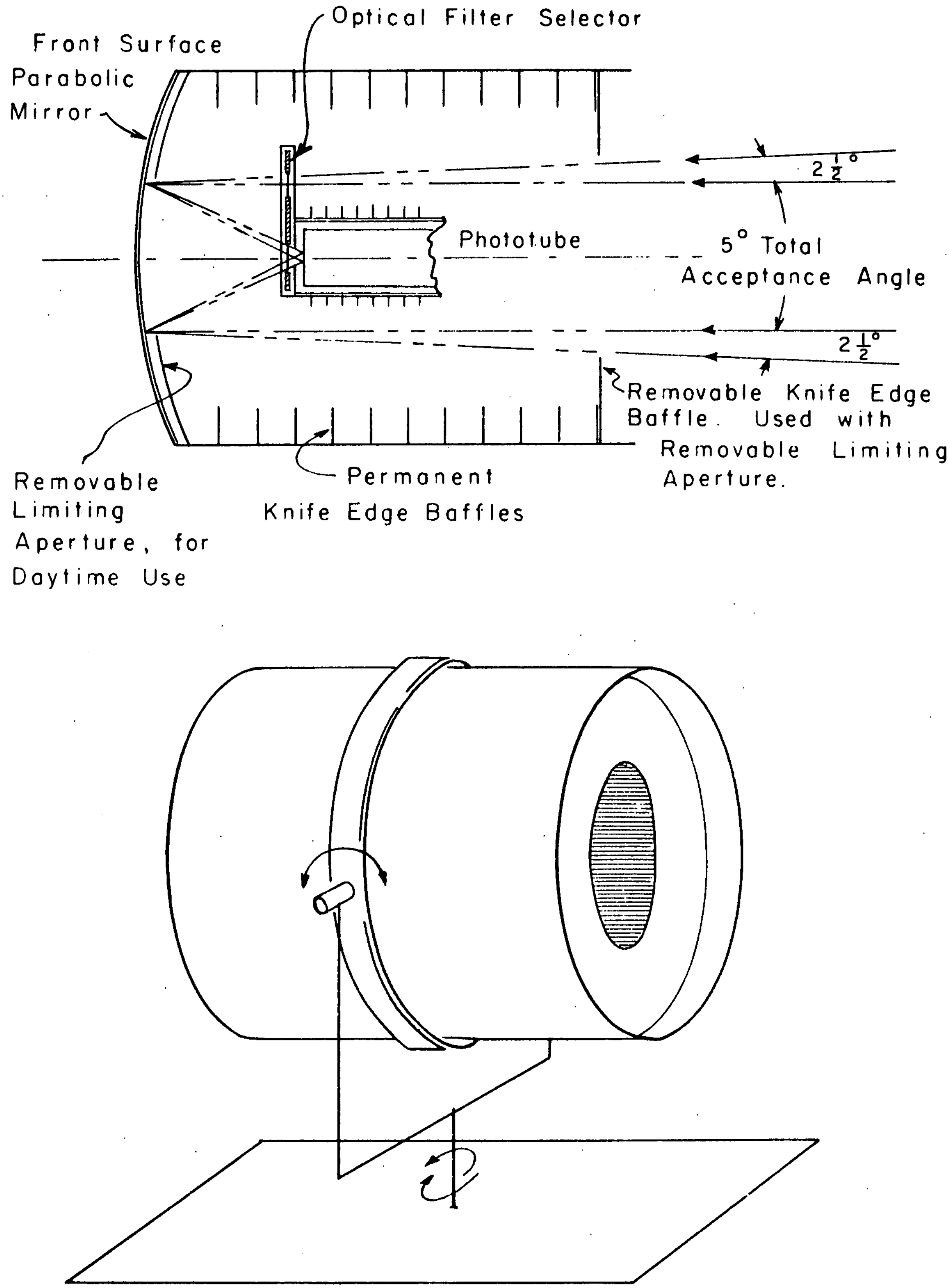
3. INSTRUMENTATION

3.1 Sky Scanning Telephotometers

3.1.1 Location. The two sky scanning telephotometers were carried by the XB-29, the upper one in the forward upper gun turret position and the lower one in a retracting mount in the rearmost lower gun turret position. The telephotometers were operated from the control position in the pressurized after compartment of the XB-29. Once started, both telephotometers continued their scanning operation until completion, at which time they automatically stopped and remained stopped until restarted.

3.1.2 Schematic. The sky scanning telephotometers are shown schematically in Fig. 4. The optical unit, shown at the top of the Figure, consists of a cylindrical shell with a 13" parabolic front surface mirror mounted on one end of the shell and an end-on multiplier phototube mounted with its light-sensitive surface at the focus of the mirror. A field stop in front of the light-sensitive surface limits the incoming rays to those contained in a 5° circular cone.

3.1.3 Light Level Range. The optical units of the sky scanning telephotometers were designed for use in both high and low light levels. For high light level or day time use the sensitivity of the photometer is reduced by the mirror limiting aperture. The flux incident on the phototube is further reduced by the use of neutral density filters. Internal scattering is kept to a minimum by the removal front knife-edge baffle and the permanent knife-edge throughout the inside lengths of the cylindrical shell and on the outside of the phototube housing.



SKY SCANNING TELEPHOTOMETER

FIG. 4

3.1.4 Filters. In front of the field stop there is an optical filter selector mechanism by which by being operable from the control position permits any one of three optical filters to be interposed in the flux path. The relative spectral sensitivities of the three filter and phototube combinations are shown in Fig. 5.

The data presented in this part of the report are the data as seen by the 400-500 mμ filter - phototube combinations.

3.1.5 Scanning patterns. The scanning patterns of the two sky scanning telephotometers are such that the optical units scan in elevation with a change of azimuth occurring in the case of the upper scanner between elevation scans and in the case of the lower scanner simultaneously with the elevation scans.

The upper sky scanning telephotometer starts from 2 1/2° below the horizontal, scans upward through the zenith and continues downward to 2 1/2° below the horizontal 180° from the starting azimuth. At the conclusion of an elevation scan the scanner shifts 10° in azimuth and then starts a return elevation scan. It makes eighteen elevation scans, thereby completing the upper sky in 90 seconds. At the end of the eighteenth elevation scan the azimuth drive reverses and the scanner scans the sky, in the reverse sequence, in 90 seconds. A change of optical filters during the time of reversal permits two complete upper sky measurements to be completed in three minutes.

As stated above, the scanning pattern of the lower sky scanning telephotometer differs from the scanning pattern of the upper sky scanning telephotometer but because the lower scanning telephotometer was inoperative and no data was recorded, the scanning pattern of this instrument will not be discussed.

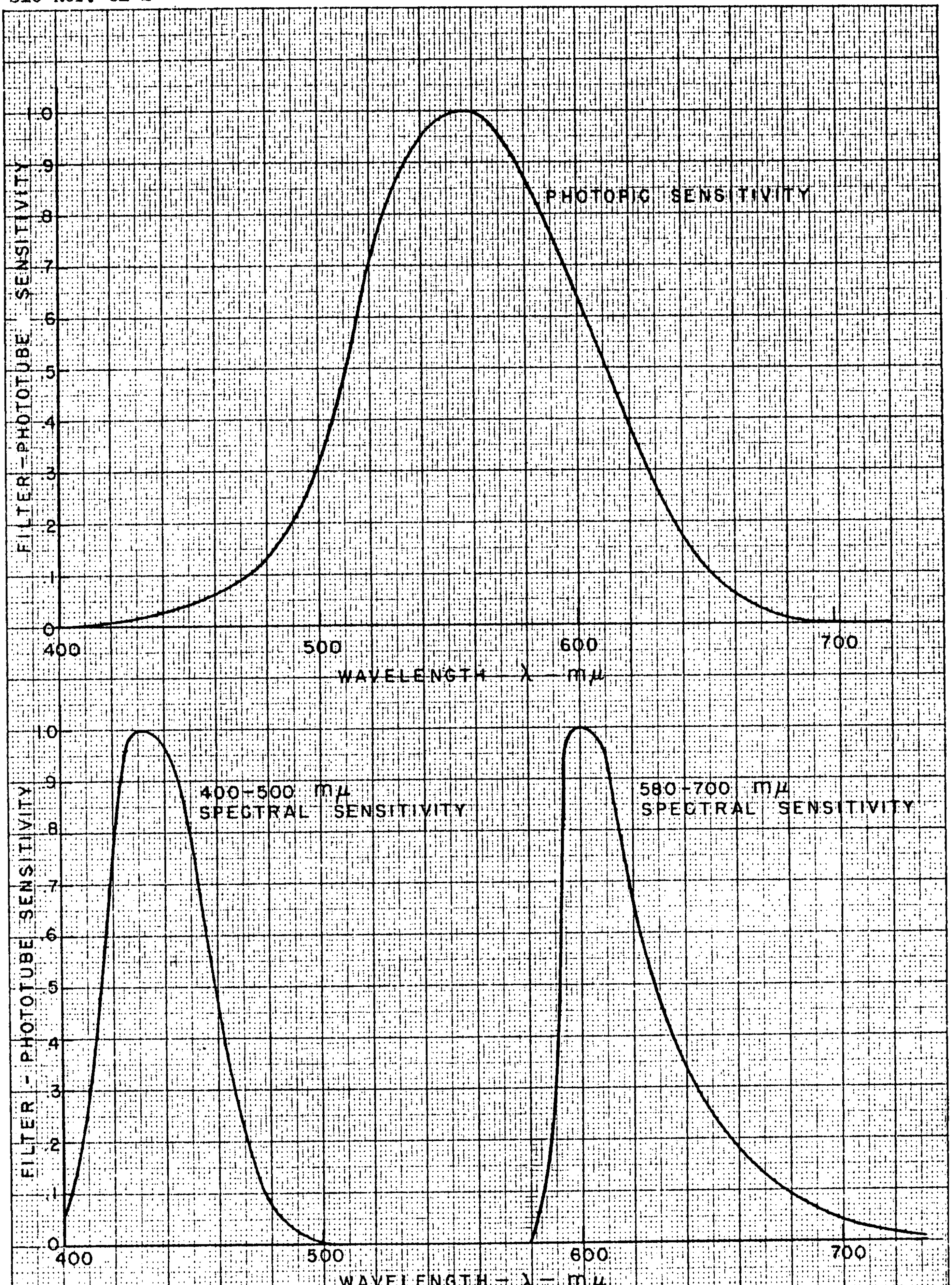

FILTER-PHOTOTUBE SENSITIVITY
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
PHOTOPIC SENSITIVITY
400
500
600
700
WAVELENGTH — λ — mμ
FILTER - PHOTOTUBE SENSITIVITY
400-500 mμ
SPECTRAL SENSITIVITY
580-700 mμ
SPECTRAL SENSITIVITY
WAVELENGTH — λ — mμ

FIG. 5

4. DATA TREATMENT

4.1 Data Recording

The sky luminance and radiance distribution values were recorded during Flight 120 on Minneapolis-Honeywell "Brown ELETRONIK" Recorder strip chart. The data were recorded as a continuous analog trace representing the value of sky luminance or radiance depending on which optical filter was in the flux path as the scanner operated through its cycle. The angular positions of the scanner in elevation, that is, its zenith angle position, were indicated by a marking stylus which was activated by a microswitch in contact with a protractor type cam. The data recording stylus and the zenith angle marking stylus recorded continuously and simultaneously so that zenith angle indications and corresponding sky luminance or radiance data were synchronized. Because the scanner always started from and stopped in the same azimuthal position, the azimuth of each elevation scan was easily determined by counting the number of elevation scans.

4.2 Data Reduction

The strip chart data were transferred to IBM computer cards by the use of computer peripheral equipment. Through the operation of a Burroughs No. 220 computer at the U.S. Navy Electronics Laboratory, San Diego, California, which was programmed to correct for the nonlinearities of the airborne electronic recording equipment the data points were converted into tables of equivalent luminance and radiance values. These values were plotted against azimuth values on semi-logarithmic paper, the azimuth being with reference to geographical north. The azimuthal scale marked off along the linear coordinates of the graph paper was then shifted to cause the azimuthal scale to indicate azimuth with reference to the sun. The last step was to re-plot the luminance and radiance values for selected zenith angles against altitude on semi-logarithmic graph paper. Continuous curves were then drawn through these points.

5. PRESENTATION OF DATA

5.1 Notation

The notation in this report follows the notation for the various radiometric and photometric optical quantities discussed in detail elsewhere.[3] The general symbol for radiance is N; the symbol for its photometric counterpart, luminance, is B. The particular symbol for the radiance or luminance of a path of sight when neither the path length is specified nor the source of radiance identified is $N(z,\theta,\phi)$ or $B(z,\theta,\phi)$, the parenthetic symbols indicating that the photometer is at altitude z and that the path of sight is as specified by the zenith angle θ and the azimuth ϕ. The zenith angle varies from 0° for looking vertically upward to 180° for looking vertically downward. The azimuth in this report is with reference to the sun.

5.2 Organization of Data

The data are presented as a series of graphs which have altitude as the ordinate values and sky luminance, or radiance, as abscissa values. Each curve represents the sky luminance, or radiance, value for a specific azimuth and a specific zenith angle. The curves for one specific azimuth

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3. S.Q. Duntley, A.R. Boileau, and R.W. Preisendorfer, "Image Transmission by the Troposphere I," J. Opt. Soc. Am. 47, 499-506 (1957)

are grouped together in one Figure, each Figure normally consisting of two sheets. The Figures are arranged in order of increasing azimuth of 20° increments starting with 0° and ending with 340°. This group of Figures is one "set" of Figures. There are two sets of Figures, viz., the set composed of Figures 7-24 covering the data starting at 21 000 feet at 0647 and ending with data recorded at 2000 feet at 0813 and Figures 25-42 covering data starting at 22 00 feet at 0907 and ending at 2000 feet at 1033.

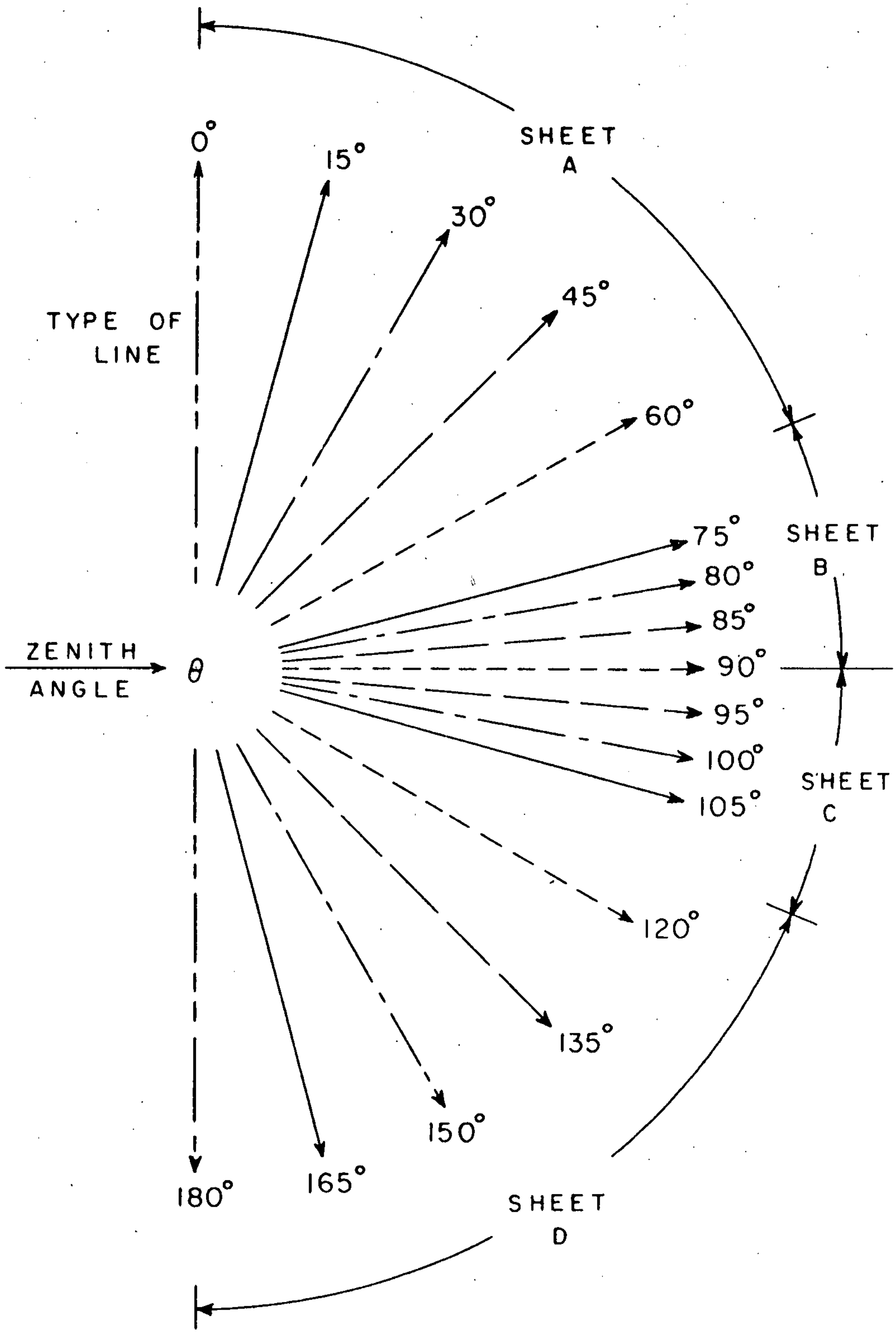
Each Figure, with several exceptions, consist of two sheets as follows:

Sheet a - zenith angles of 0°, 15°, 30°, 45°, and 60°.

Sheet b - zenith angles of 75°, 80°, 85°, and 90°.

To differentiate between the different graphs on each sheet, five distinctive types of lines are used. Fig. 6, immediately following this page, identifies the sheet, the zenith angles, and the distinctive line used for each zenith angle. (The four sheets indicated in this figure apply to both upper and lower sky presentations, however, in this report only two sheets, sheets a and b, are applicable.)

The exceptions to the above organization of data are for zenith angles close to the sun. In case of the first data Figure, i.e., Fig. 7, with azimuth of 0°, the data for zenith angle of 60° are presented on a separate sheet identified as "aa" in which the abscissa scale values have been increased by a factor of ten. This sheet (page 20) bears the warning "NOTE CHANGE OF SCALE." Sheet 7b of the same Figure (page 23) and part of Fig. 25 (page 58) also bear this warning.



LINES USED FOR SKY LUMINANCE AND RADIANCE PLOTS

FIGURE 6

6. INDEX OF GRAPHS

6.1 First Set - Descent from 0652

6.2 Second Set - Descent from 0912

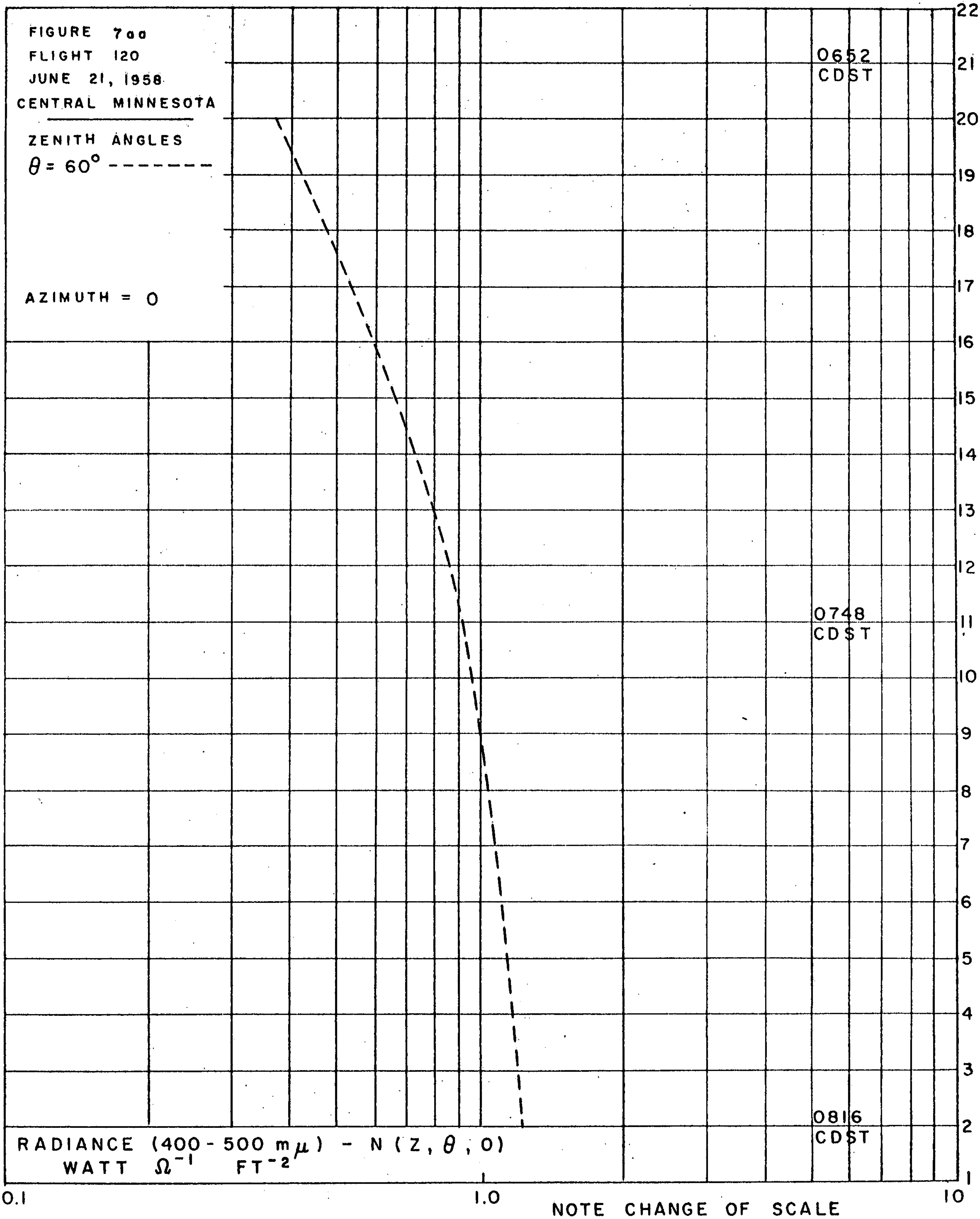


FIGURE 7aa
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 60°
AZIMUTH = 0
0652 CDST
0748 CDST
0816 CDST
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ALTITUDE – THOUSANDS OF FEET
RADIANCE (400 - 500 mμ) - N (Z, θ, 0)
WATT Ω⁻¹ FT⁻²
0.1
1.0
10
NOTE CHANGE OF SCALE

Note that Fig. 7aa bears the notation "NOTE CHANGE OF SCALE."

Usually the spread of luminance values does not exceed two orders of magnitude. In the case of the zero azimuth, i.e., the azimuth of the sun, the spread of luminance values does exceed two orders of magnitude due to the proximity of the sun. In order to keep the abscissa values of the graphs at two orders of magnitude it is necessary, in certain cases, to use a separate graph in which the abscissa values are increased by a factor of ten. The sky luminance in the azimuth of the sun for the zenith angle of 60^{o} is a case in point.

Note that the luminance values in Fig. 7b, page 23, are also increased by a factor of ten and this Figure also has the notation "NOTE CHANGE OF SCALE."

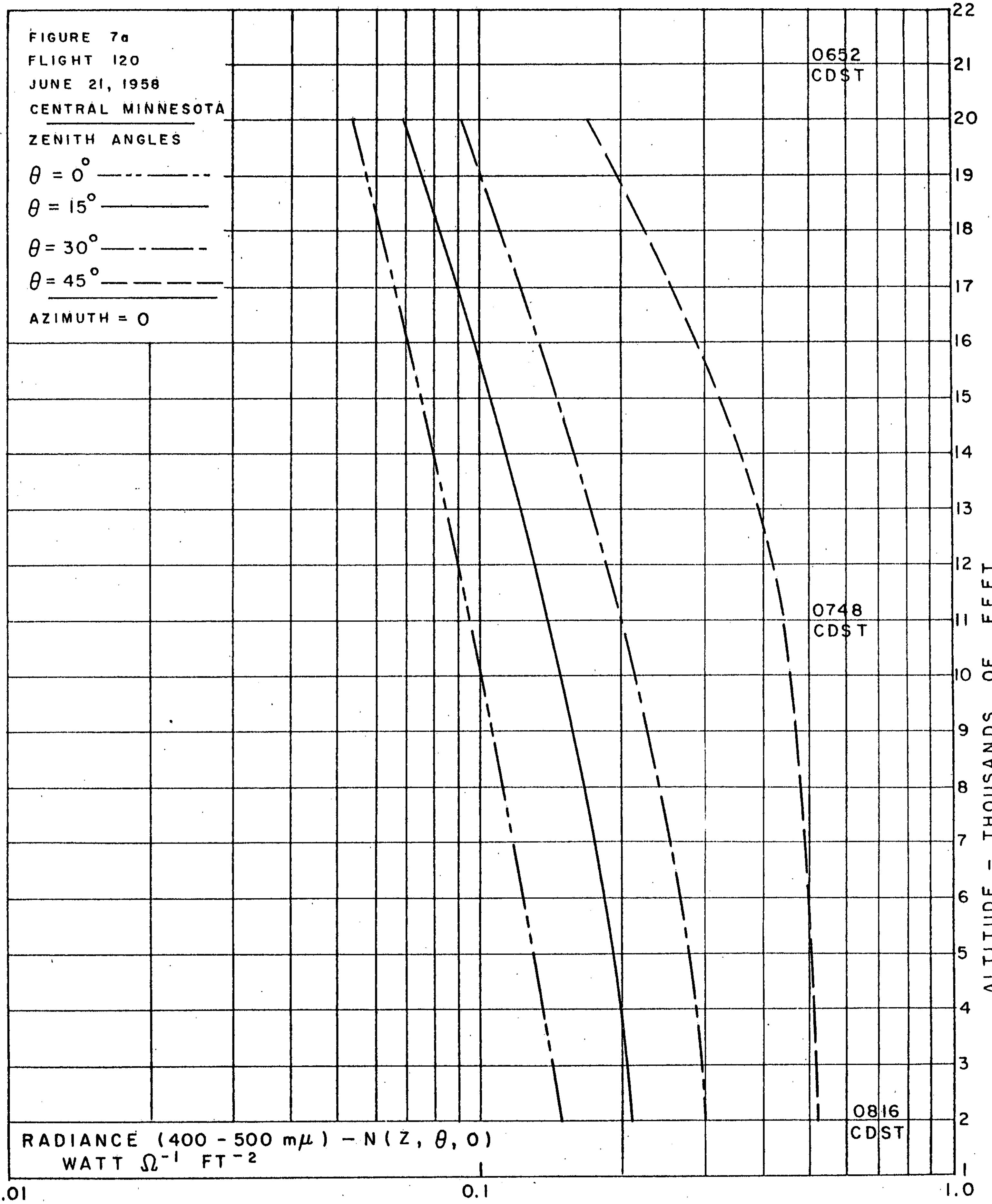


FIGURE 7a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
AZIMUTH = 0
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) - N(Z, θ, 0)
WATT Ω⁻¹ FT⁻²
.01
0.1
1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
ALTITUDE - THOUSANDS OF FEET

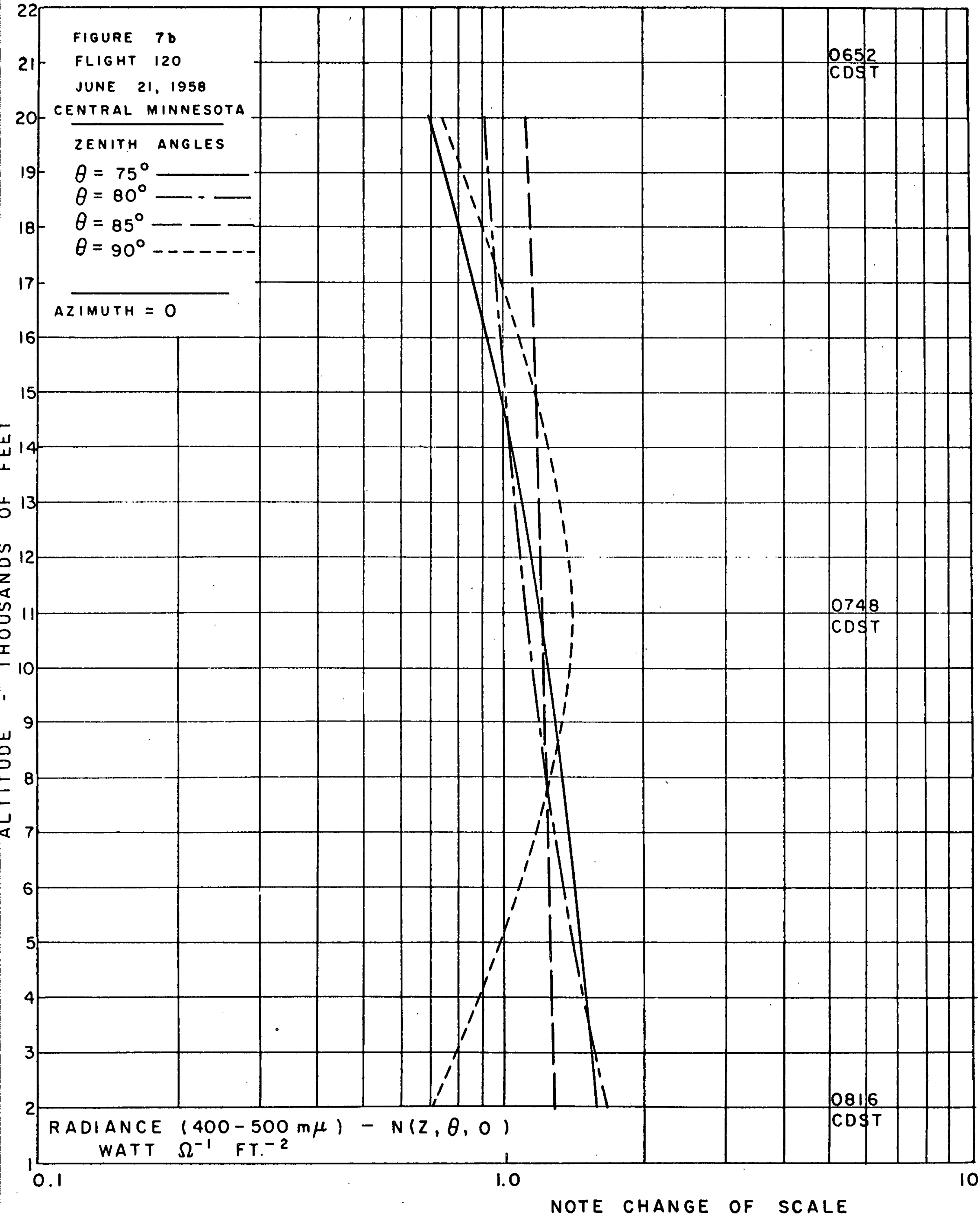


FIGURE 7b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 0
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ, 0) WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
NOTE CHANGE OF SCALE

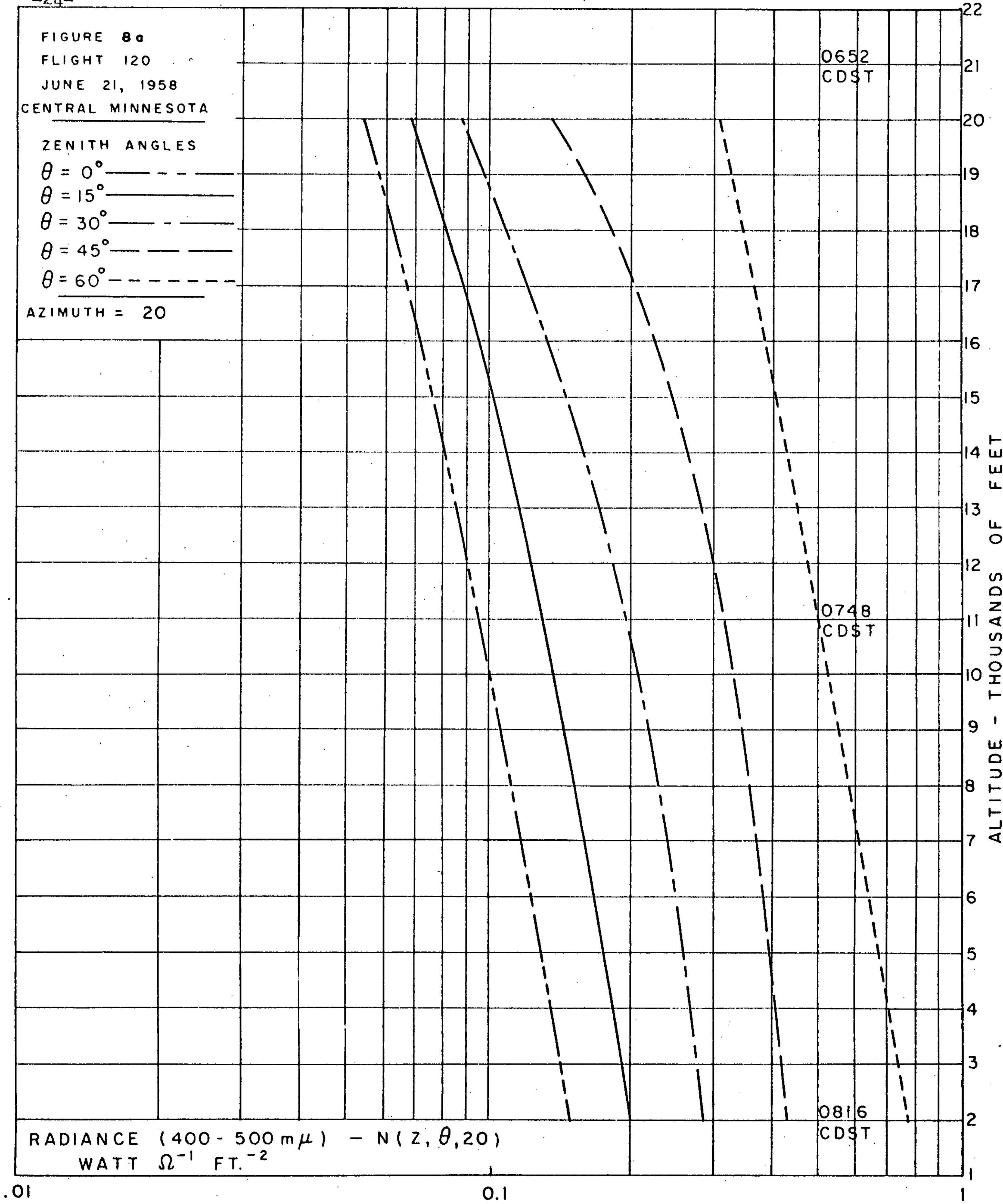


FIGURE 8a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 20
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) – N(Z, θ, 20)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ALTITUDE - THOUSANDS OF FEET

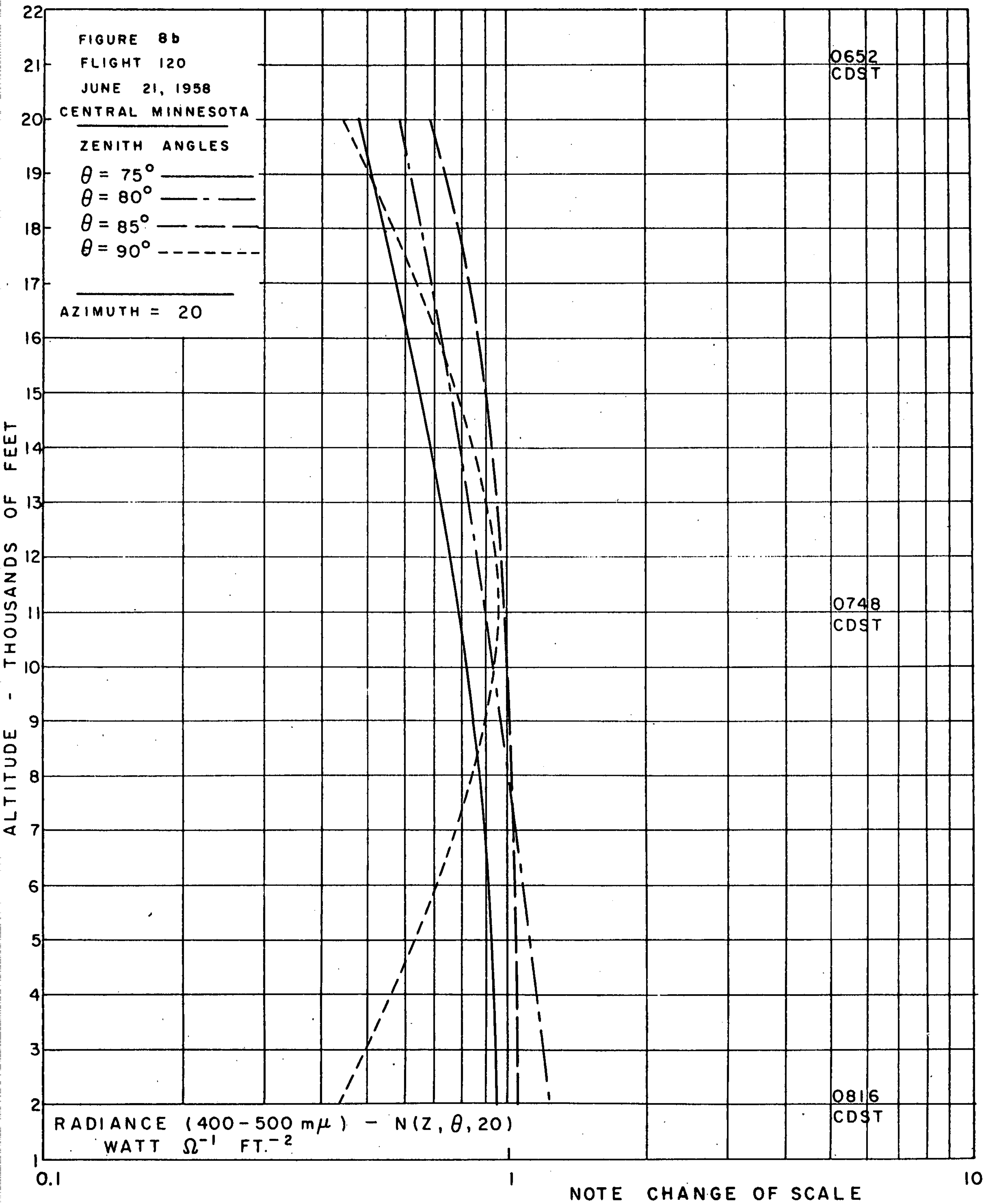


FIGURE 8b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 20
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
RADIANCE (400-500 mμ) - N(Z, θ, 20)
WATT Ω⁻¹ FT.⁻²
0.1
1
10
NOTE CHANGE OF SCALE

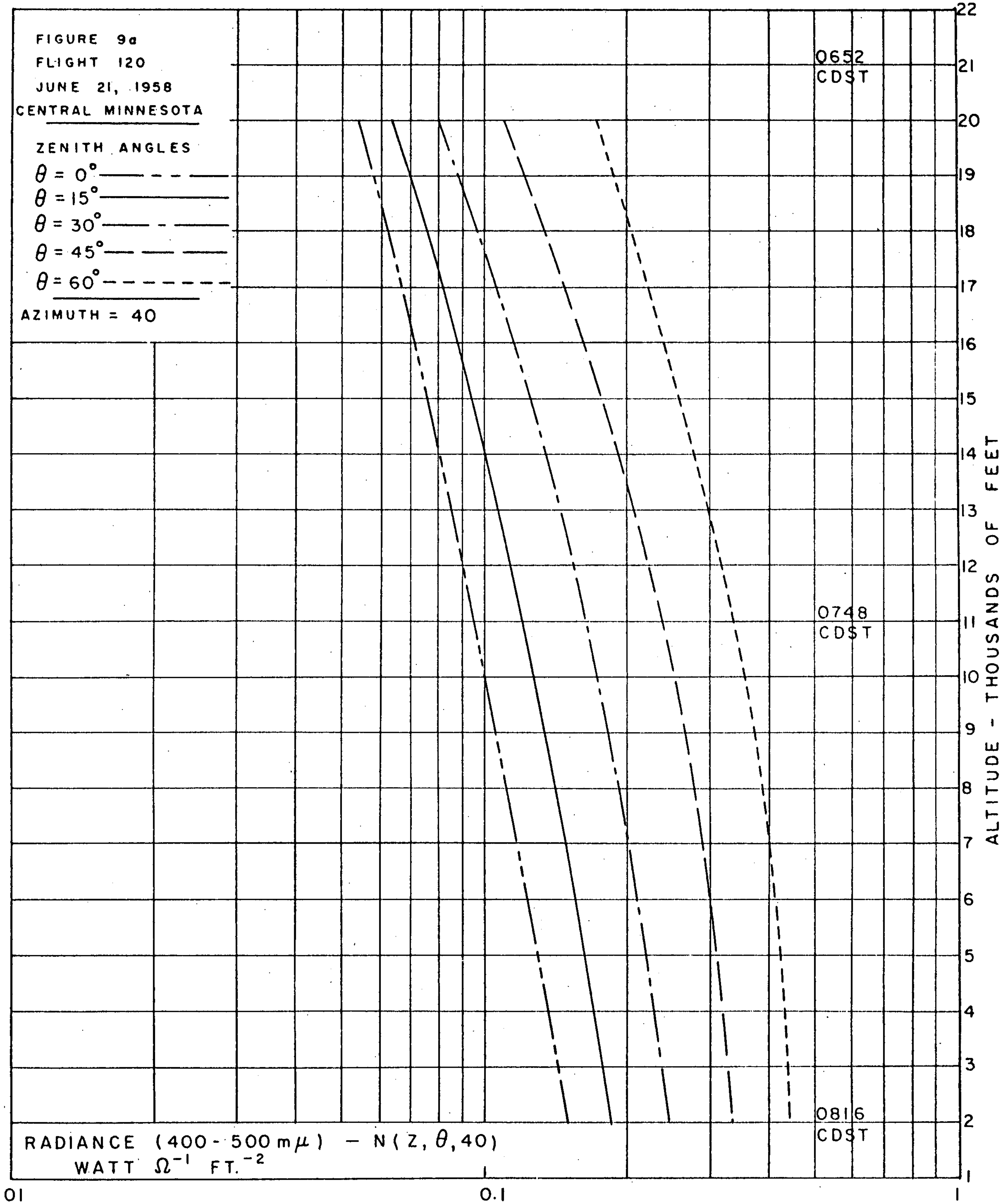


FIGURE 9a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 40
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) — N(Z, θ, 40)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

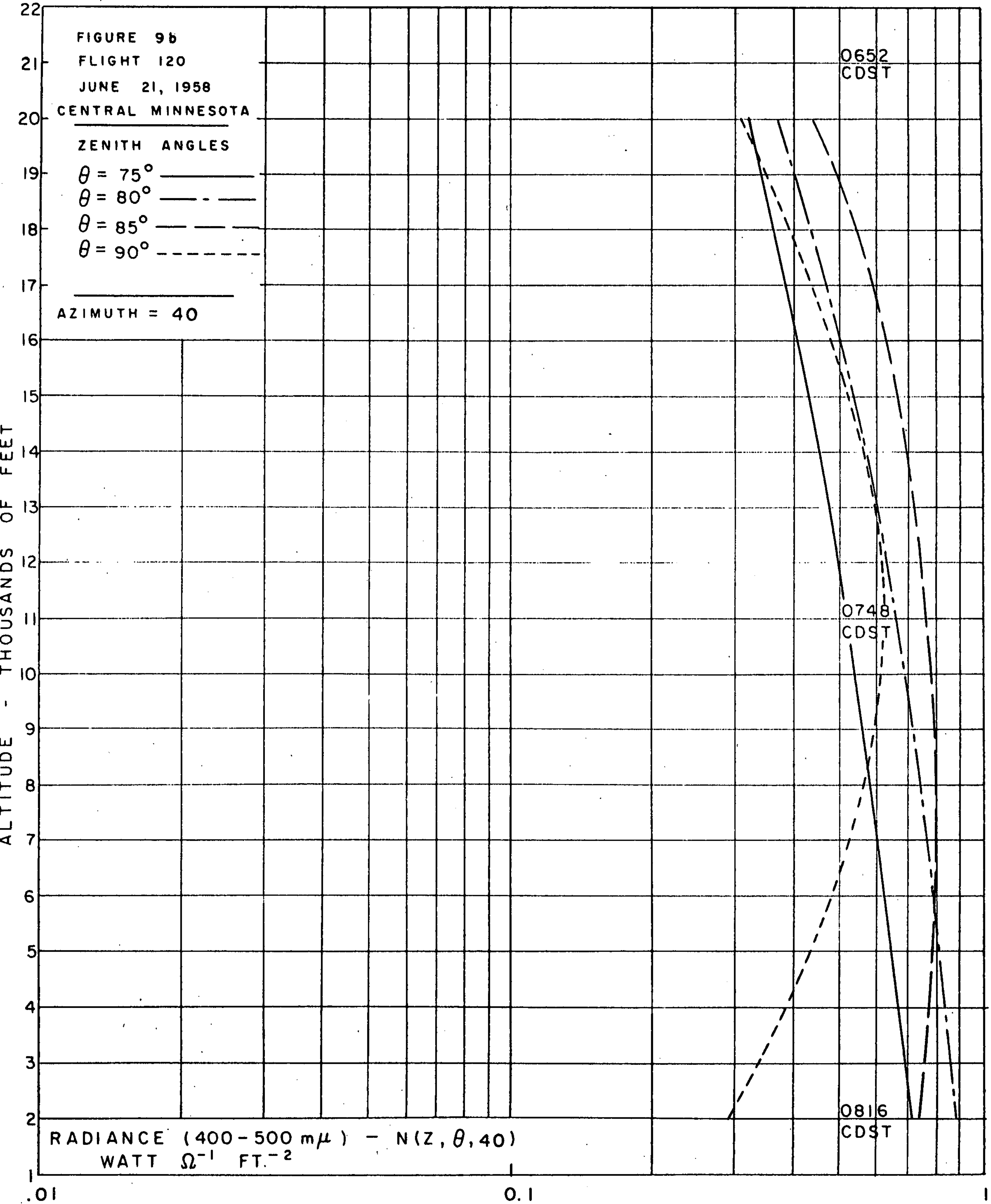


FIGURE 9b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 40
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ, 40)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1

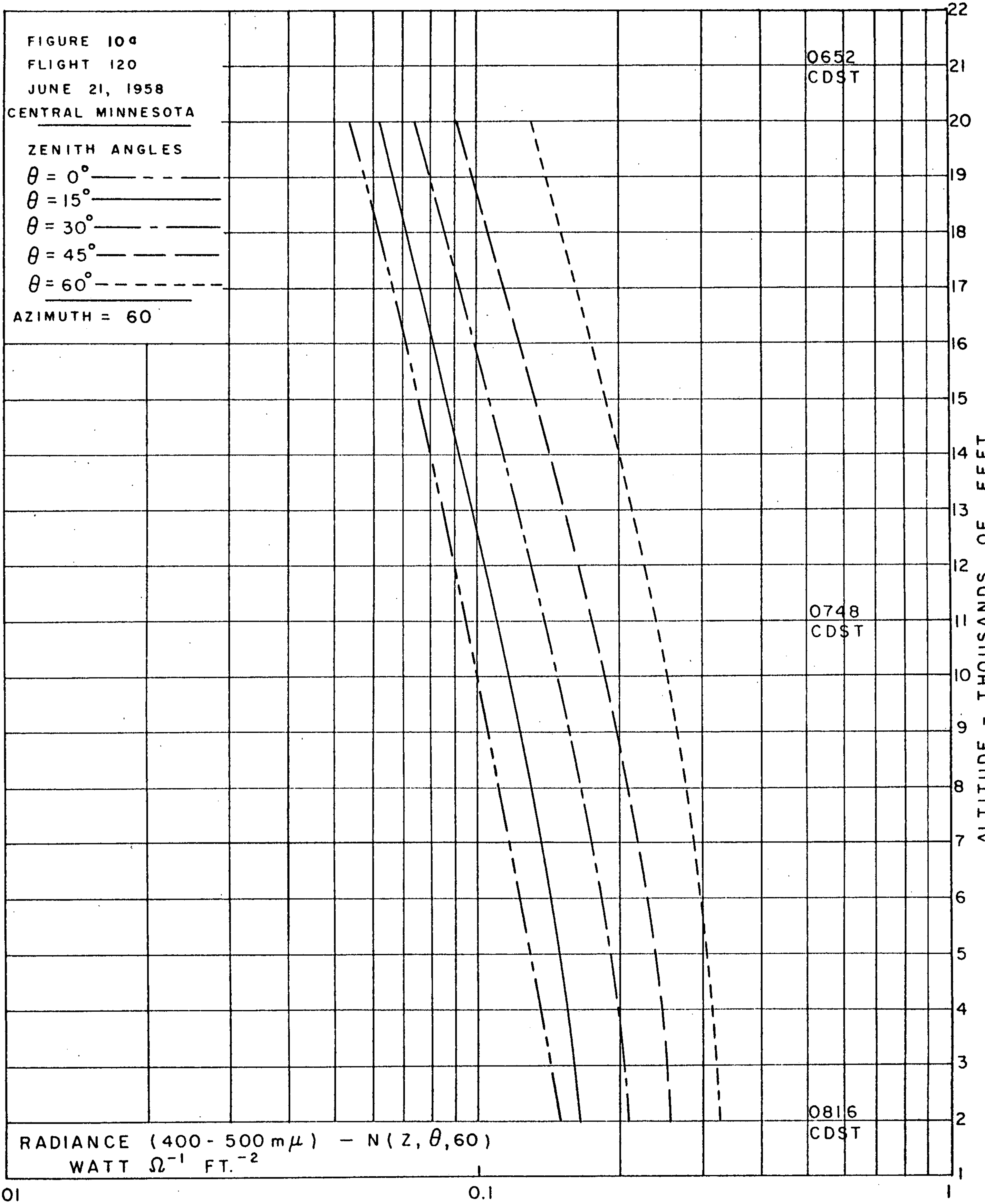


FIGURE 10a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 60
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400-500 mμ) – N(Z, θ, 60)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

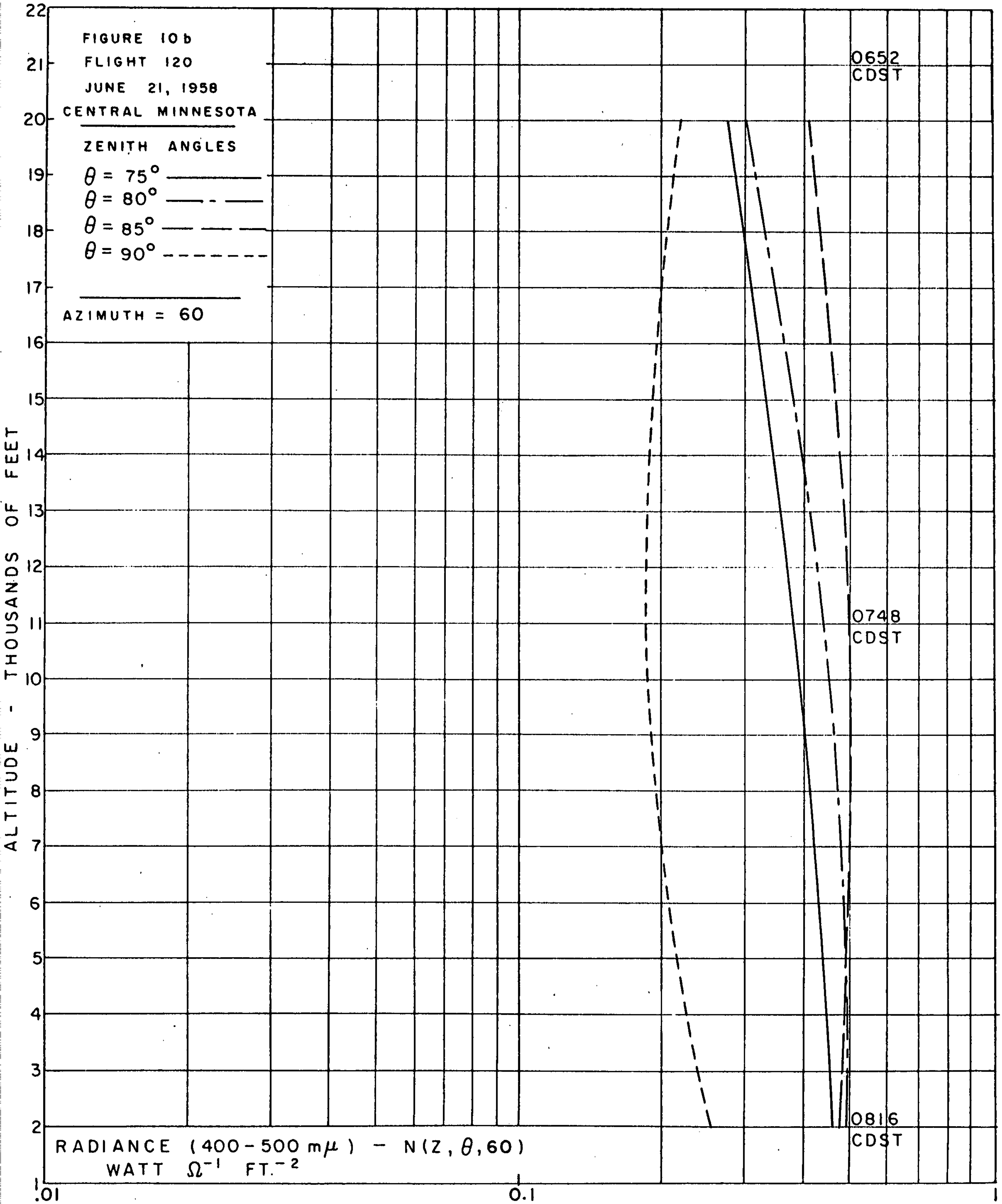


FIGURE 10b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 60
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ, 60)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

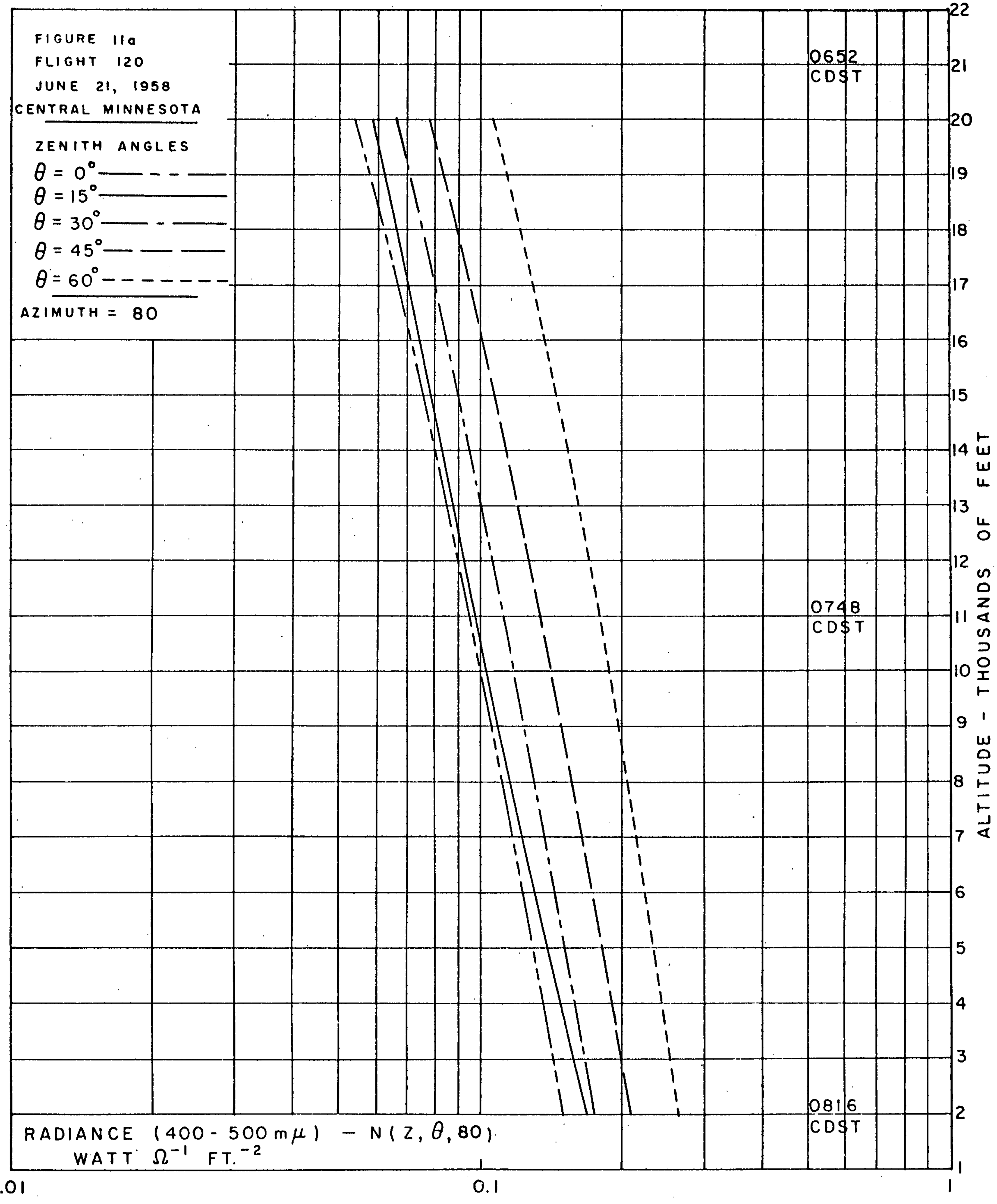


FIGURE 11a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 80
0652
CDST
0748
CDST
0816
CDST
RADIANCE (400 - 500 mμ) – N(Z, θ, 80)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

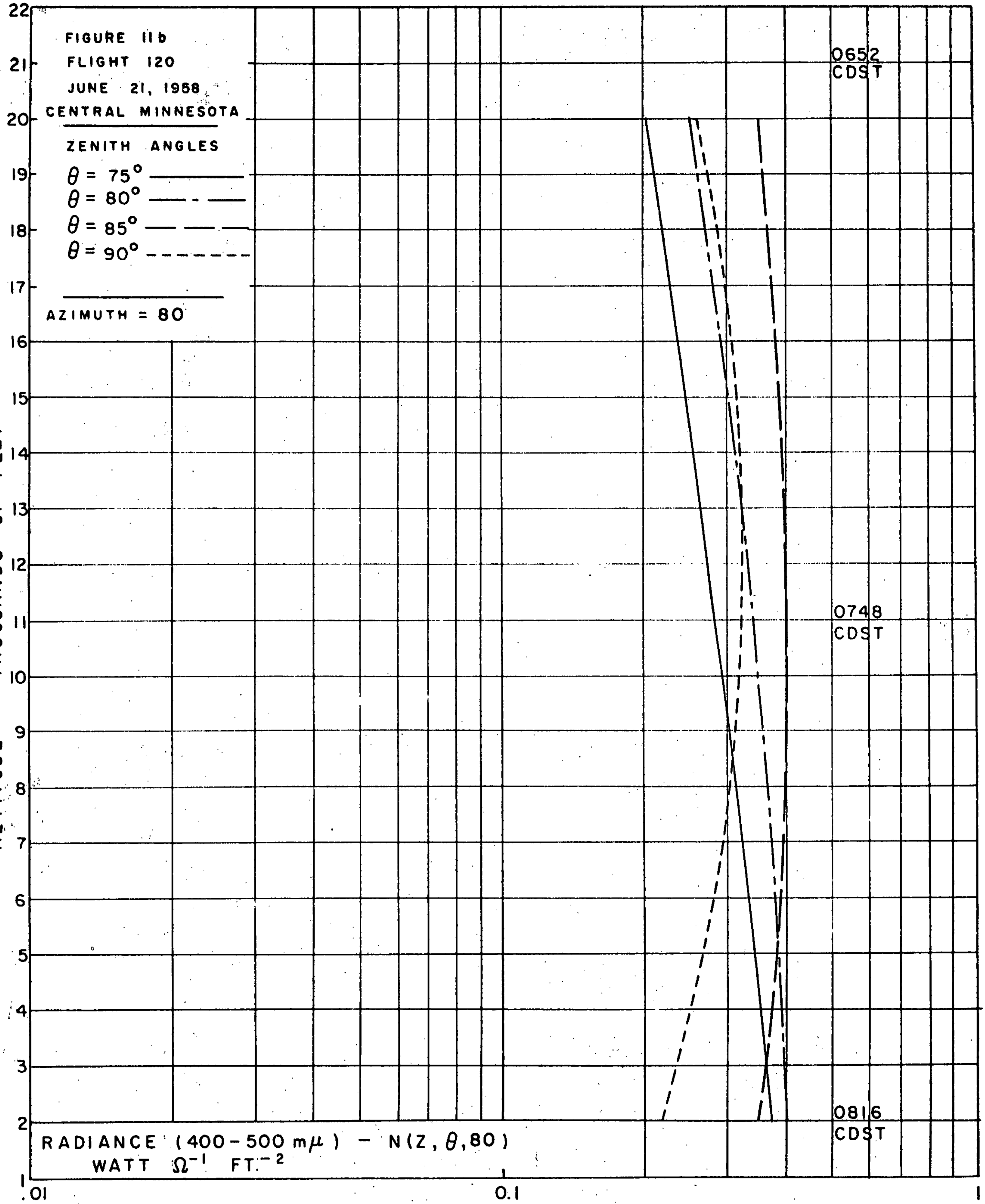


FIGURE 11b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 80
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ,80)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1

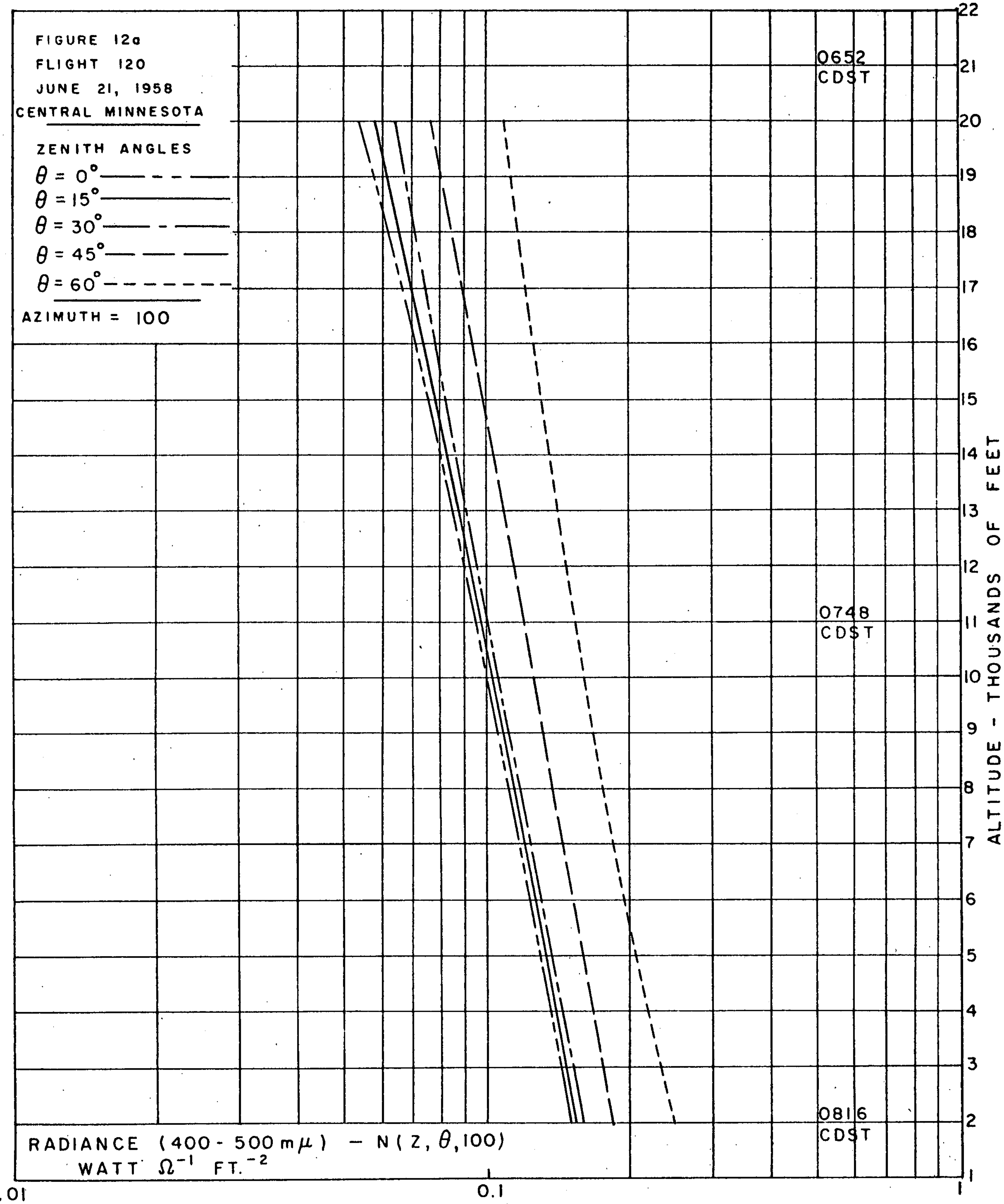


FIGURE 12a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 100
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) — N(Z, θ,100)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
1
2
3
4
5
6
7
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14
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16
17
18
19
20
21
22
ALTITUDE - THOUSANDS OF FEET

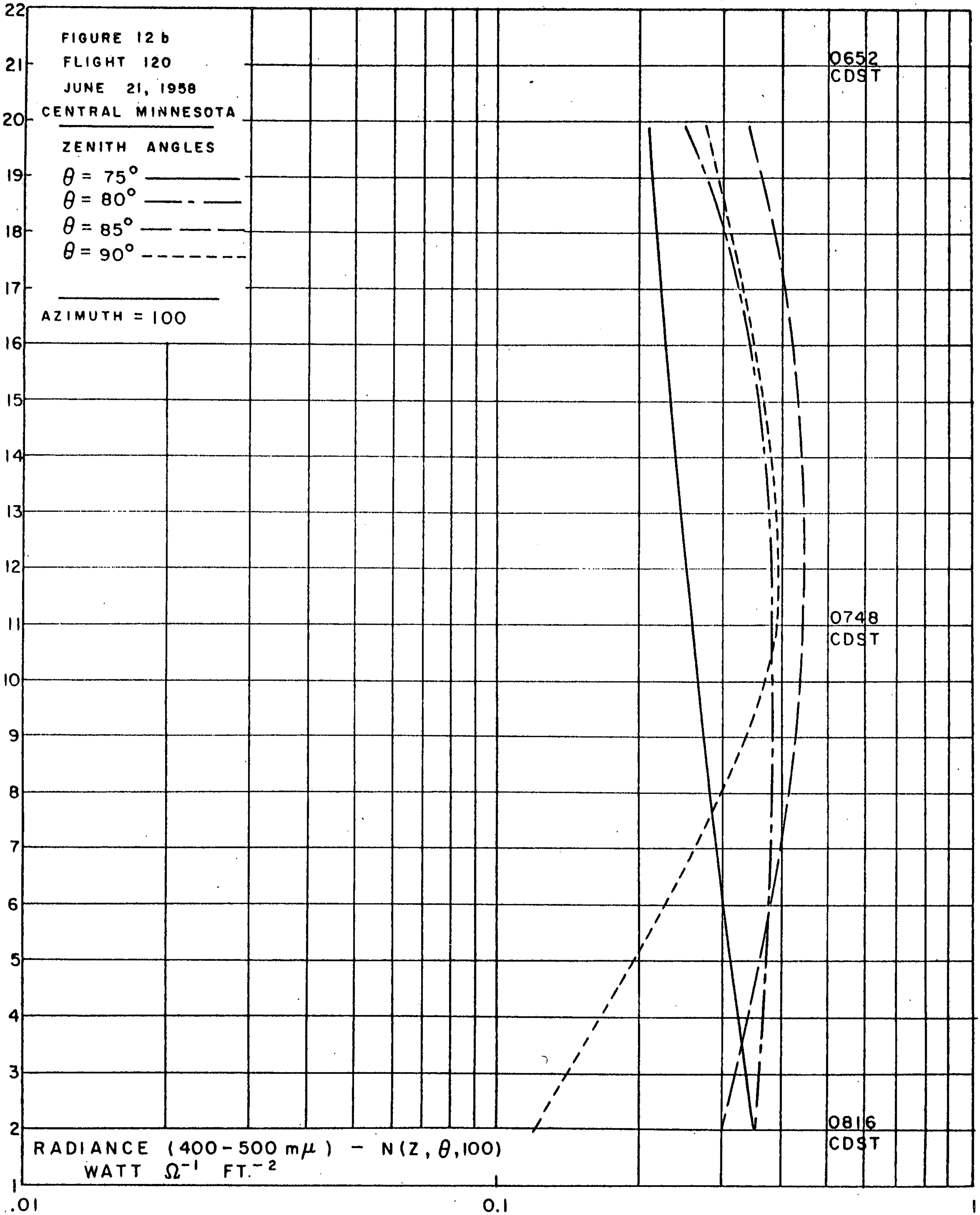
FIGURE 12 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 100
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ,100) WATT Ω⁻¹ FT.⁻²
.01
0.1
1
1
2
3
4
5
6
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21
22

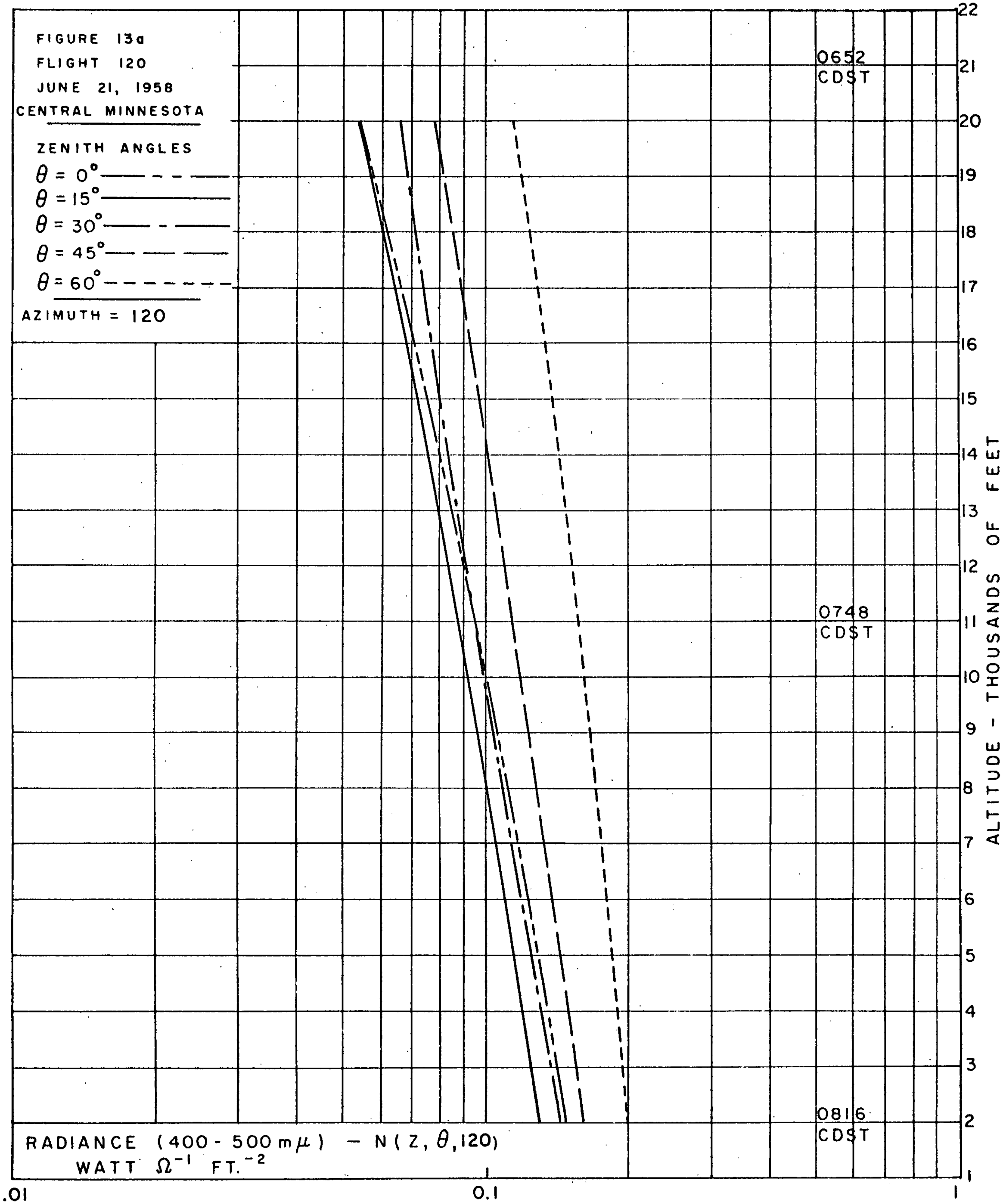
FIGURE 13a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 120
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) — N(Z, θ,120)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ALTITUDE - THOUSANDS OF FEET

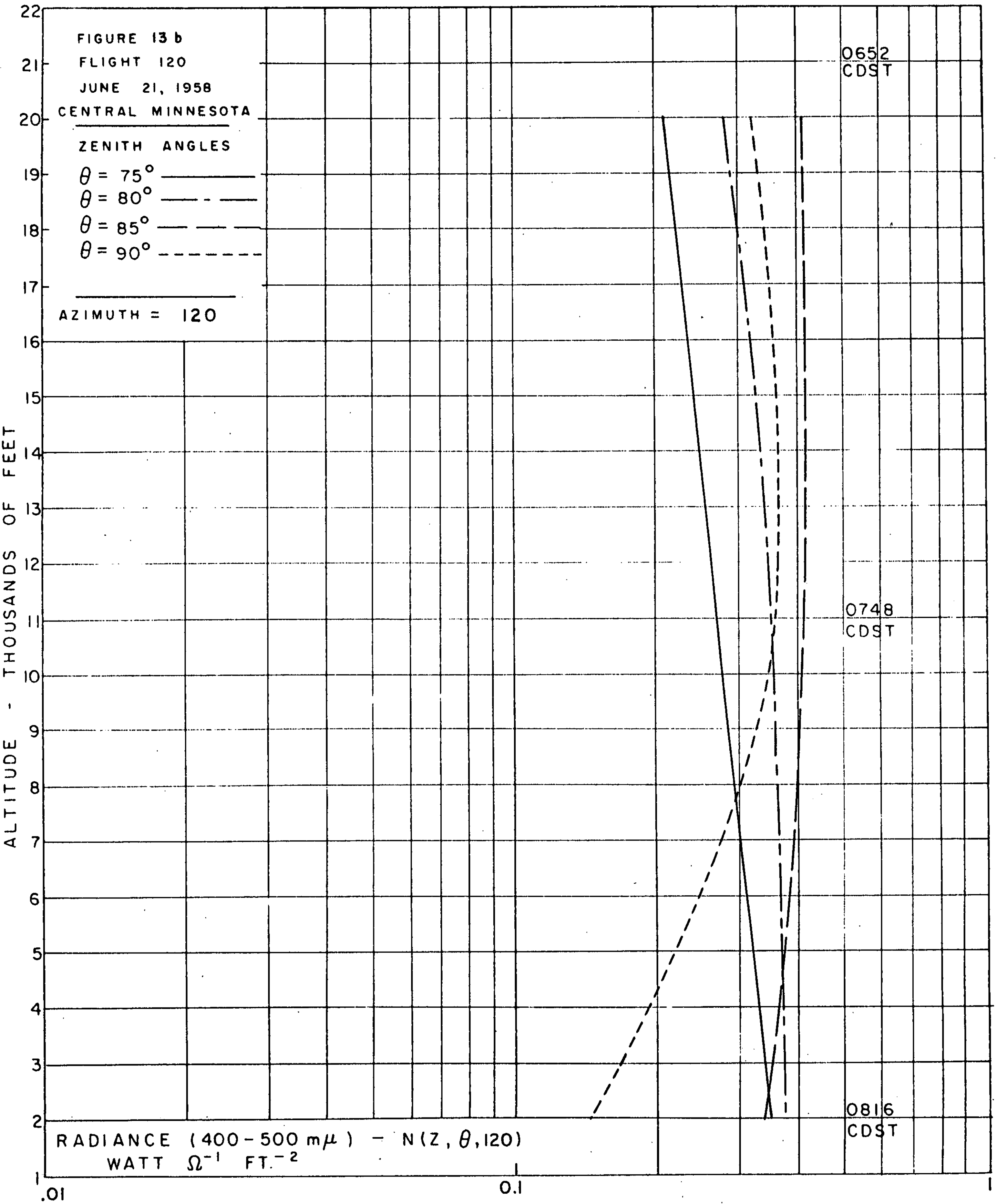
FIGURE 13 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 120
0652
CDST
0748
CDST
0816
CDST
ALTITUDE - THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
.01
0.1
1
RADIANCE (400 - 500 mμ) - N(Z, θ,120)
WATT Ω⁻¹ FT.⁻²

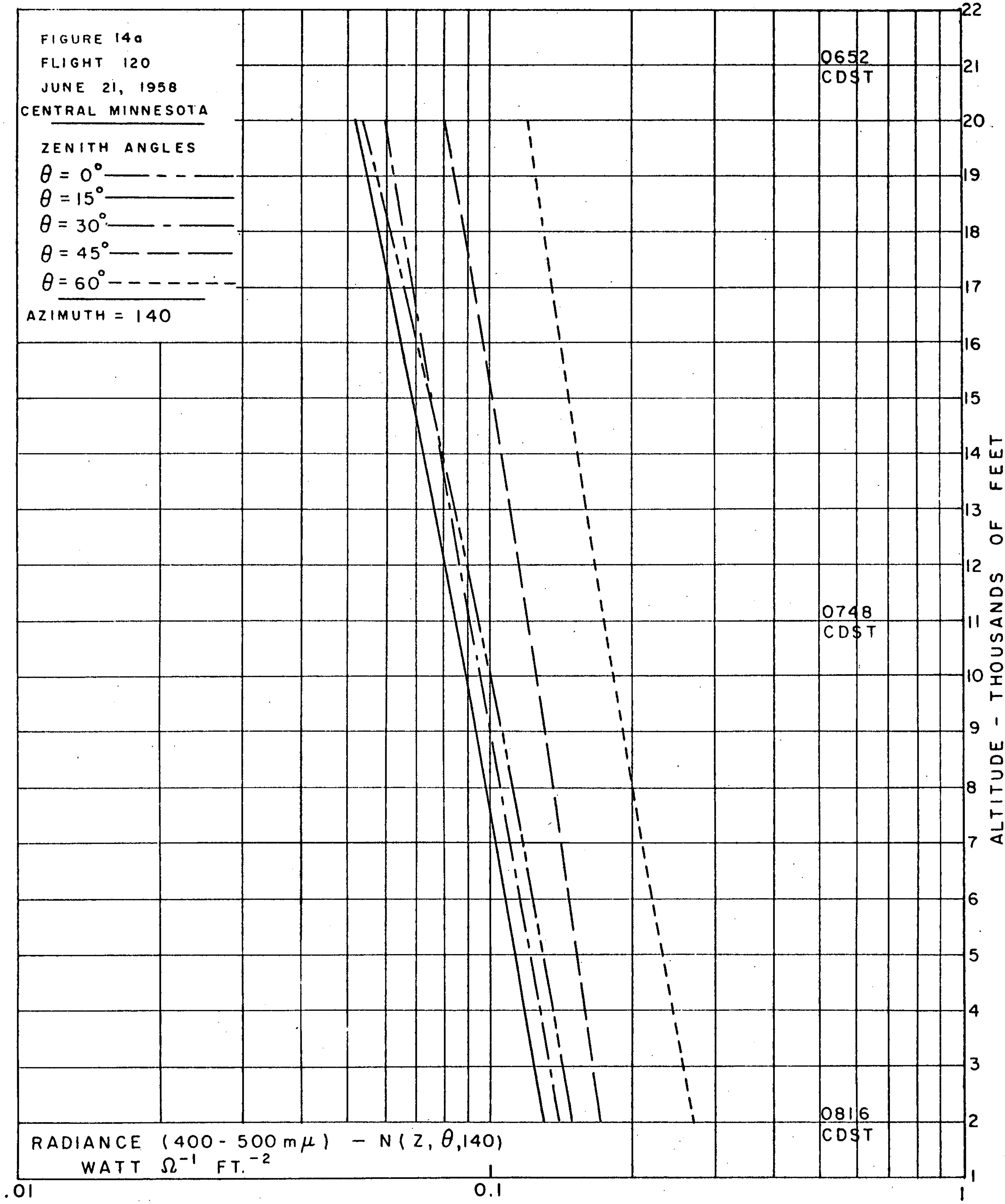
FIGURE 14a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 140
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400-500 mμ) - N(Z, θ,140)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

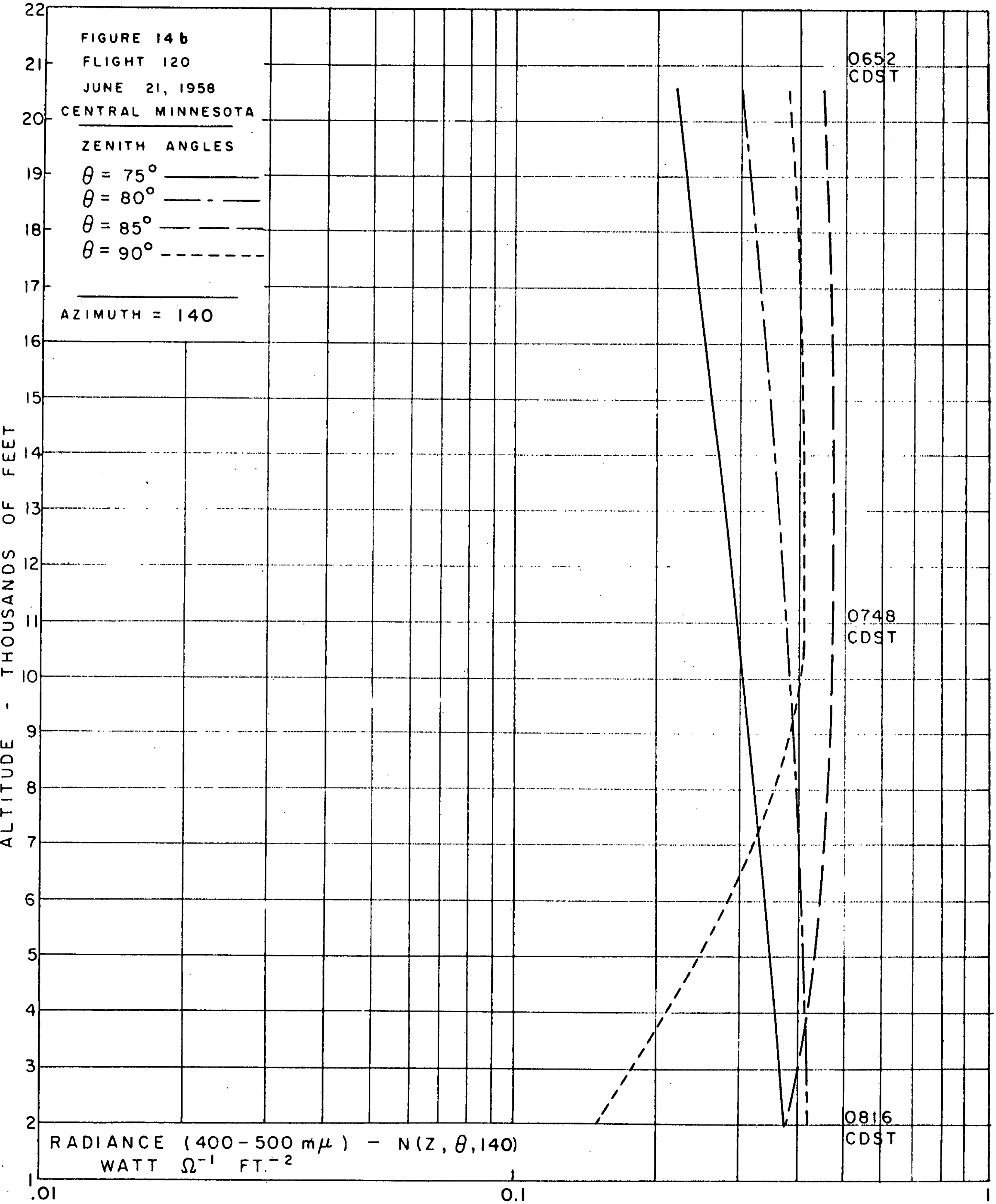
FIGURE 14 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 140
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ,140)
WATT Ω⁻¹ FT.⁻²
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
.01
0.1
1

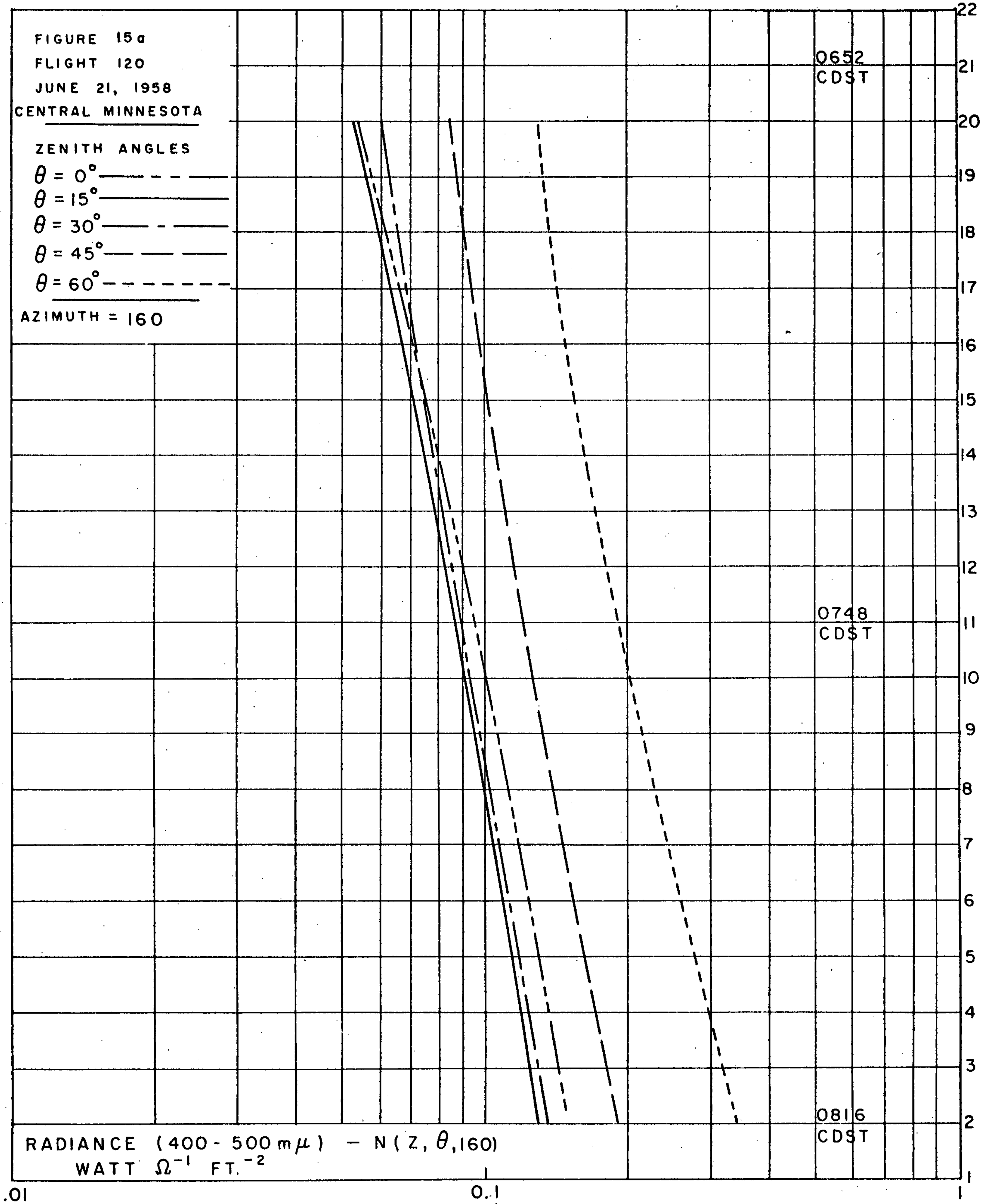
FIGURE 15a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 160
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) — N(Z, θ,160)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
ALTITUDE - THOUSANDS OF FEET
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

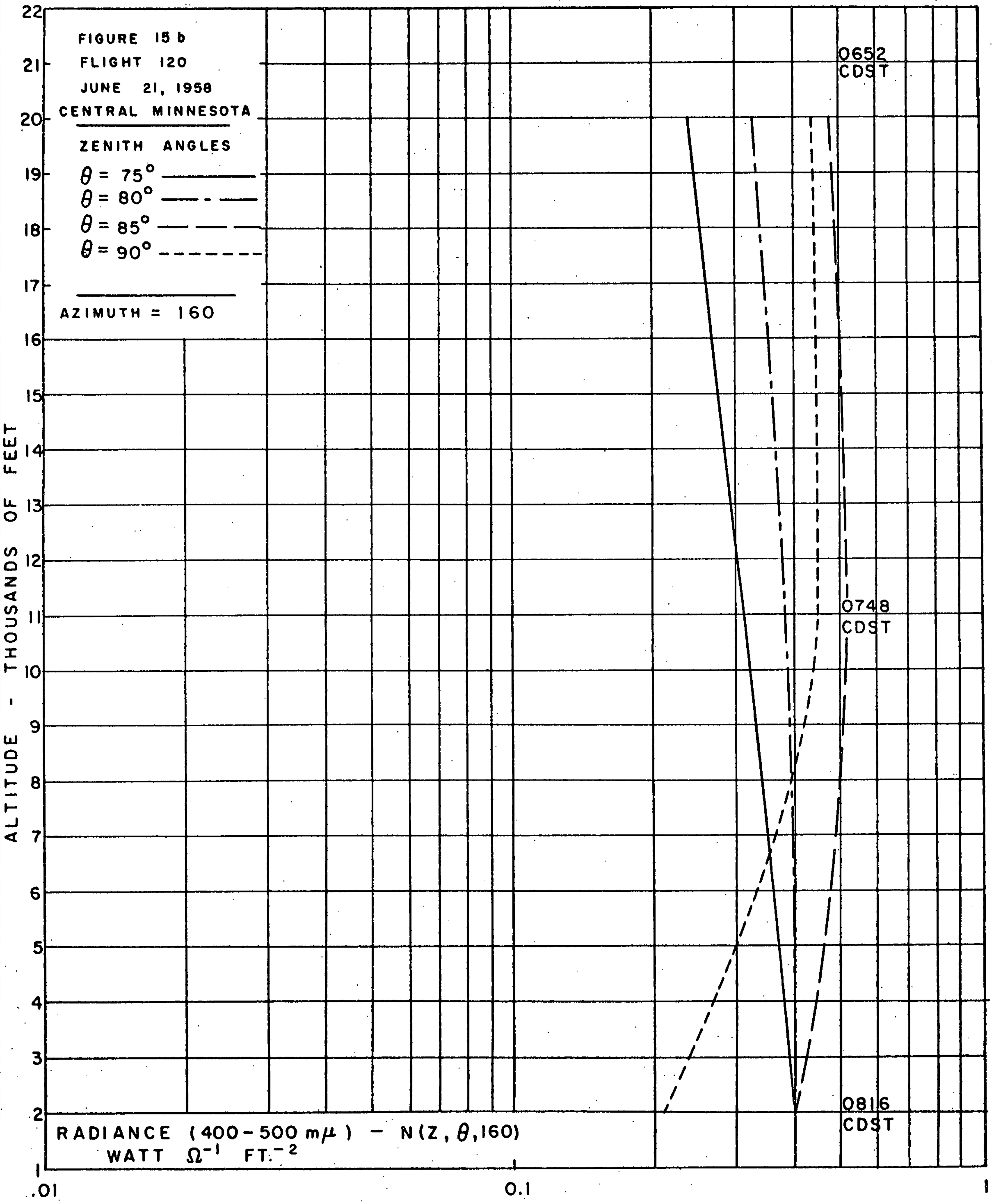
FIGURE 15 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 160
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ,160)
WATT Ω⁻¹ FT.⁻²
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
.01
0.1
1

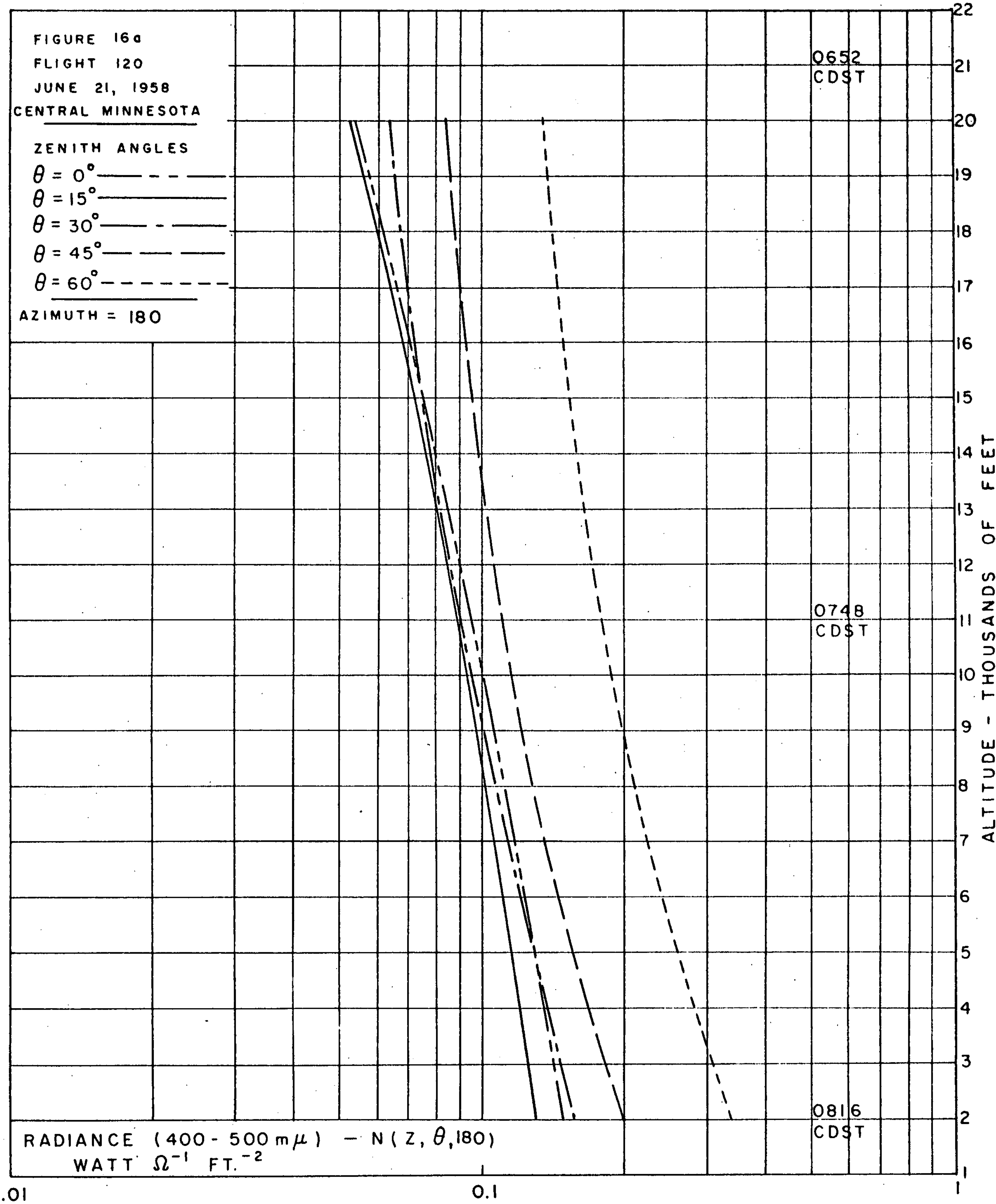
FIGURE 16a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 180
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) — N(Z, θ,180)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ALTITUDE - THOUSANDS OF FEET

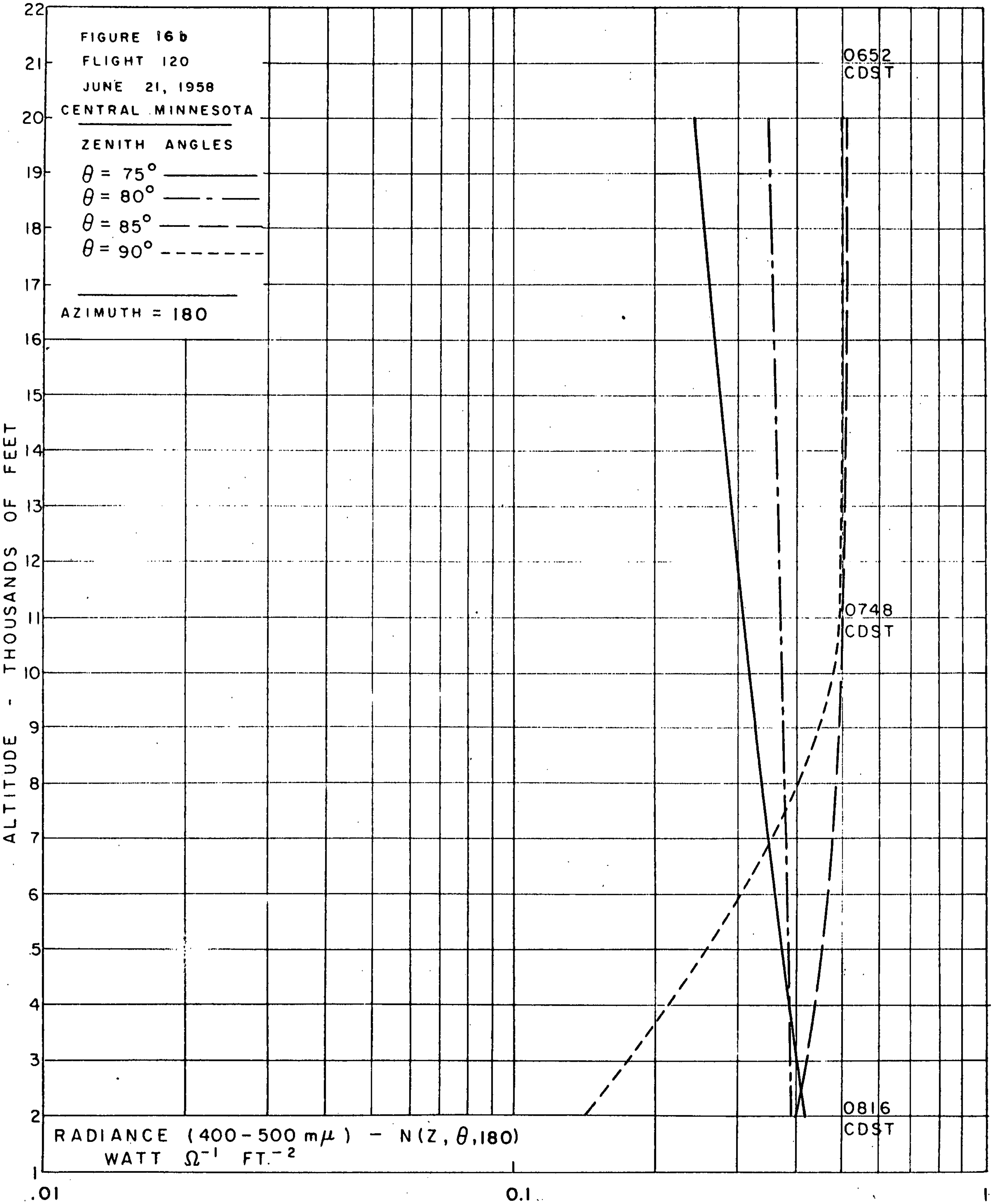
FIGURE 16b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 180
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ,180)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
22
21
20
19
18
17
16
15
14
13
12
11
10
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8
7
6
5
4
3
2
1

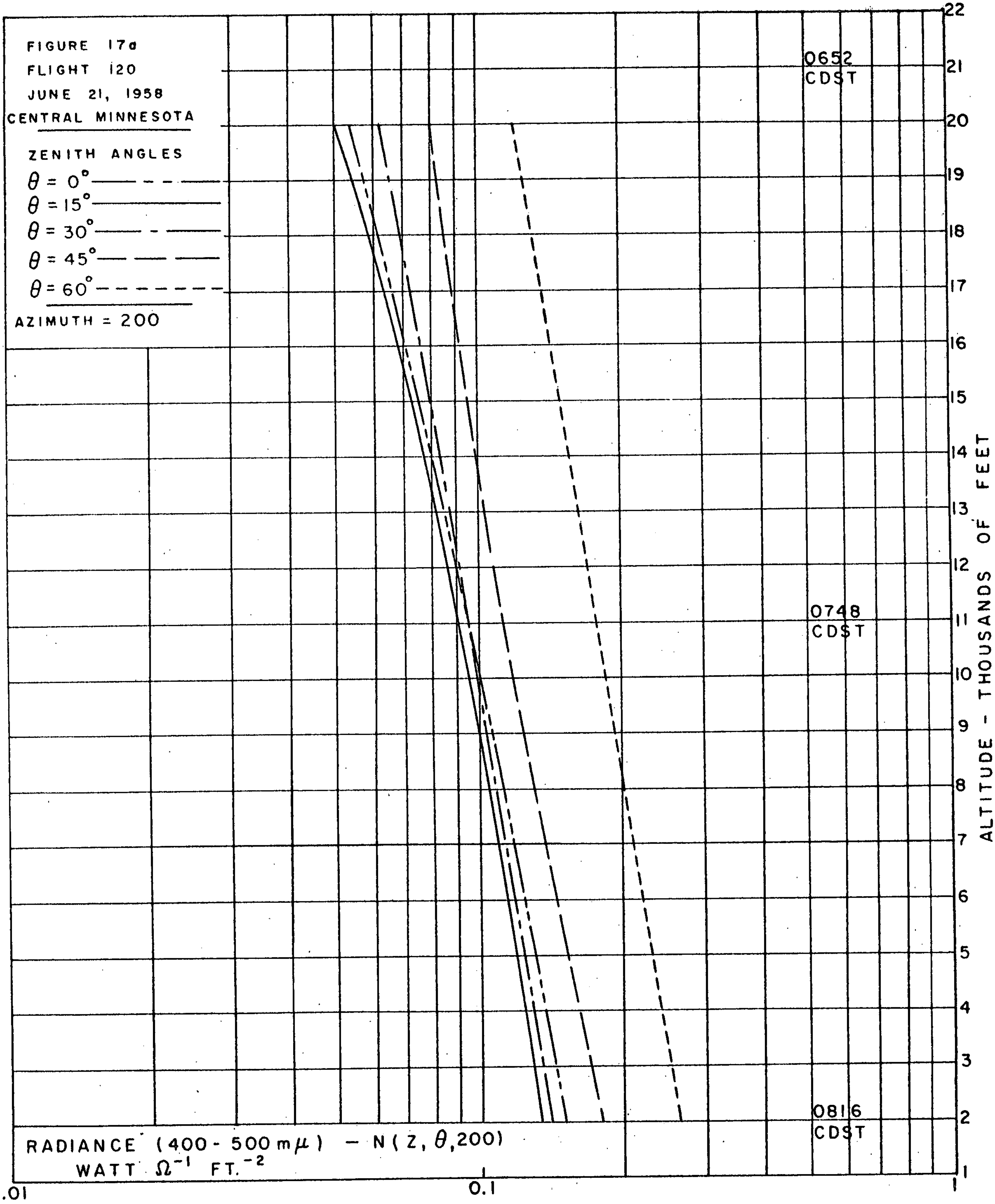
FIGURE 17a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 200
0652
CDST
0748
CDST
0816
CDST
RADIANCE (400 - 500 mμ) - N(Z, θ,200)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

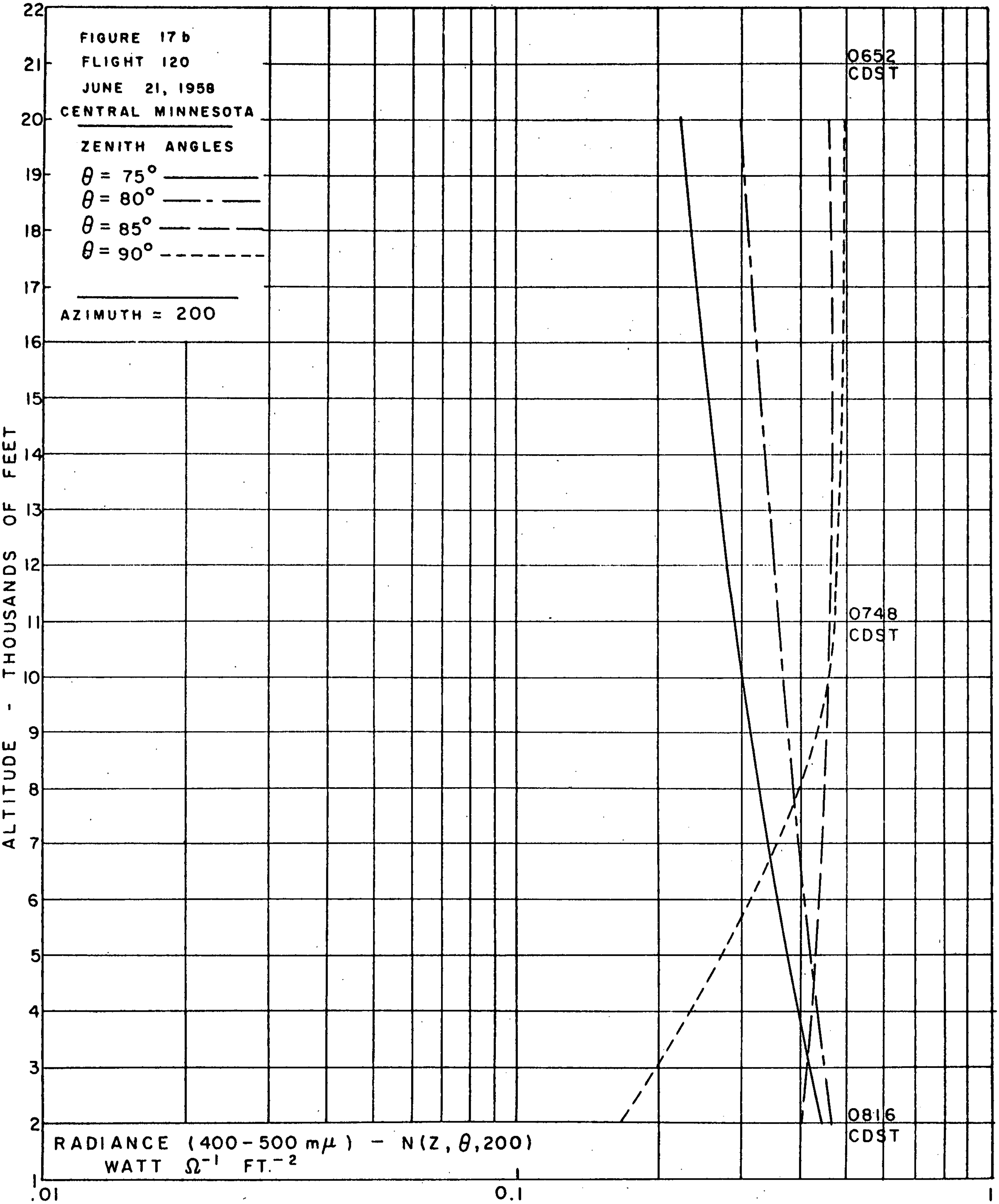
FIGURE 17 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 200
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ,200)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

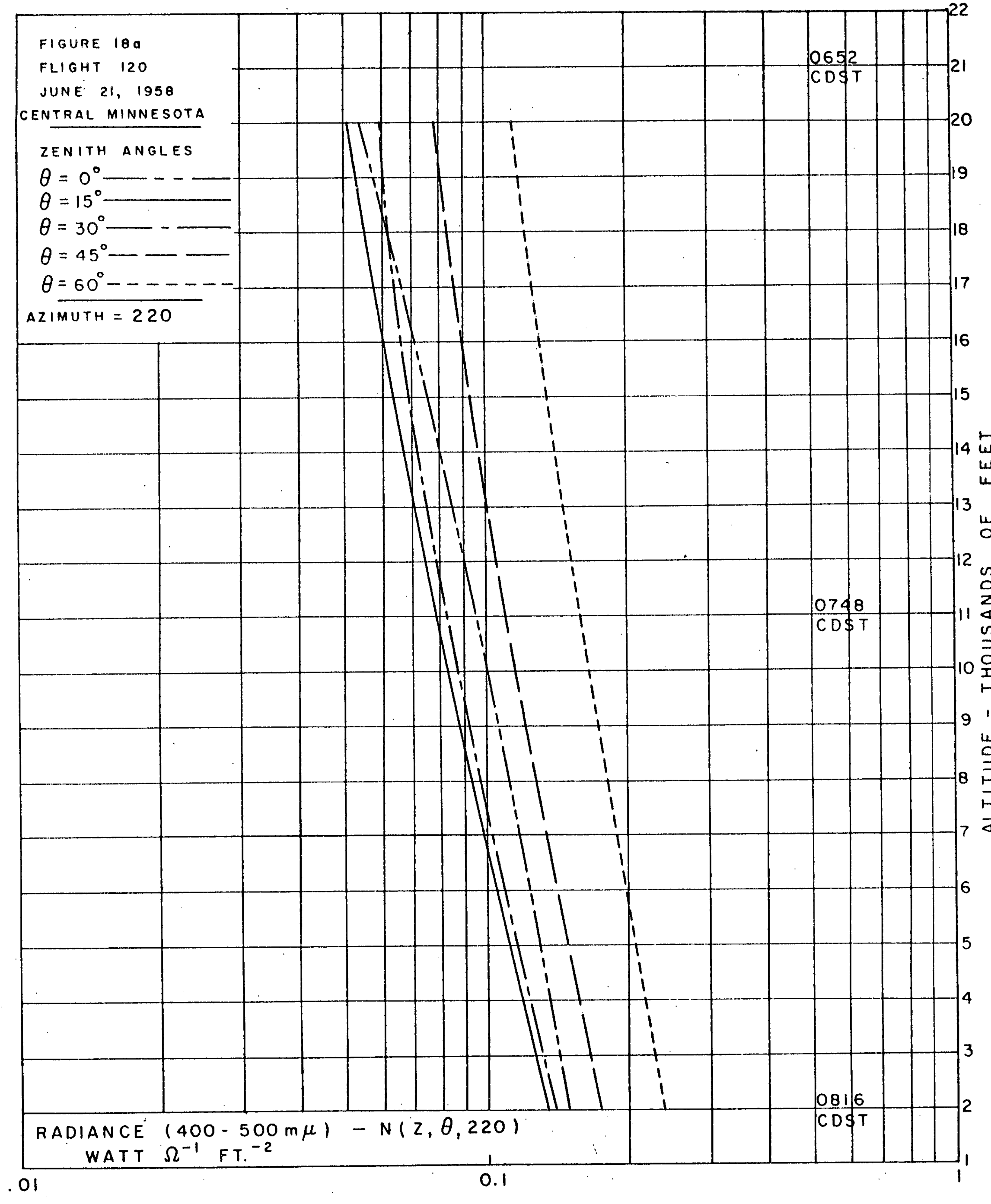
FIGURE 18a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 220
0652
CDST
0748
CDST
0816
CDST
RADIANCE (400 - 500 mμ) - N(Z, θ, 220)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
22
21
20
19
18
17
16
15
14
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12
11
10
9
8
7
6
5
4
3
2
1
ALTITUDE - THOUSANDS OF FEET

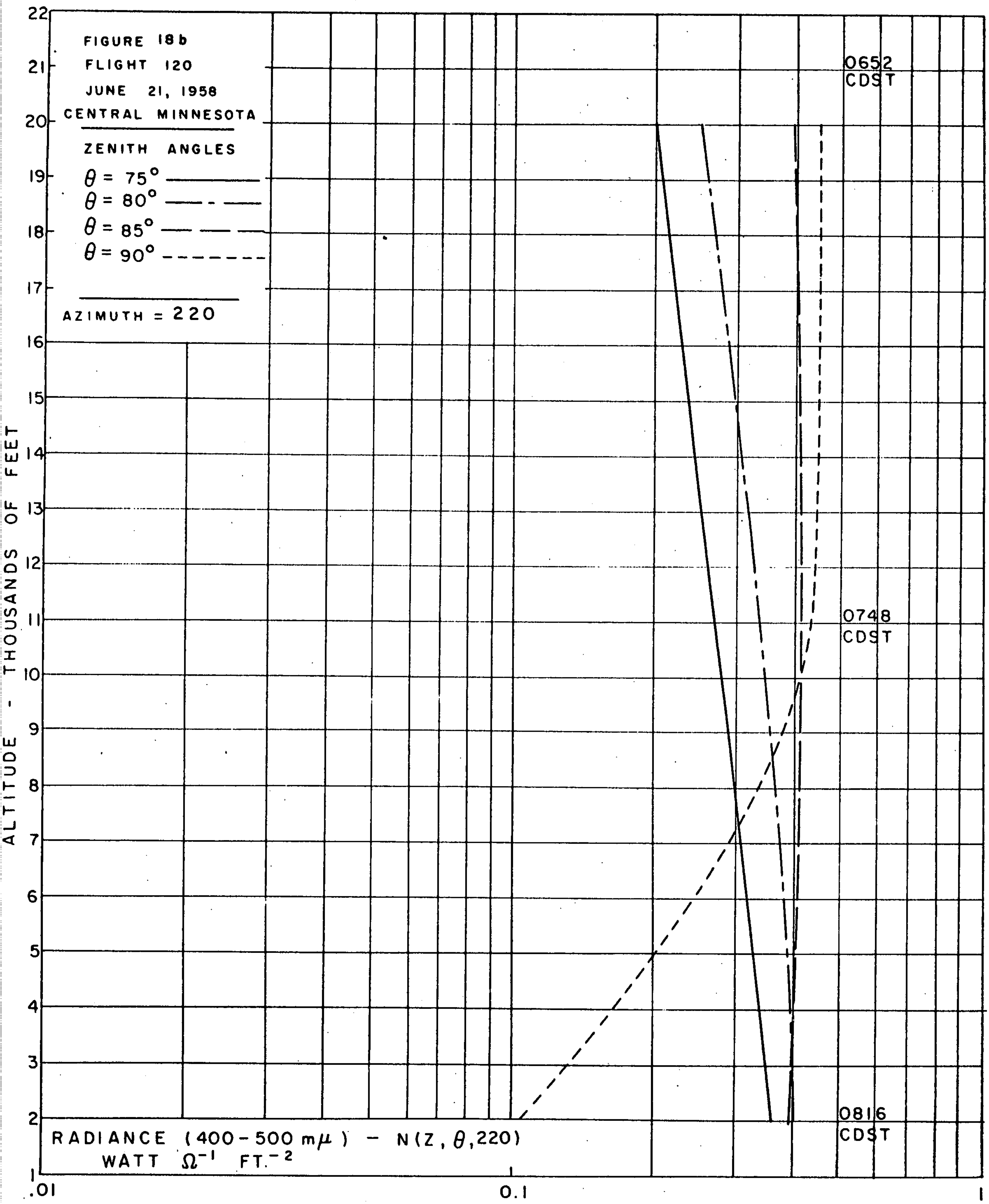
FIGURE 18b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 220
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ,220)
WATT Ω⁻¹ FT.⁻²
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
.01
0.1
1

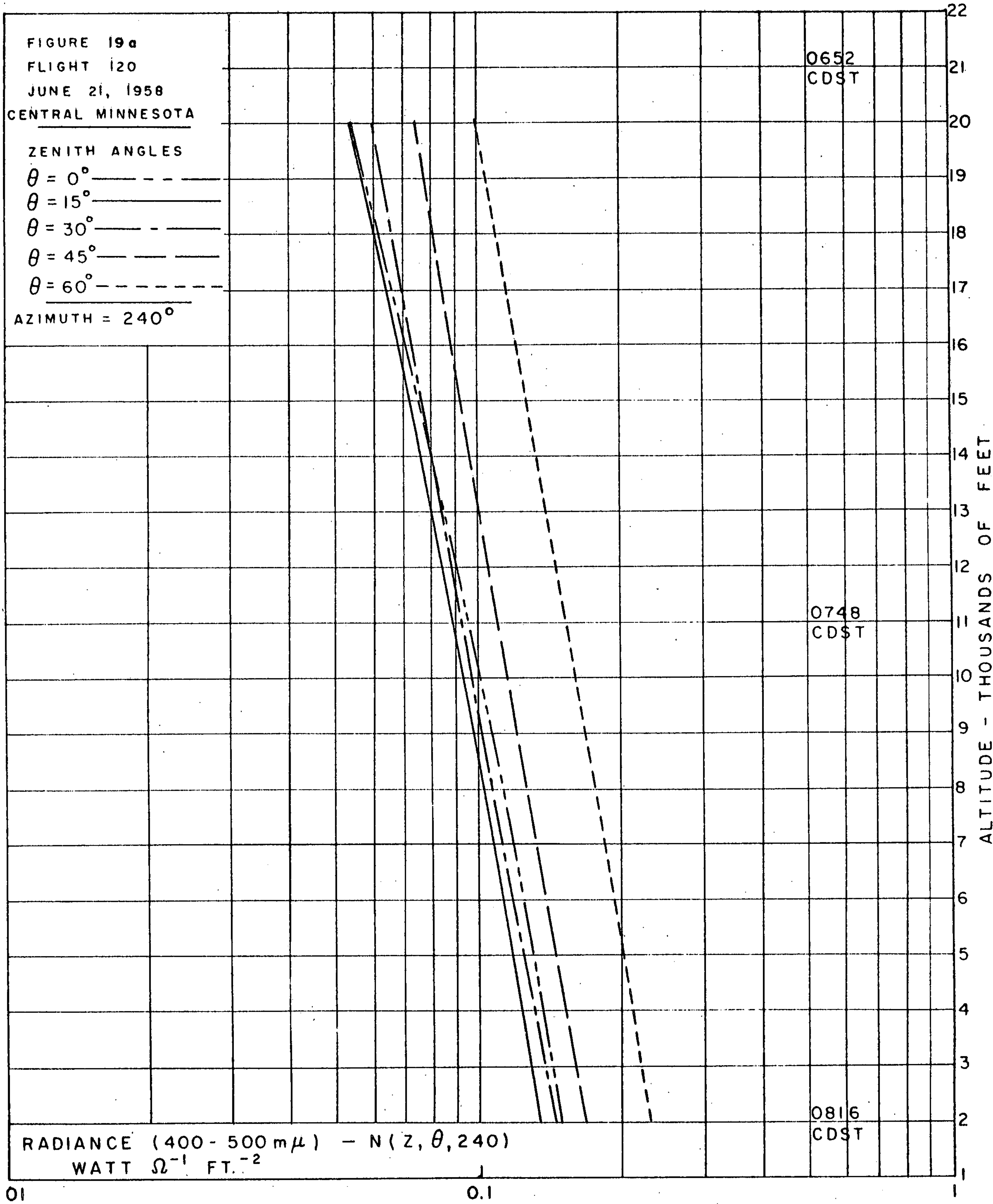
FIGURE 19a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 240°
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
RADIANCE (400 - 500 mμ) - N(Z, θ, 240)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1

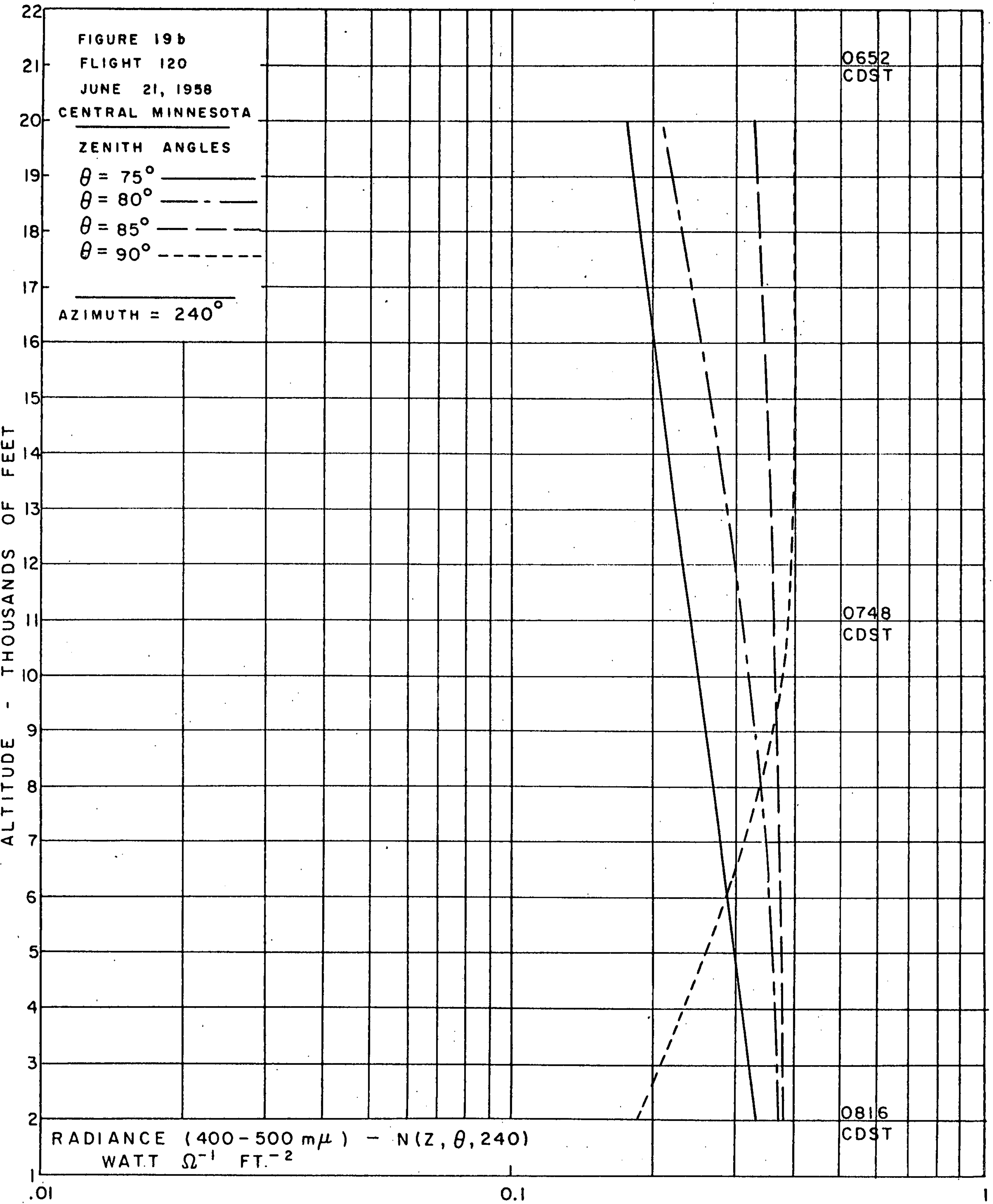
FIGURE 19b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 240°
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ, 240)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
1
2
3
4
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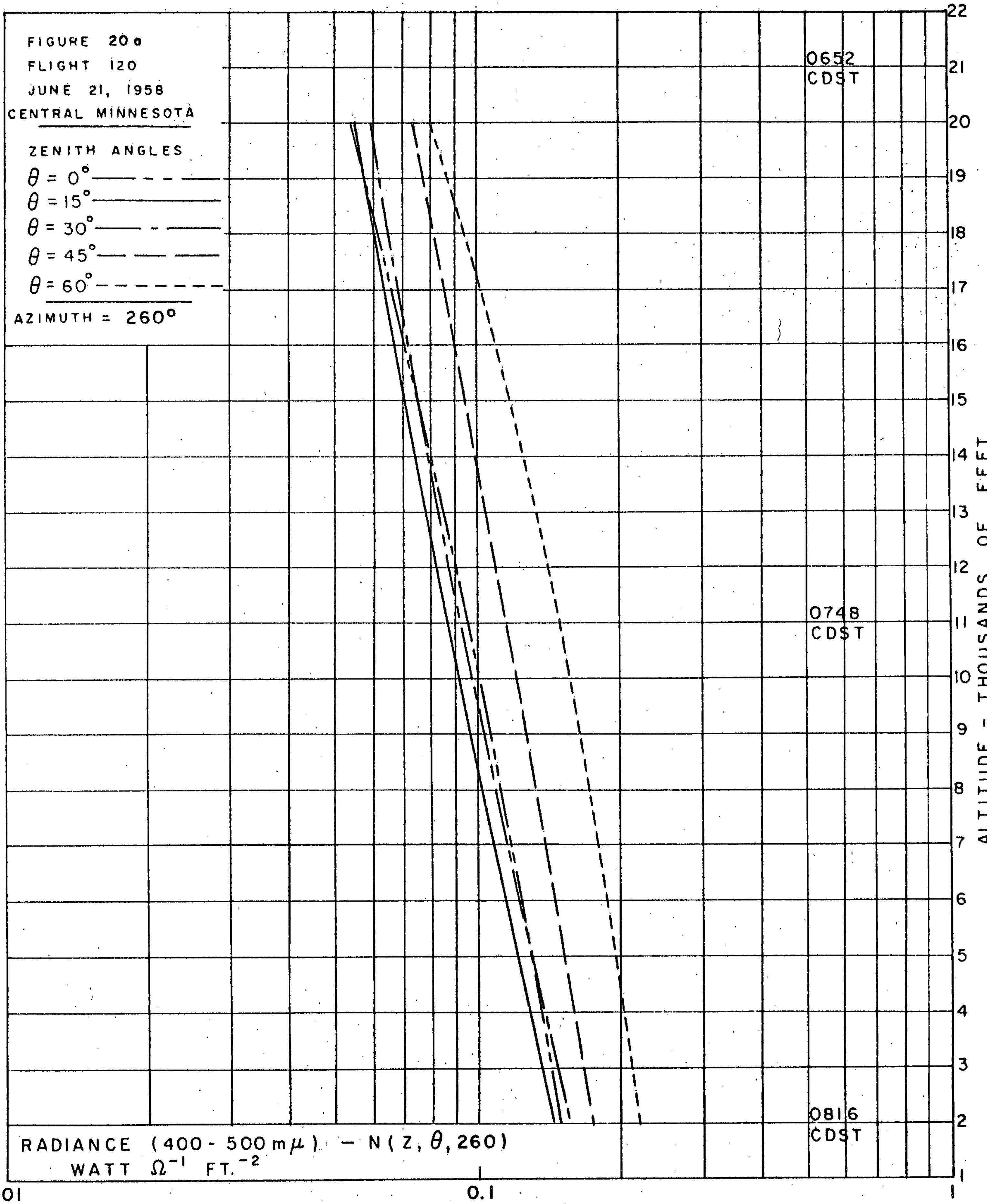
FIGURE 20a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 260°
0652
CDST
0748
CDST
0816
CDST
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ, 260)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1

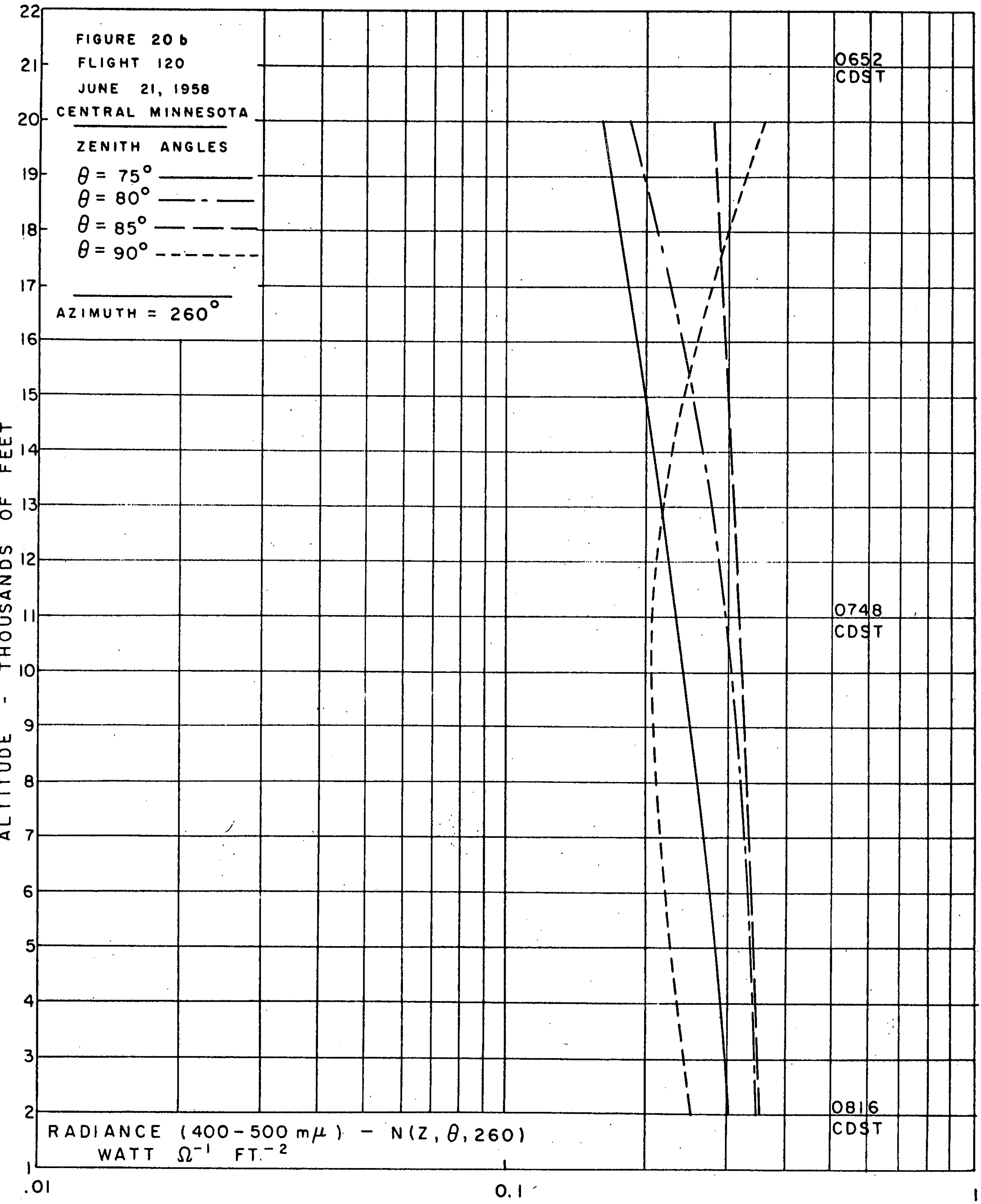
FIGURE 20 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 260°
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ, 260)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1

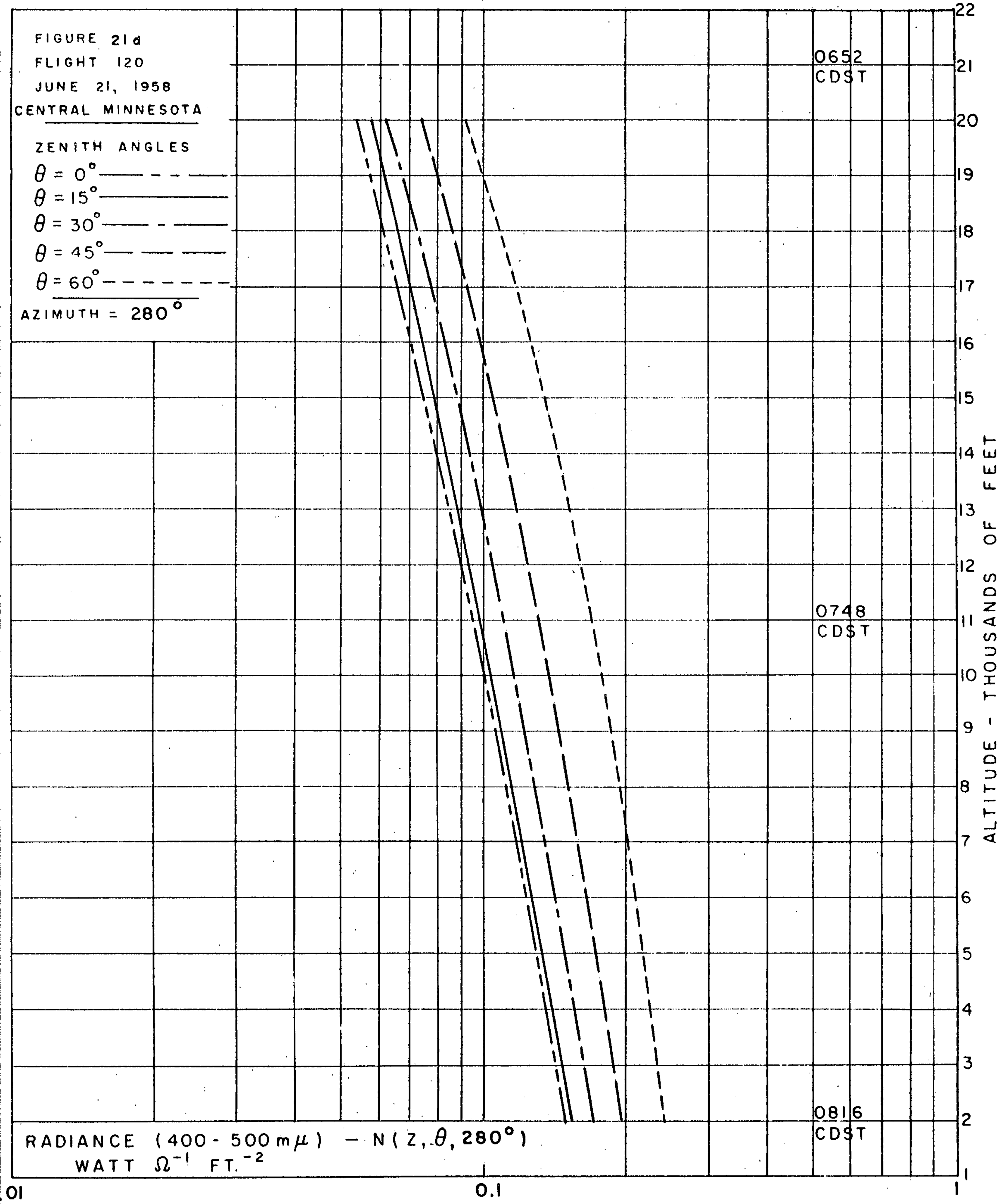
FIGURE 21d
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 280°
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) — N(Z, θ, 280°)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
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11
12
13
14
15
16
17
18
19
20
21
22

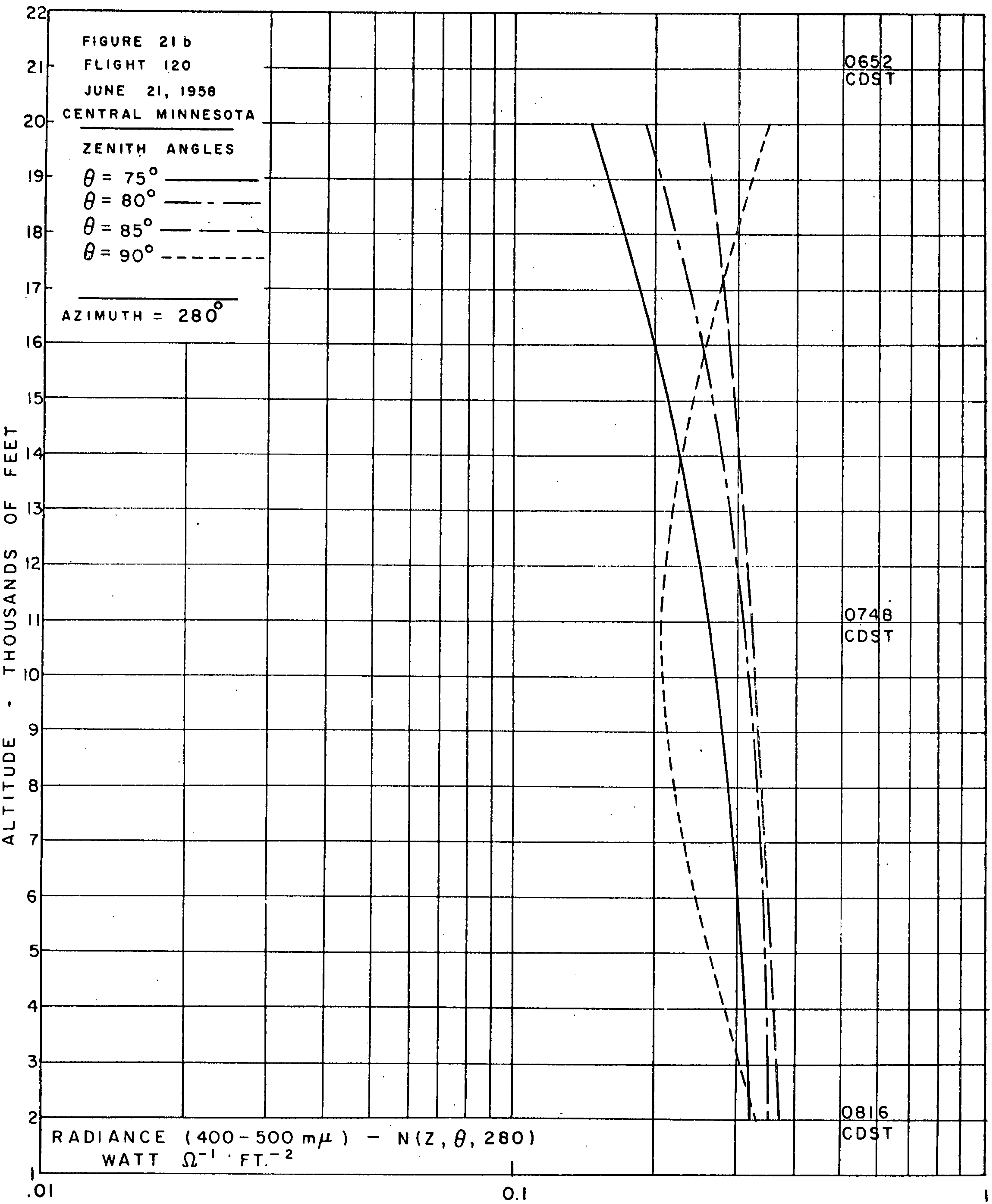
FIGURE 21 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 280°
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ, 280)
WATT Ω⁻¹ · FT.⁻²
.01
0.1
1
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

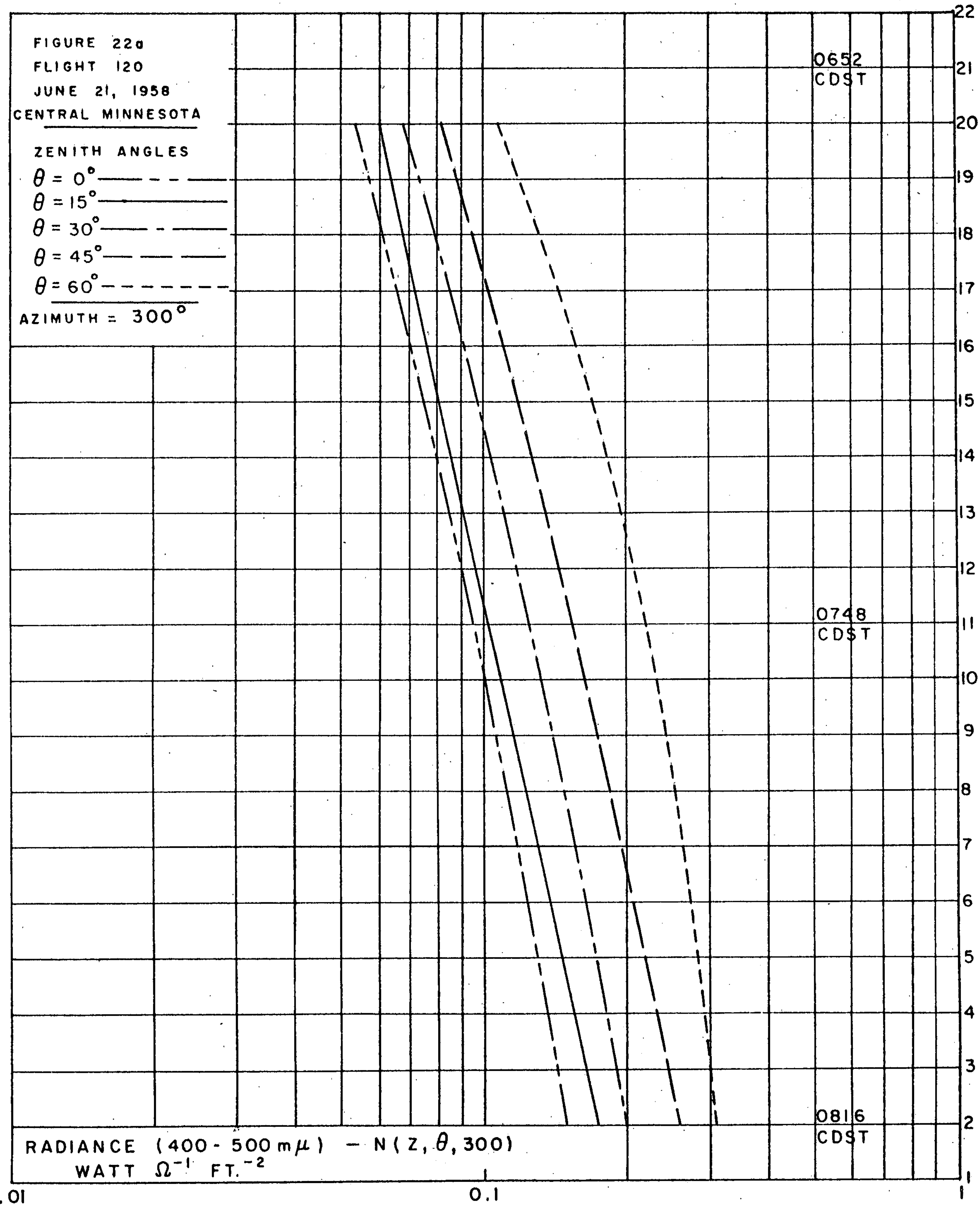
FIGURE 22a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 300°
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) — N(Z, θ, 300)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
ALTITUDE - THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

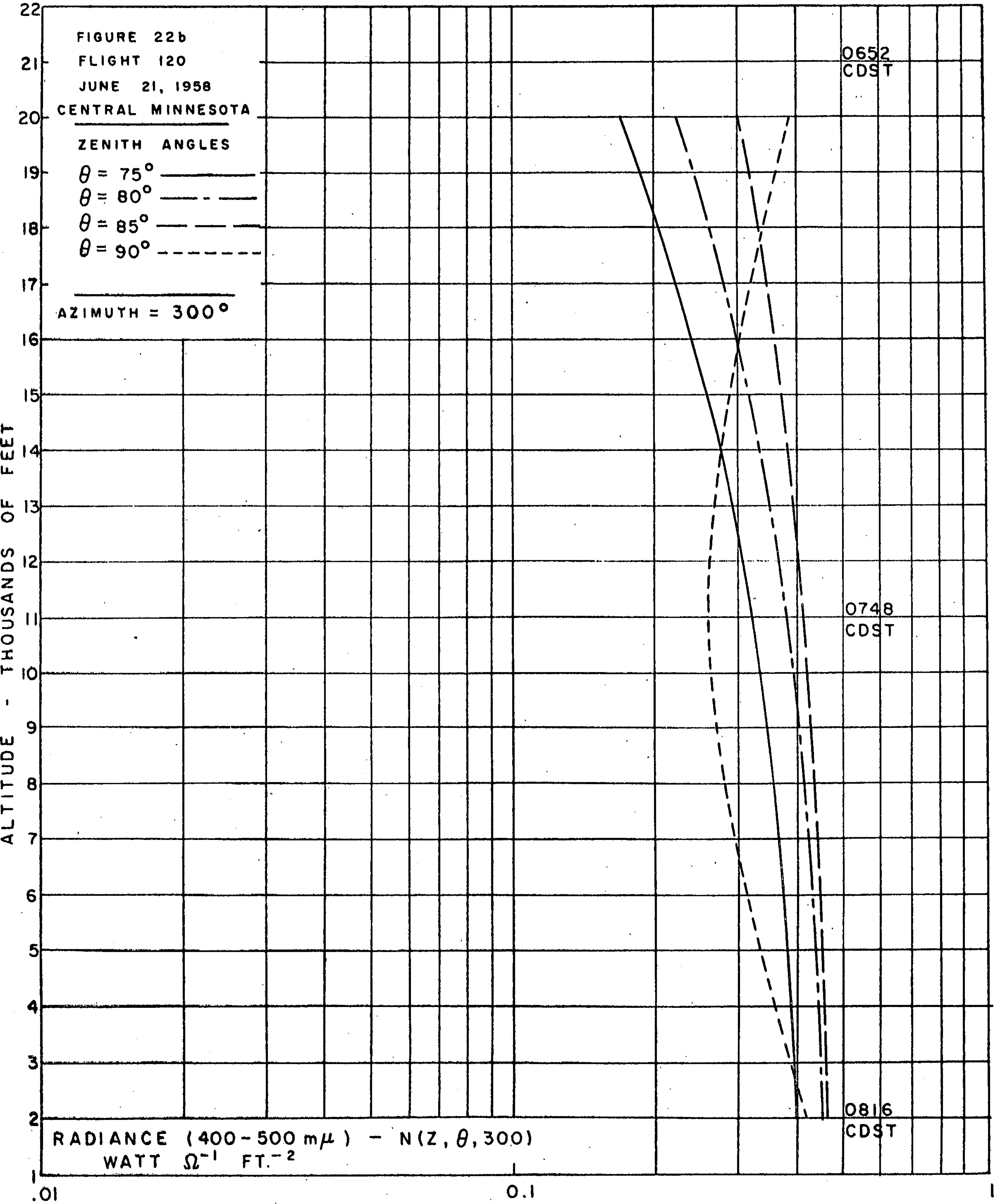
FIGURE 22b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 300°
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ, 300)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1

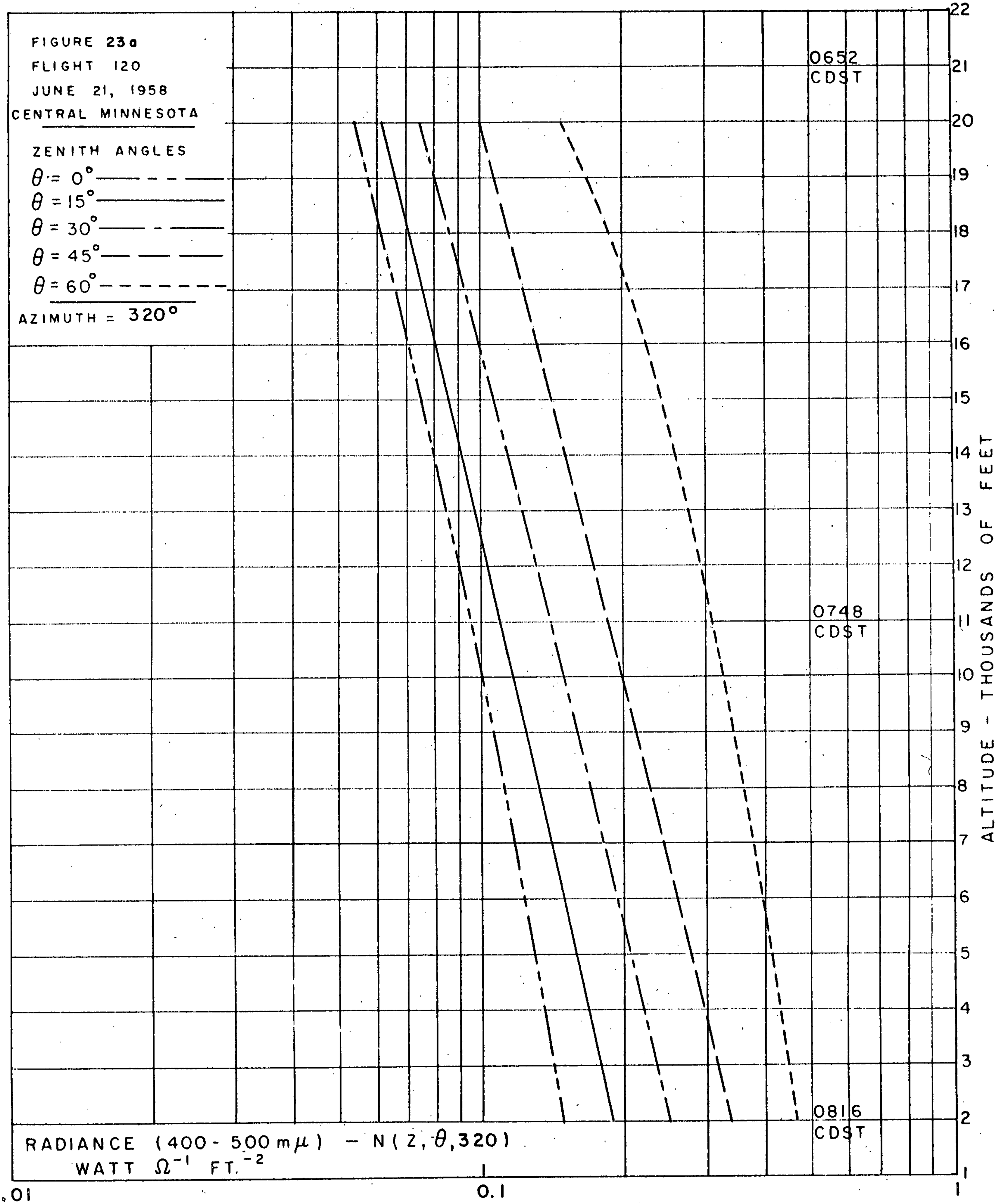
FIGURE 23a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 320°
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) - N(Z, θ, 320)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

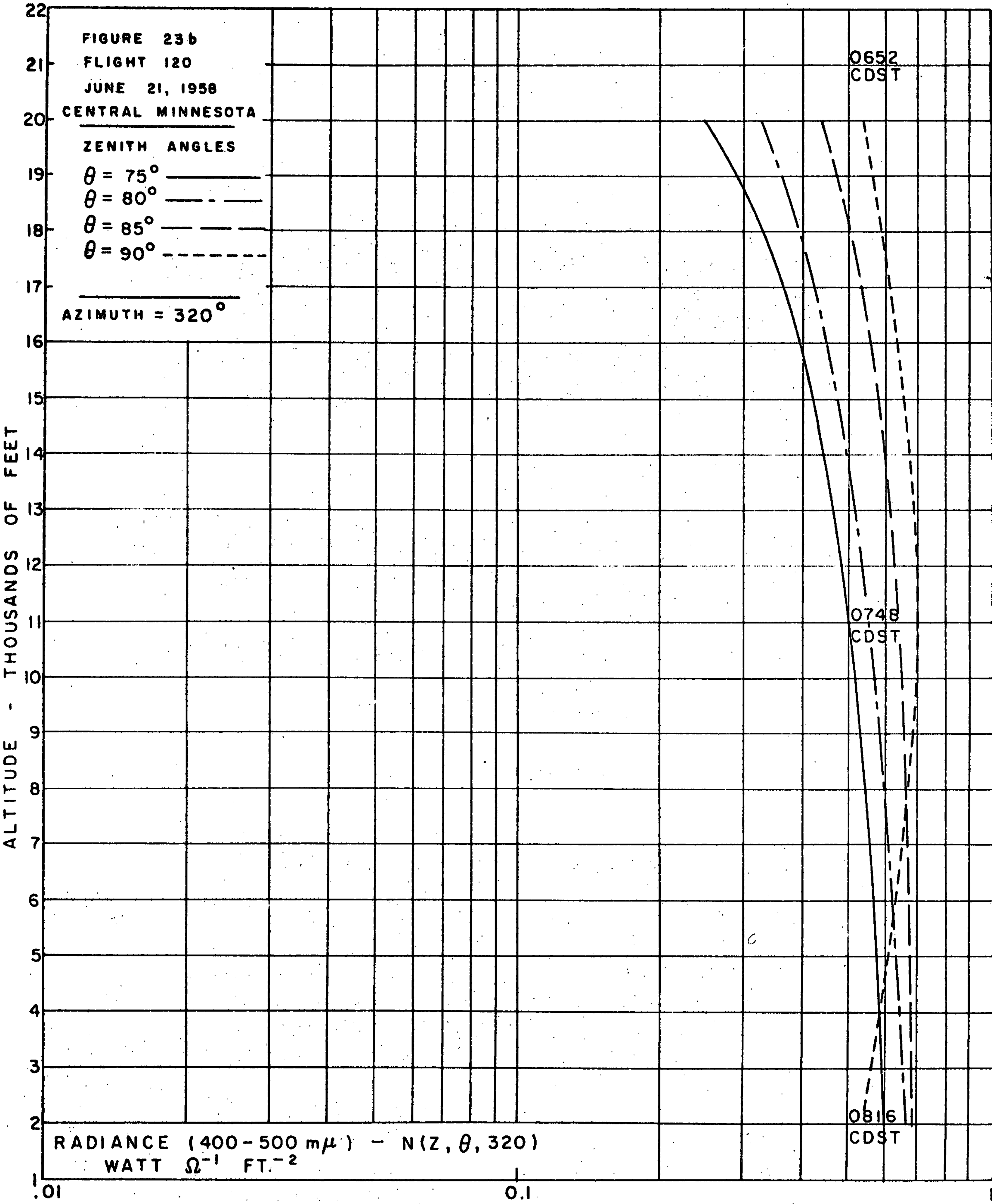
FIGURE 23b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 320°
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ, 320)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
22
21
20
19
18
17
16
15
14
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12
11
10
9
8
7
6
5
4
3
2
1

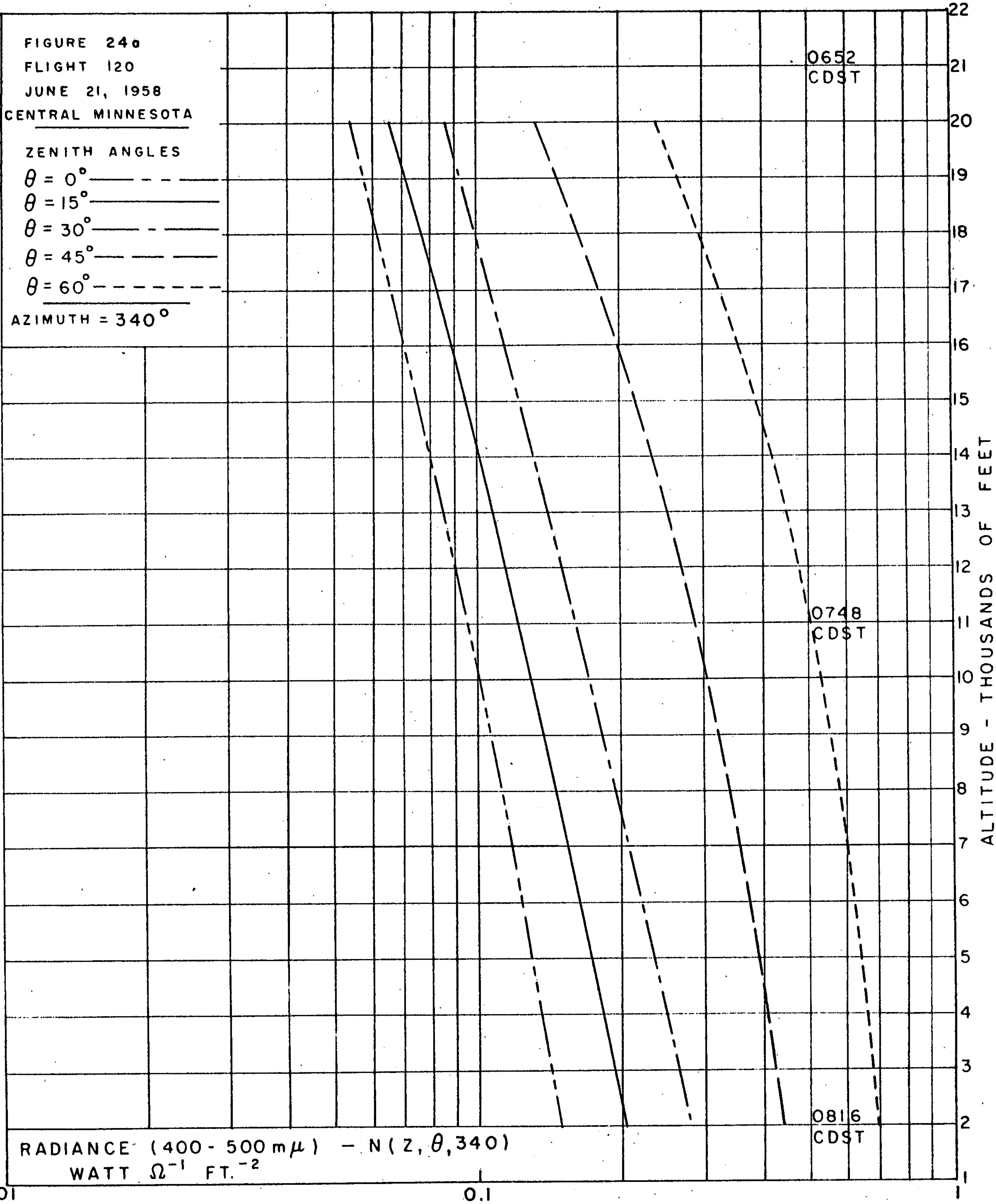


FIGURE 24a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 340°
0652 CDST
0748 CDST
0816 CDST
RADIANCE (400 - 500 mμ) — N(Z, θ, 340)
WATT Ω⁻¹ FT.⁻²
.01
0.1
1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
ALTITUDE - THOUSANDS OF FEET

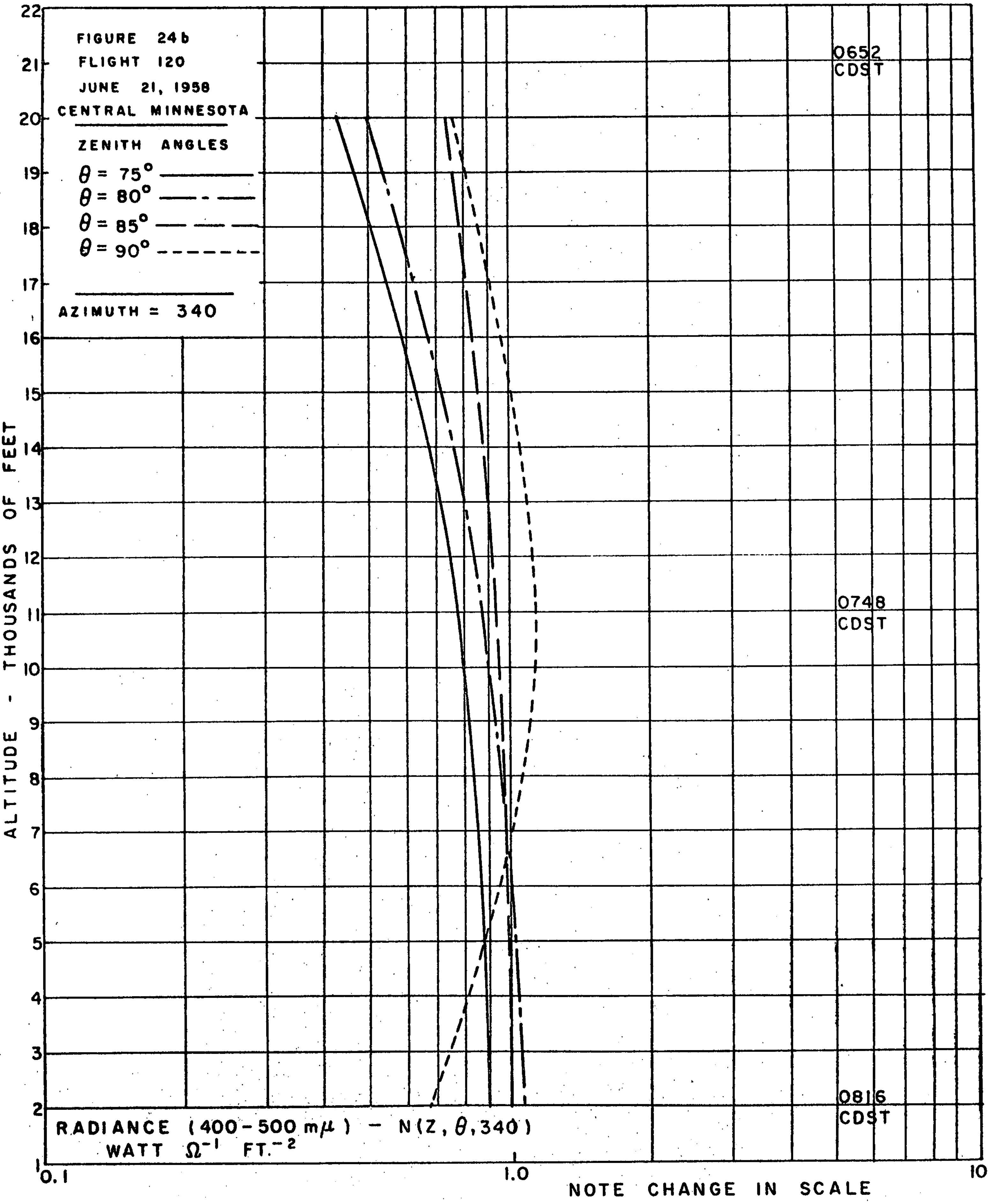
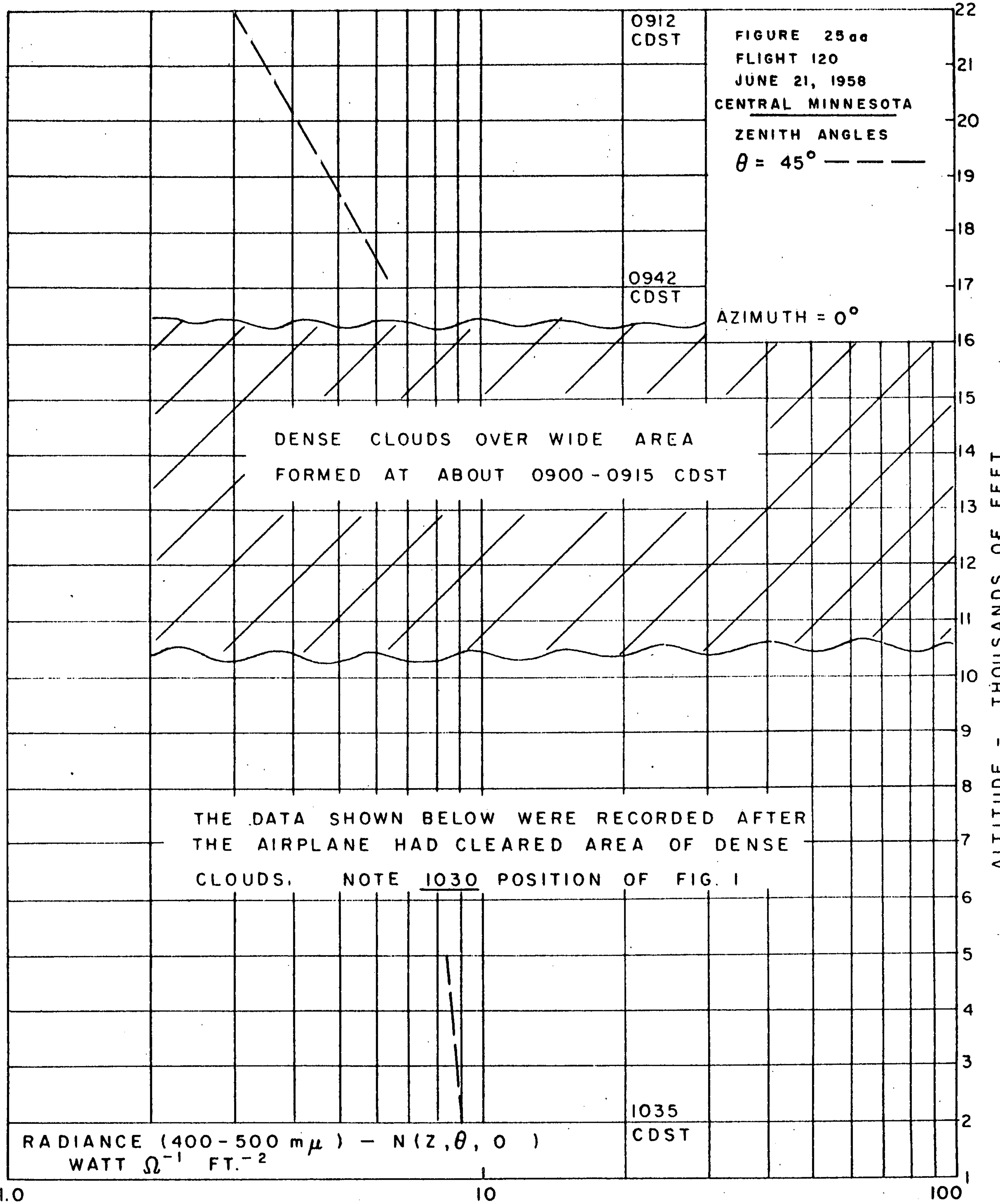


FIGURE 24b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 340
0652 CDST
0748 CDST
0816 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N(Z, θ, 340)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
NOTE CHANGE IN SCALE



NOTE CHANGE IN SCALE

The remarks on page 21 concerning Fig. 7aa apply in the case of Fig. 25aa also. In order to keep the pattern for the abscissa values to two orders of magnitude it is necessary for the 0° azimuth, 45° zenith angle plot to be placed on a separate sheet.

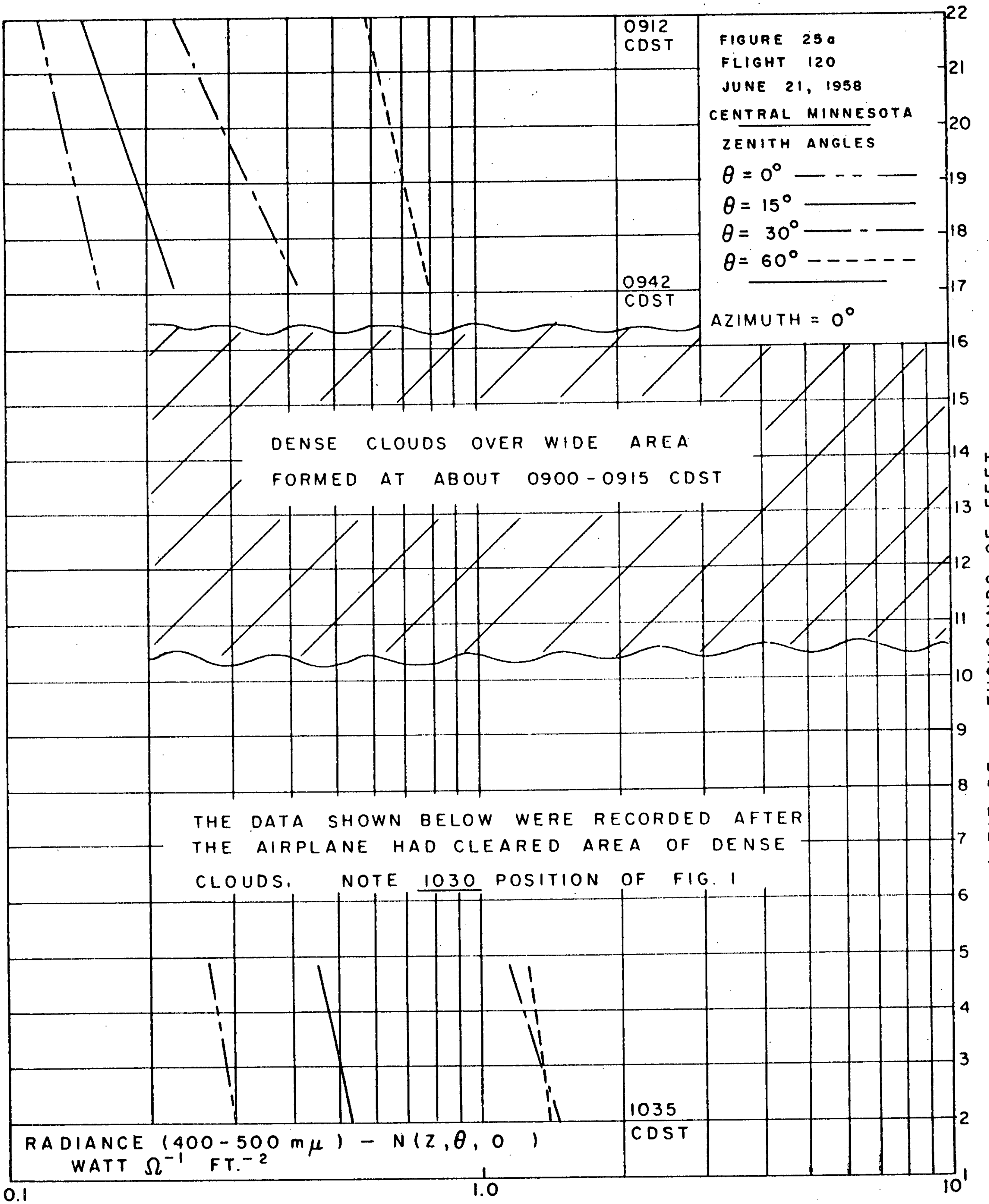


FIGURE 25a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 60°
AZIMUTH = 0°
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) - N(Z,θ,0)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10¹
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

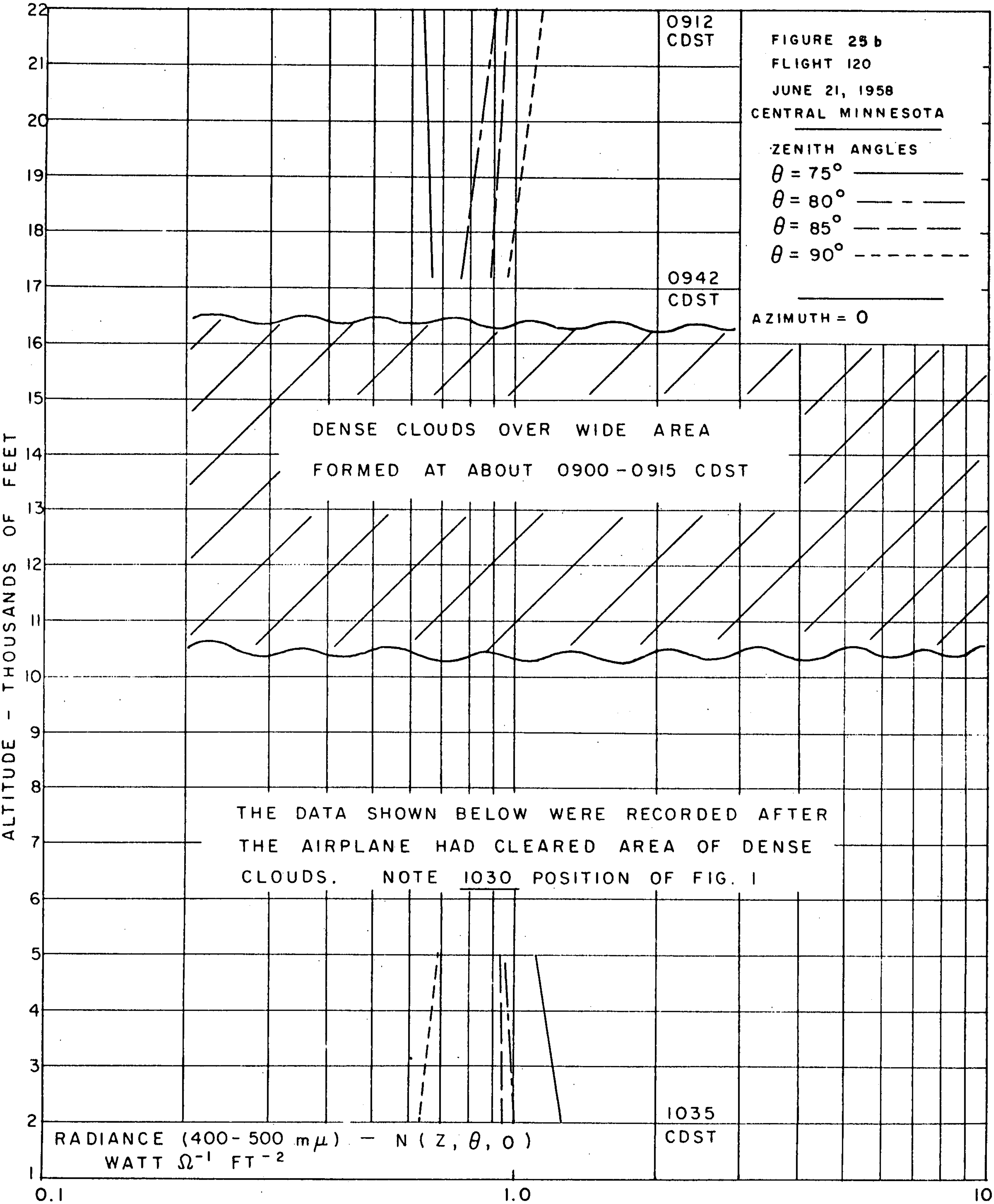


FIGURE 25 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 0
0912 CDST
0942 CDST
1035 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) — N (Z, θ, 0)
WATT Ω⁻¹ FT⁻²
0.1
1.0
10

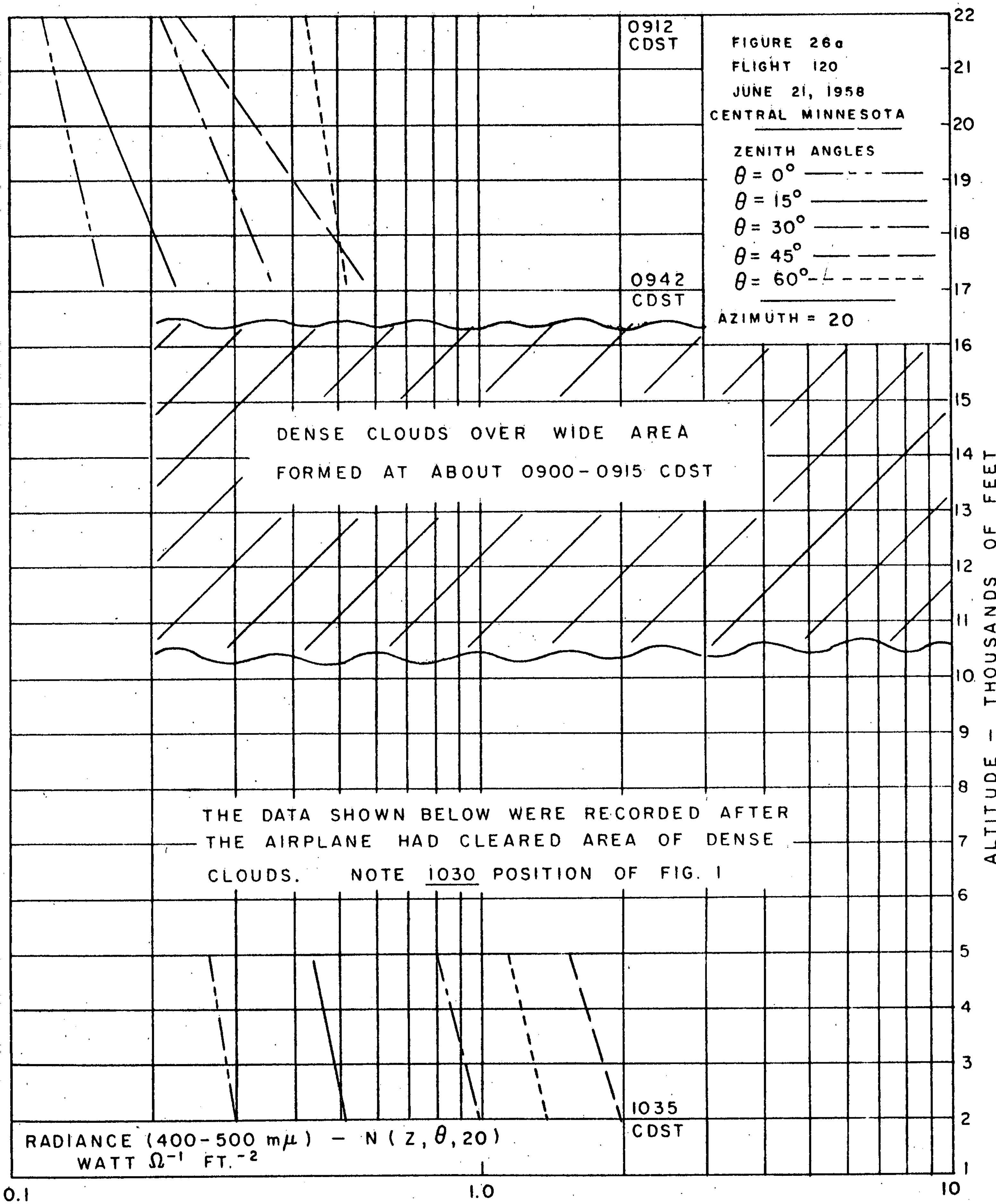


FIGURE 26a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 20
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) — N (Z, θ, 20)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE — THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

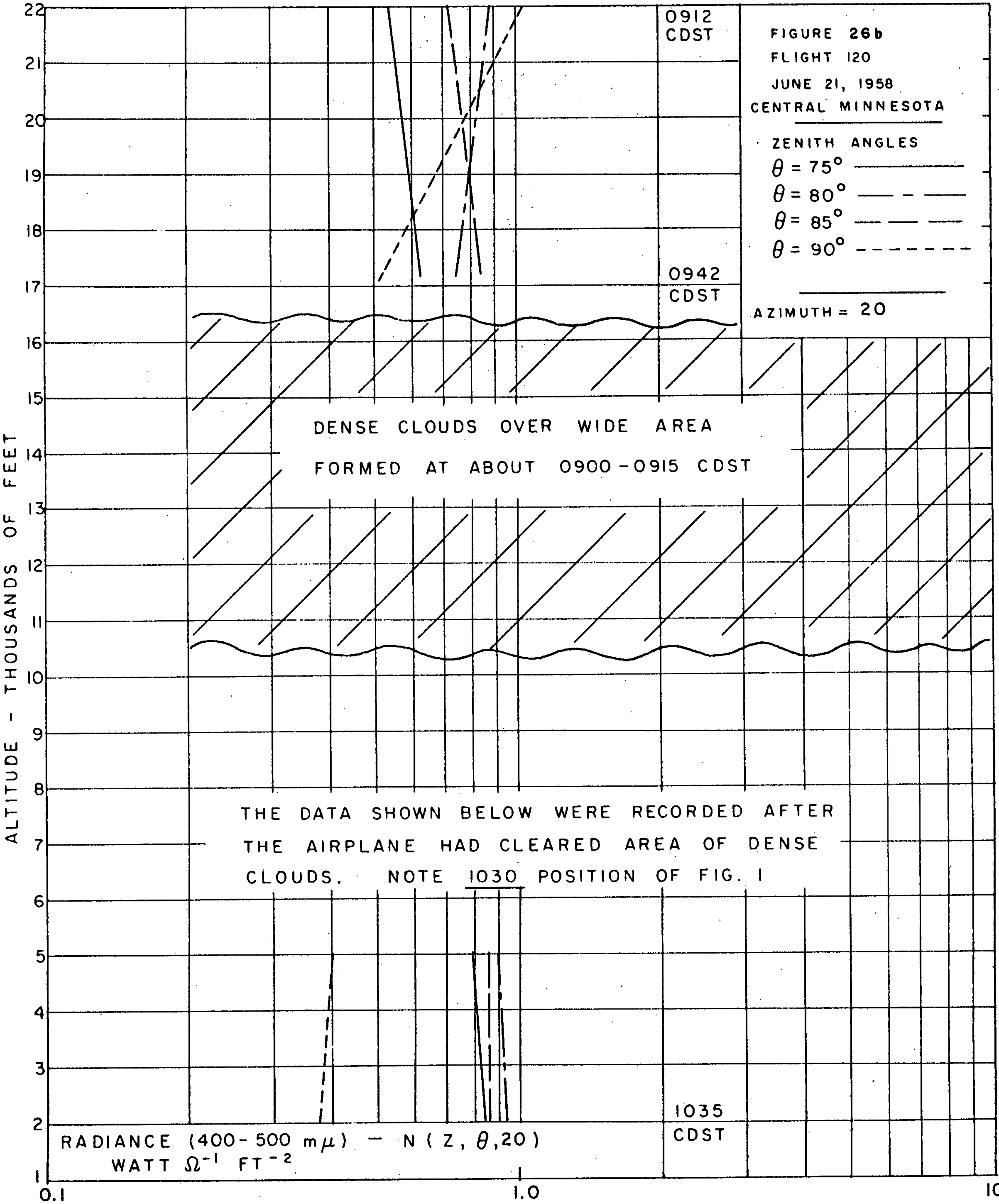


FIGURE 26b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 20
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) — N (Z, θ,20) WATT Ω⁻¹ FT⁻²
0.1
1.0
10

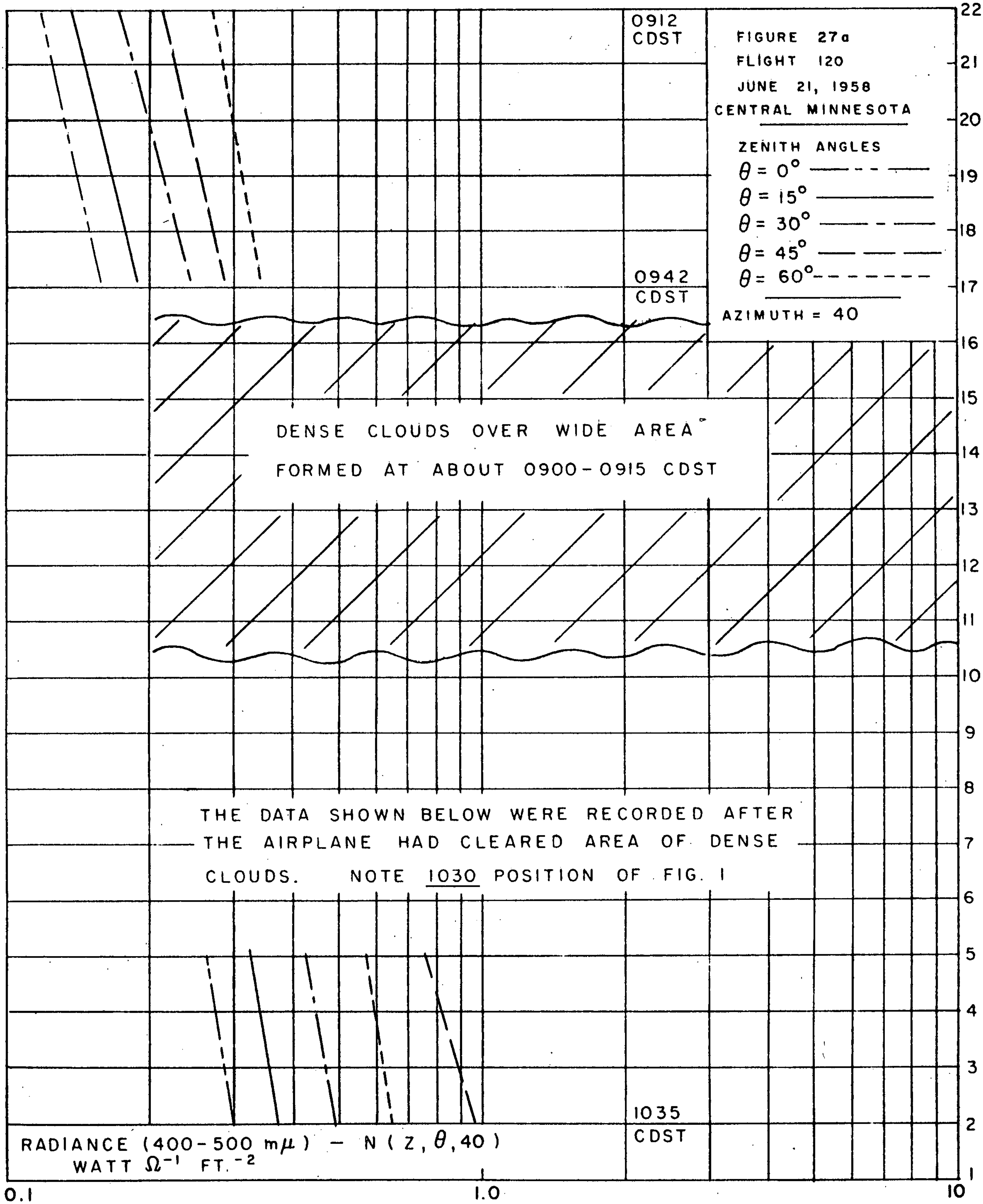


FIGURE 27a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 40
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) - N (Z, θ, 40)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

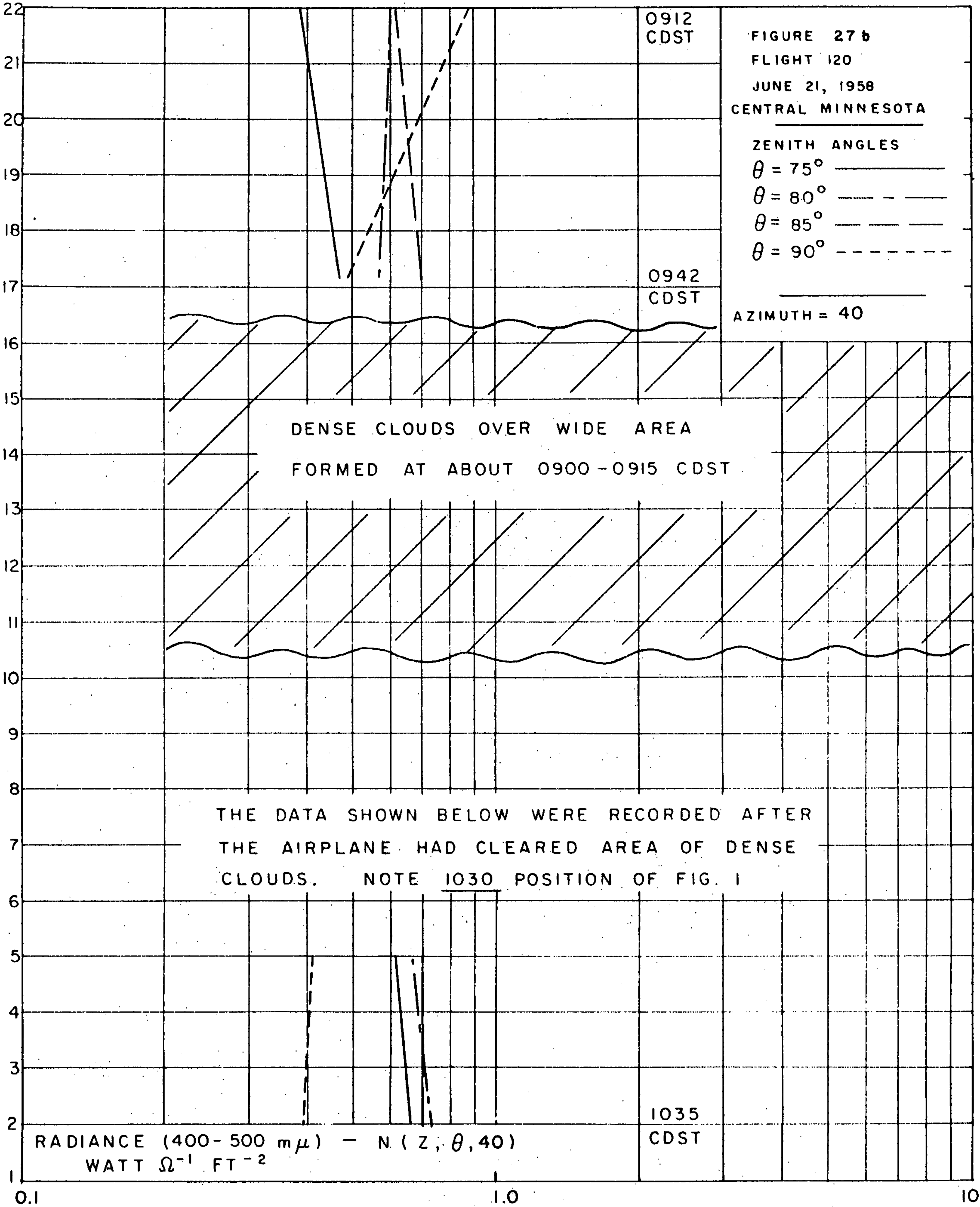
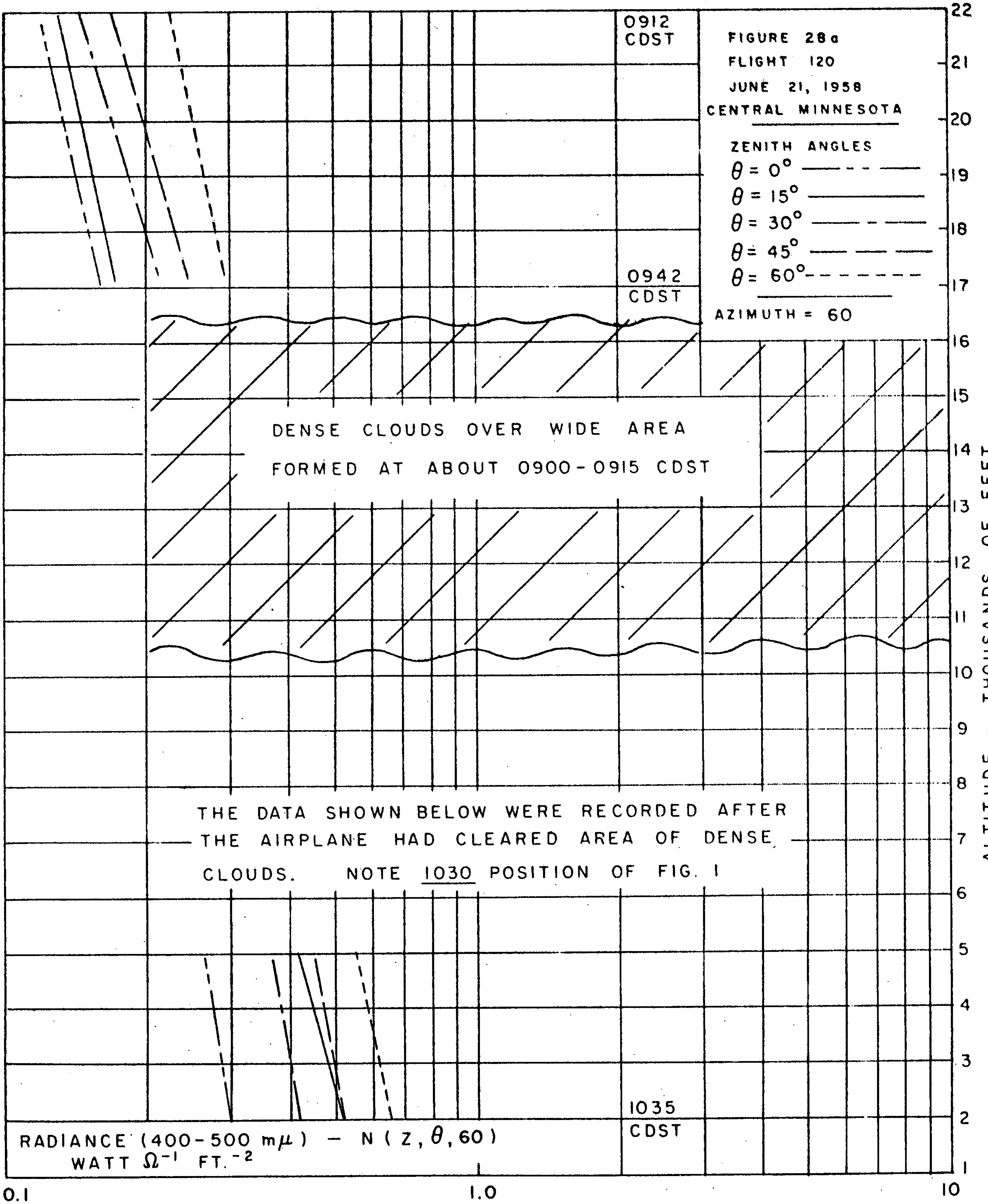


FIGURE 27b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 40
0912 CDST
0942 CDST
1035 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) — N (Z, θ, 40)
WATT Ω⁻¹ FT⁻²
0.1
1.0
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22


0912
CDST
FIGURE 28a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 60
0942
CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. I
1035
CDST
RADIANCE (400-500 mμ) — N (Z, θ, 60)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE - THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

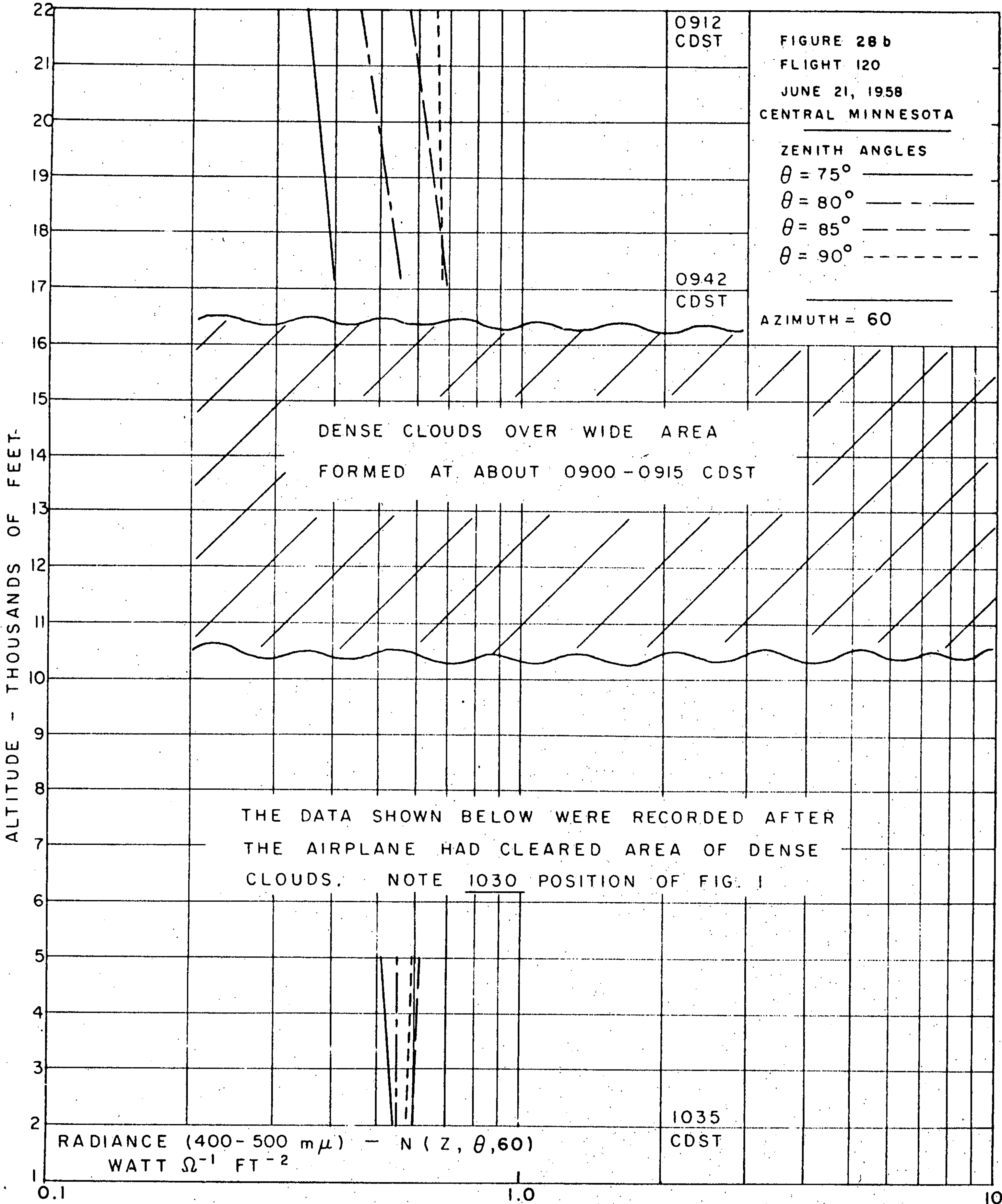
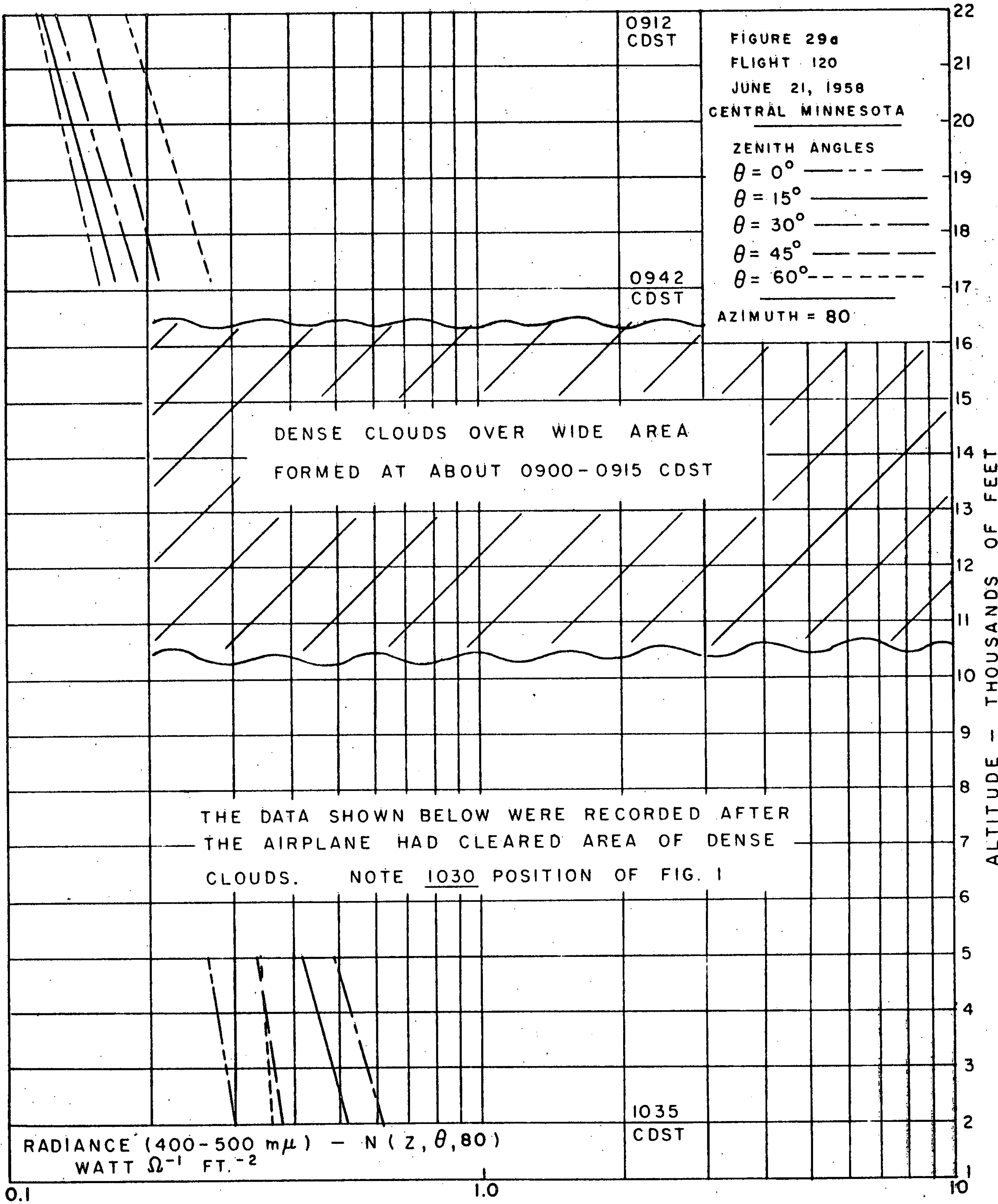
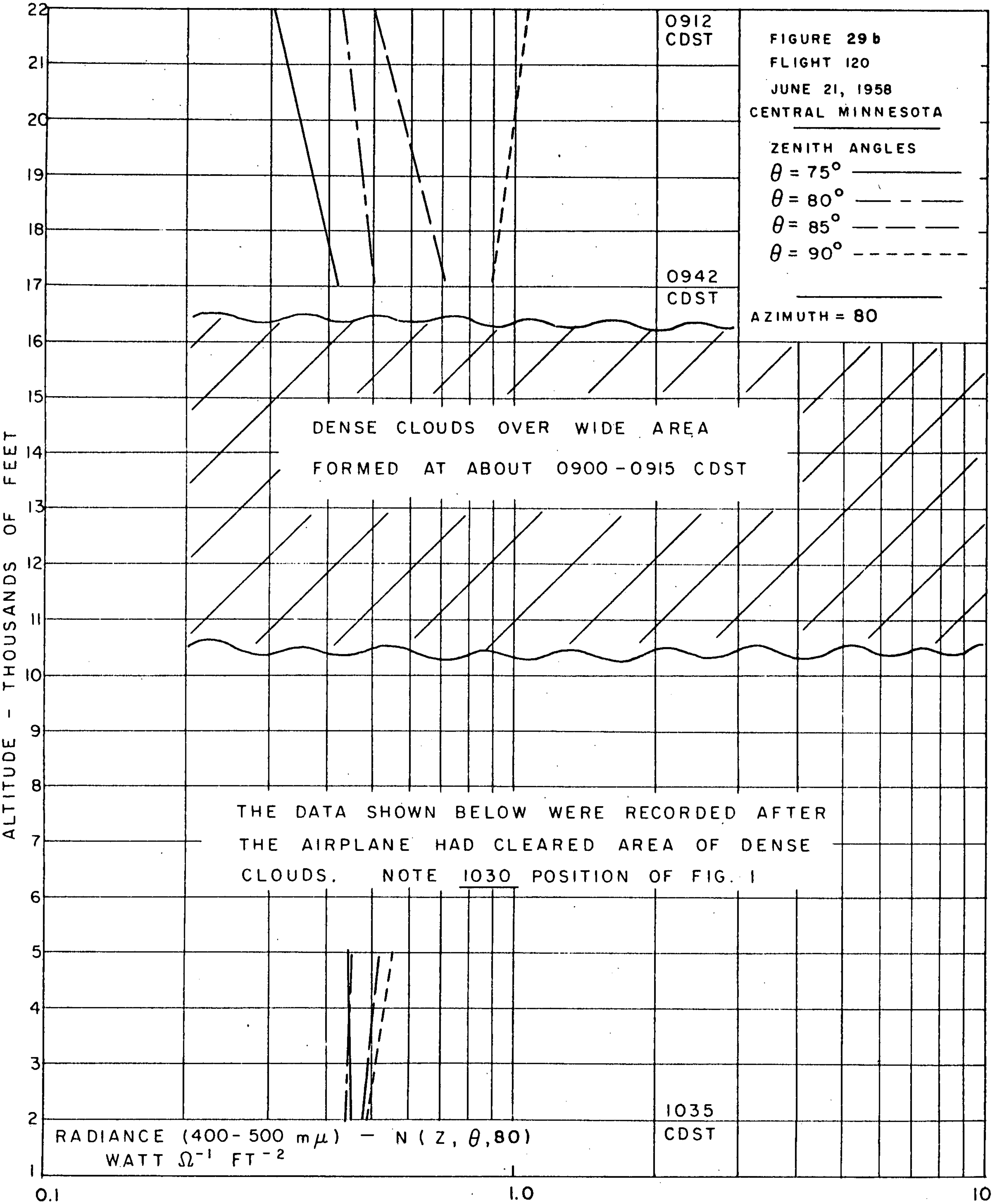


FIGURE 28 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 60
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) — N (Z, θ,60)
WATT Ω⁻¹ FT⁻²
ALTITUDE - THOUSANDS OF FEET
0.1
1.0
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22


0912
CDST
FIGURE 29a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 80
0942
CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
RADIANCE (400-500 mμ) - N (Z, θ, 80)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE - THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1


0912
CDST
FIGURE 29 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
0942
CDST
AZIMUTH = 80
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
RADIANCE (400-500 mμ) — N (Z, θ,80)
WATT Ω⁻¹ FT⁻²
ALTITUDE - THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0.1
1.0
10

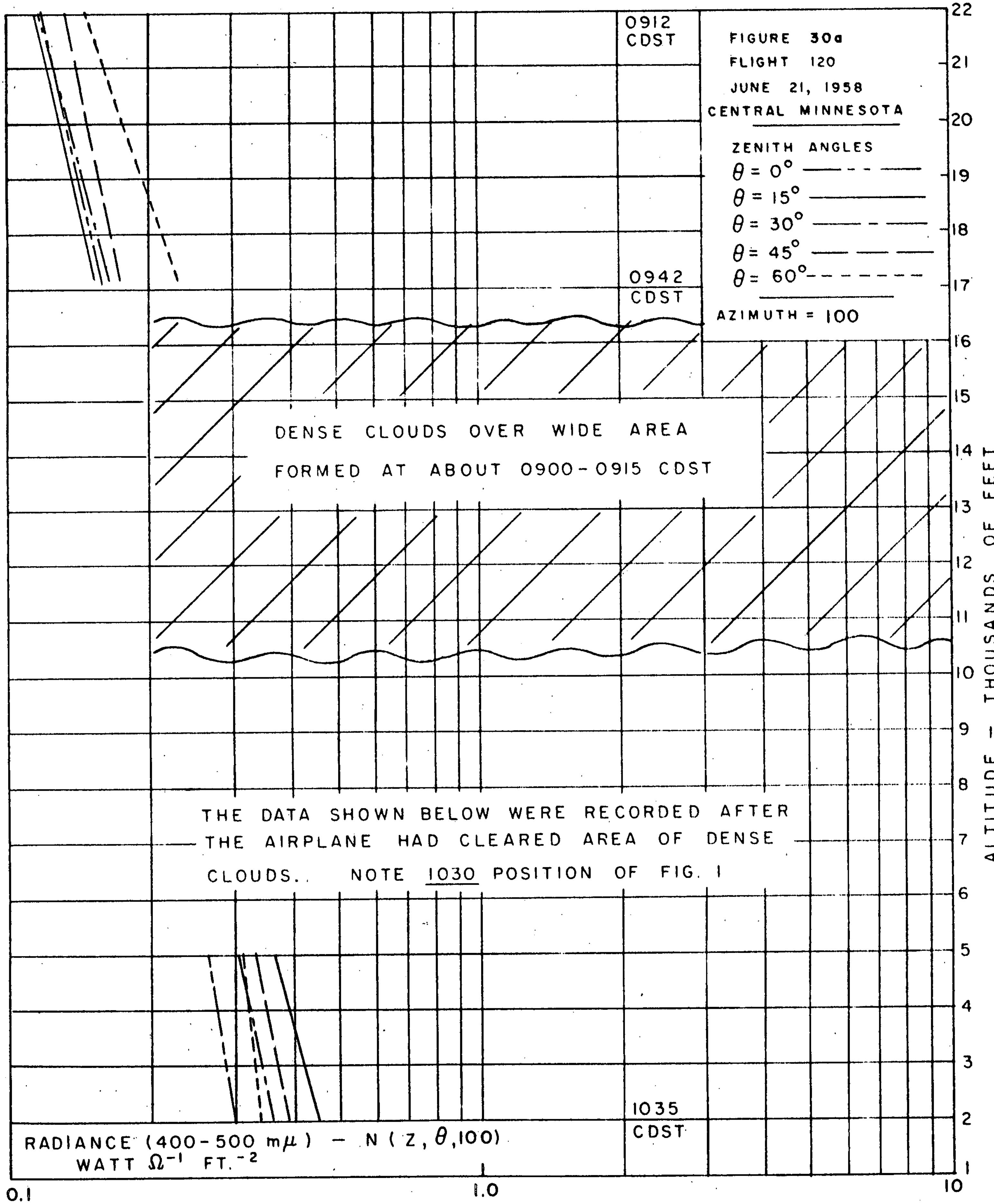


FIGURE 30a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 100
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) - N (Z, θ,100)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

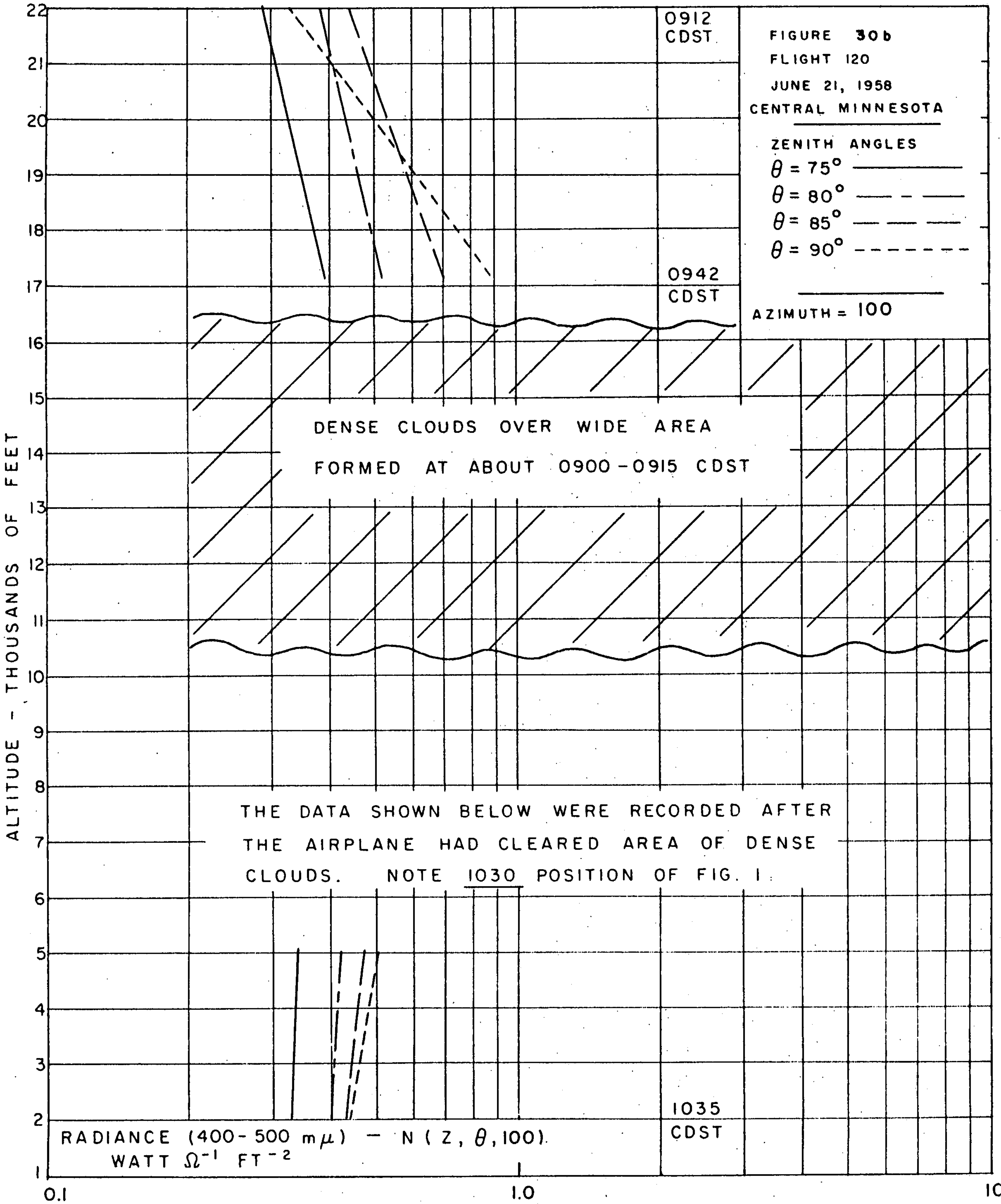


FIGURE 30b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 100
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N (Z, θ, 100)
WATT Ω⁻¹ FT⁻²
0.1
1.0
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

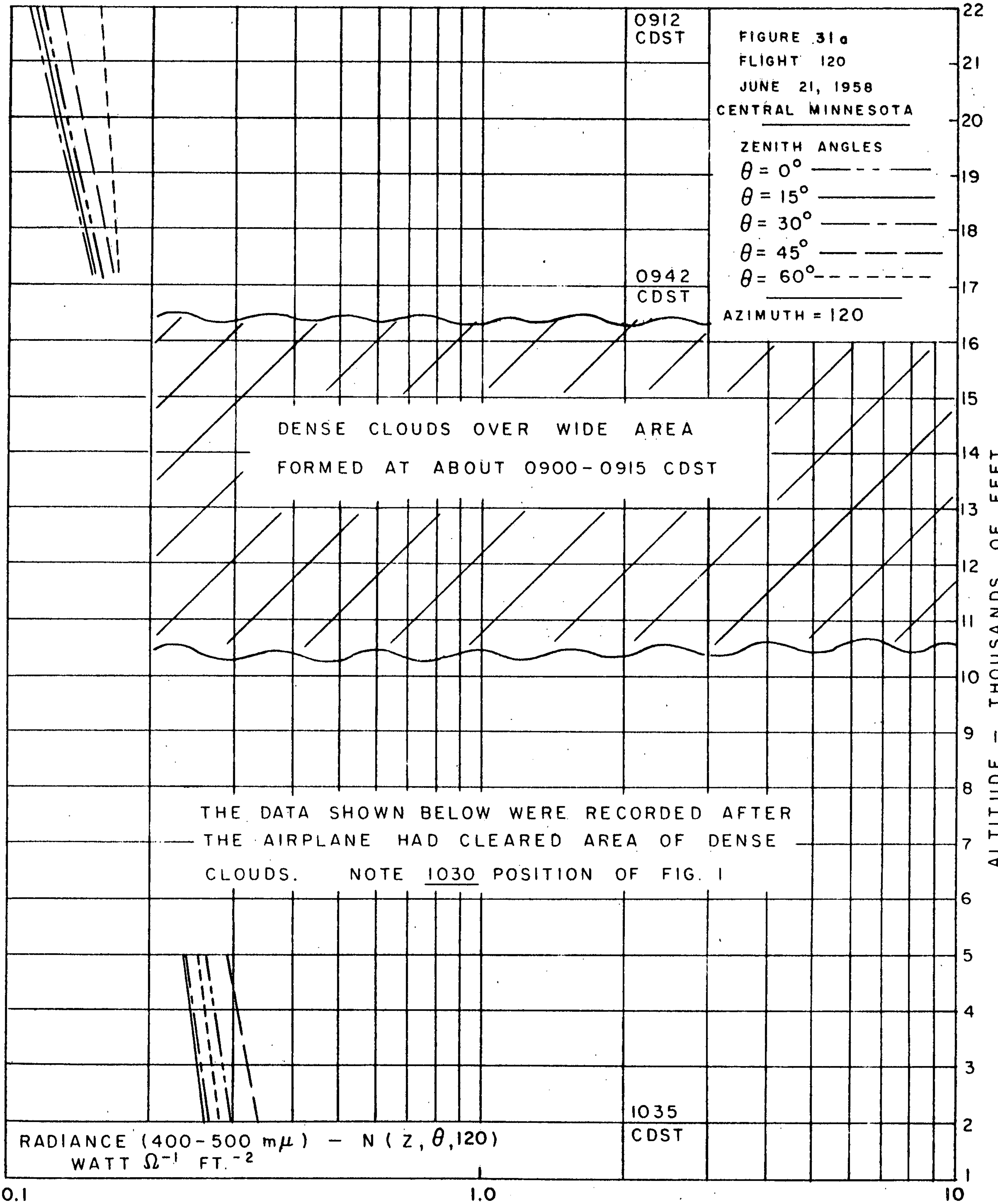


FIGURE 31a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 120
0912 CDST
0942 CDST
1035 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
RADIANCE (400-500 mμ) – N (Z, θ,120)
WATT Ω⁻¹ FT.⁻²
ALTITUDE – THOUSANDS OF FEET
0.1
1.0
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

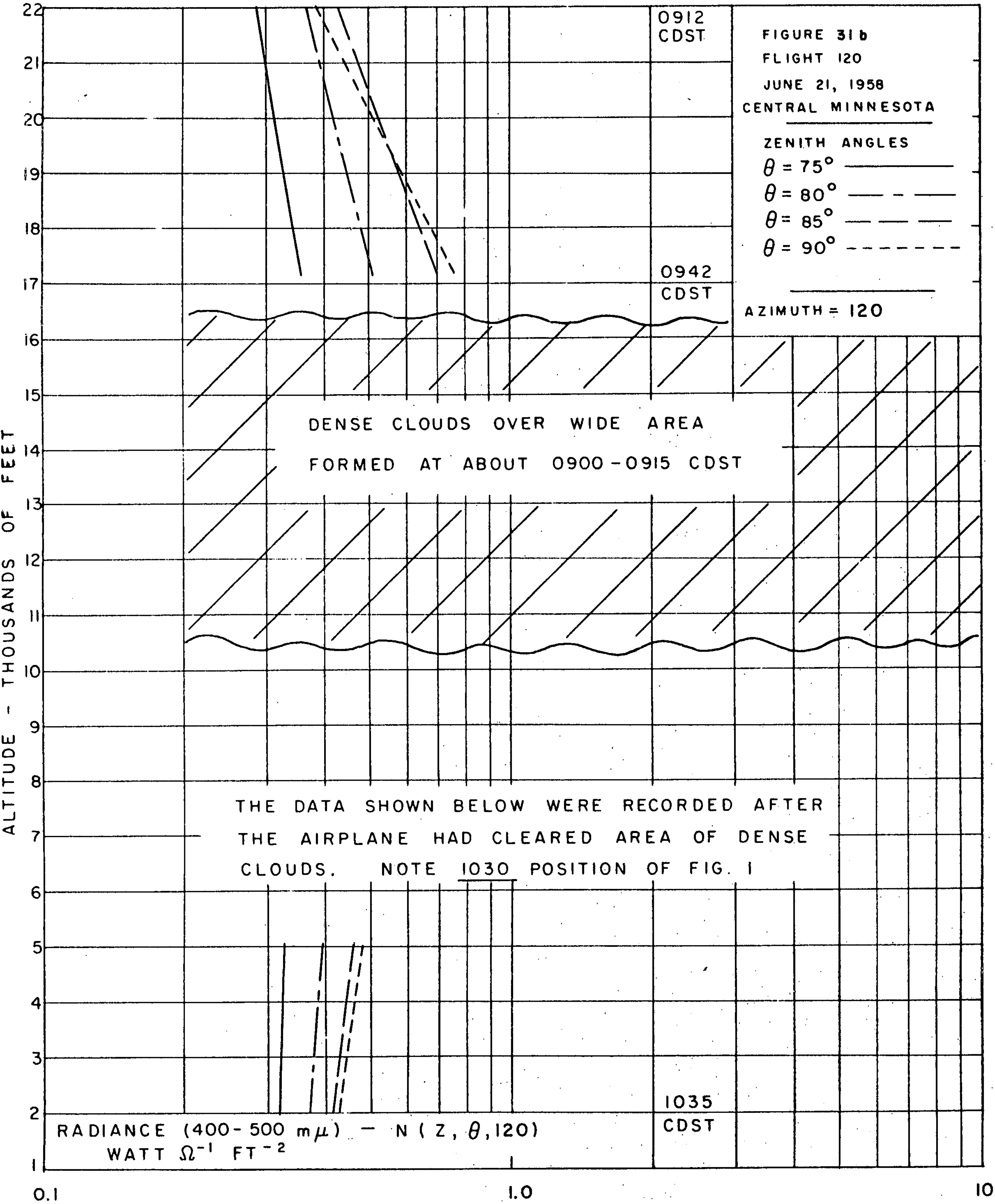
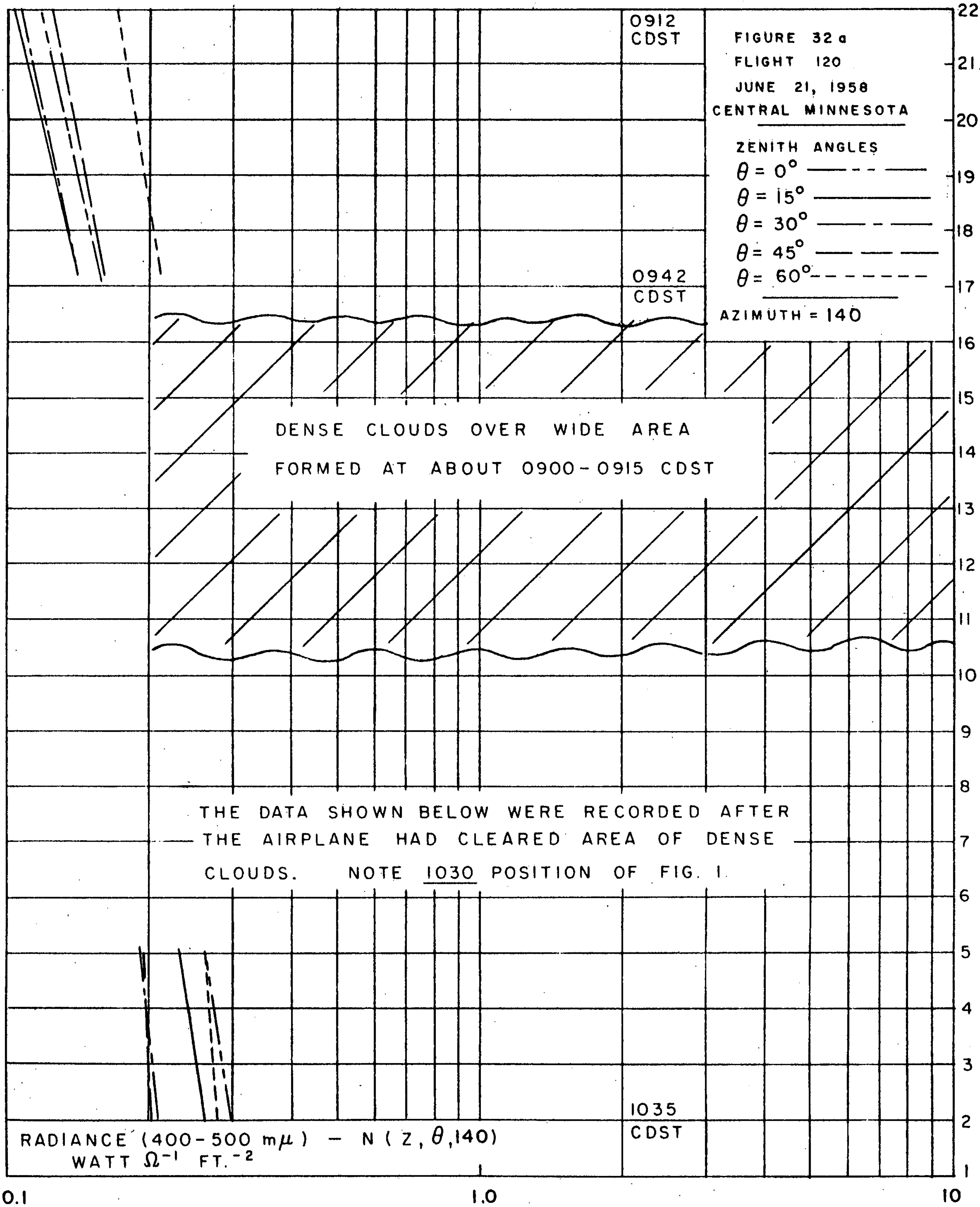
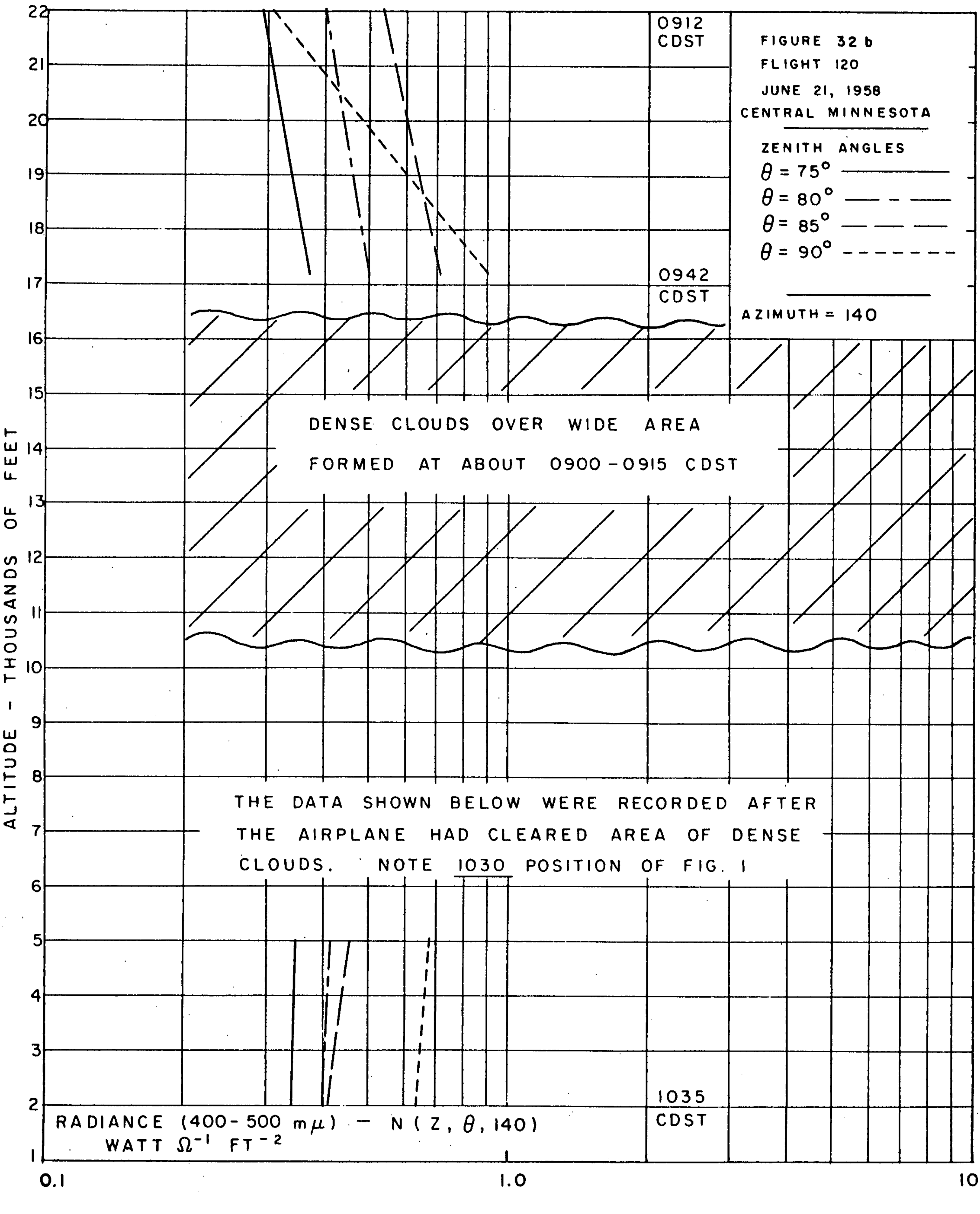
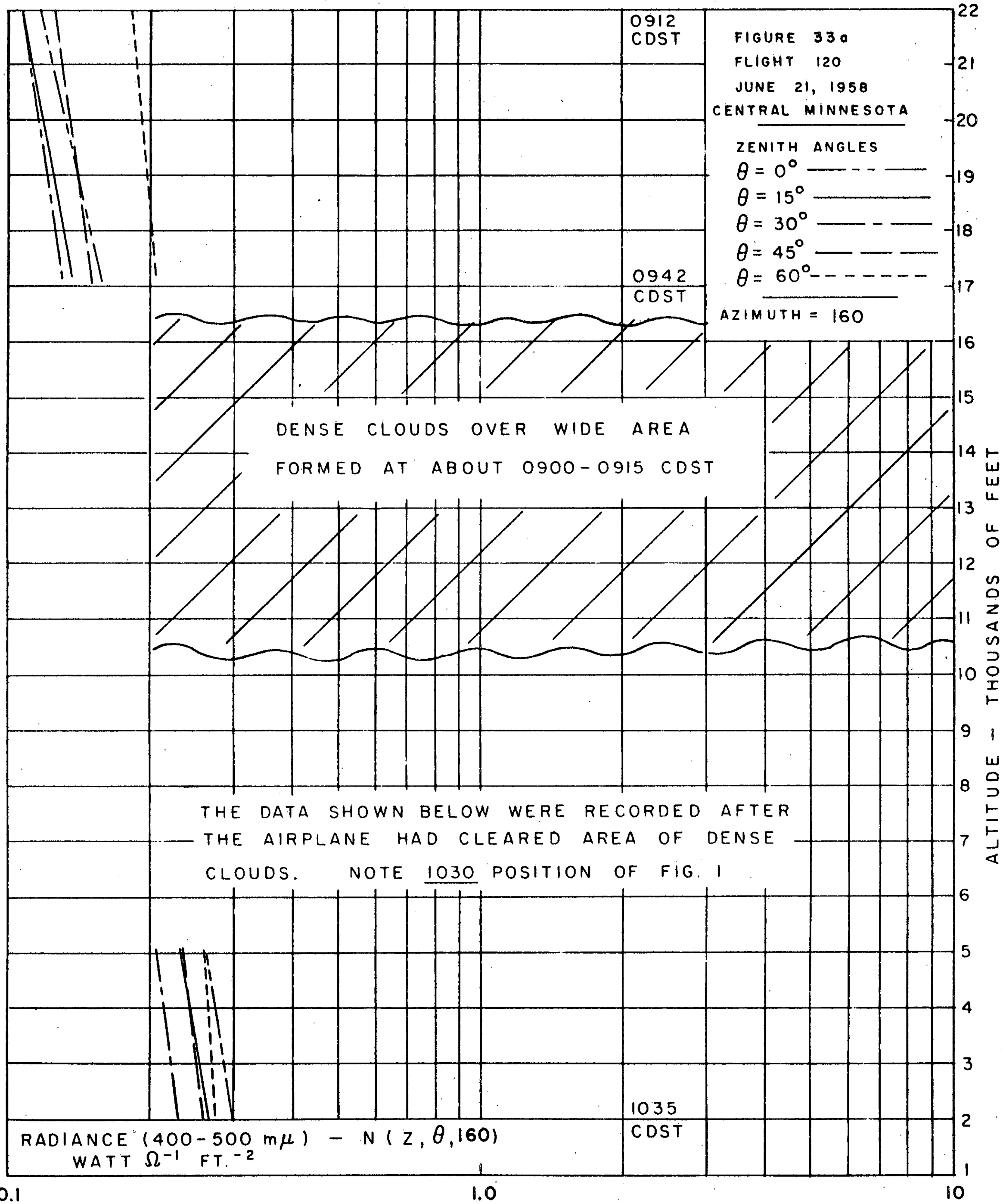


FIGURE 31 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 120
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) — N (Z, θ, 120)
WATT Ω⁻¹ FT⁻²
ALTITUDE - THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0.1
1.0
10


0912
CDST
FIGURE 32 a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 140
0942
CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
RADIANCE (400-500 mμ) - N (Z, θ,140)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ALTITUDE - THOUSANDS OF FEET


0912
CDST
FIGURE 32 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 140
0942
CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
RADIANCE (400-500 mμ) — N (Z, θ, 140)
WATT Ω⁻¹ FT⁻²
ALTITUDE - THOUSANDS OF FEET
0.1
1.0
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22


0912
CDST
FIGURE 33a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 160
0942
CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
RADIANCE (400-500 mμ) - N (Z, θ, 160)
WATT Ω⁻¹ FT.⁻²
ALTITUDE - THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0.1
1.0
10

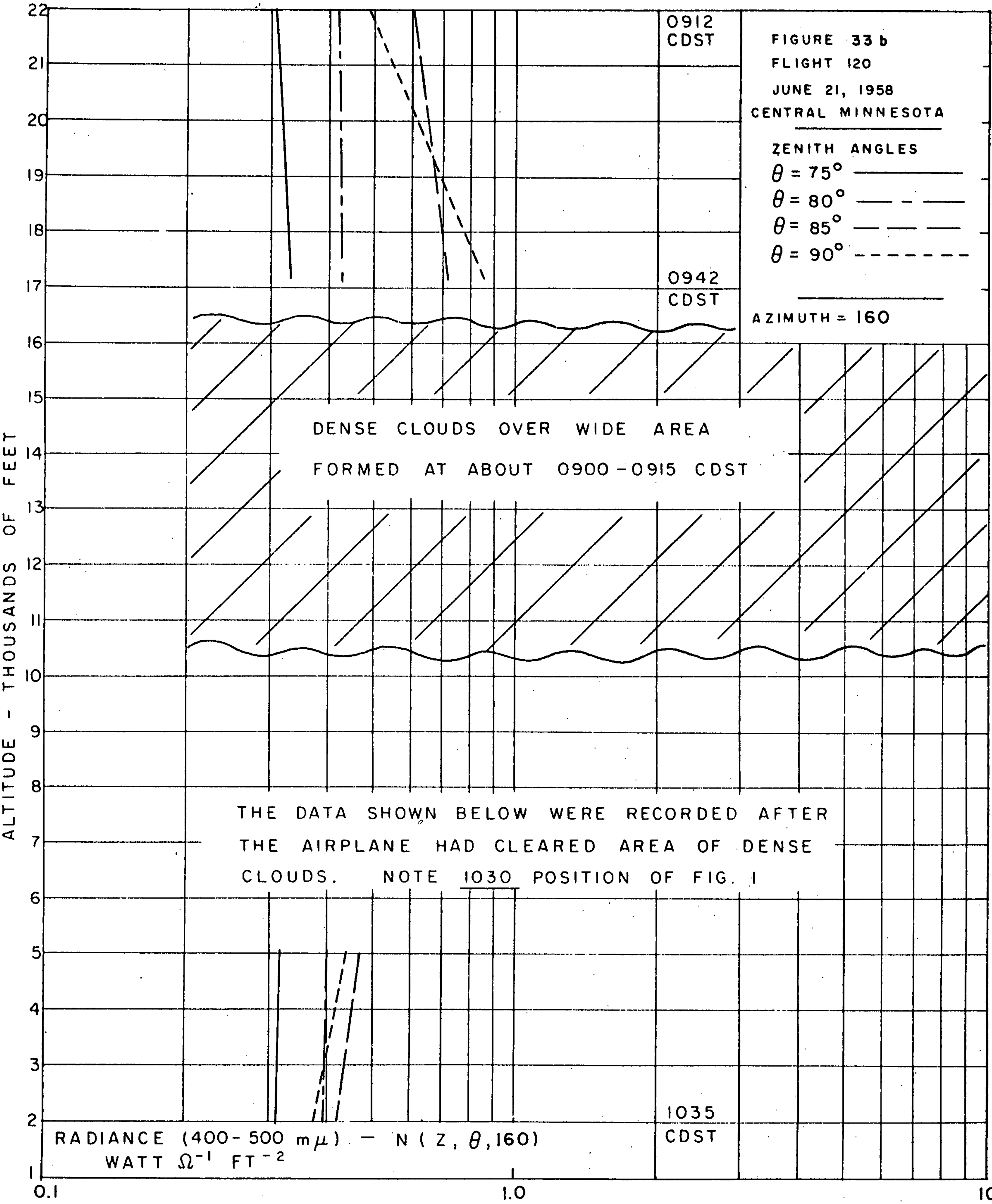


FIGURE 33 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 160
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N (Z, θ, 160)
WATT Ω⁻¹ FT⁻²
0.1
1.0
10

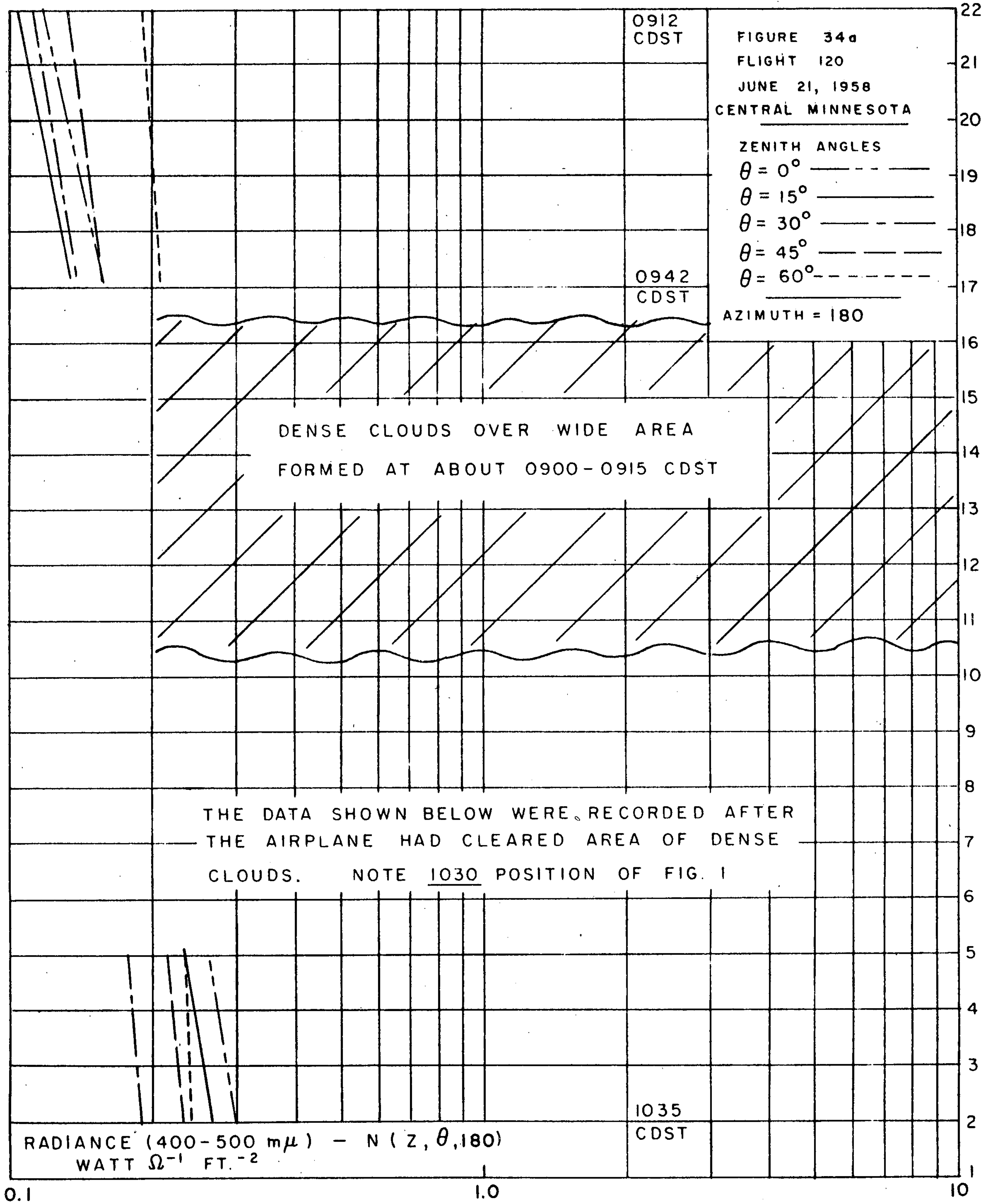


FIGURE 34a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 180
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) – N (Z, θ, 180)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE – THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

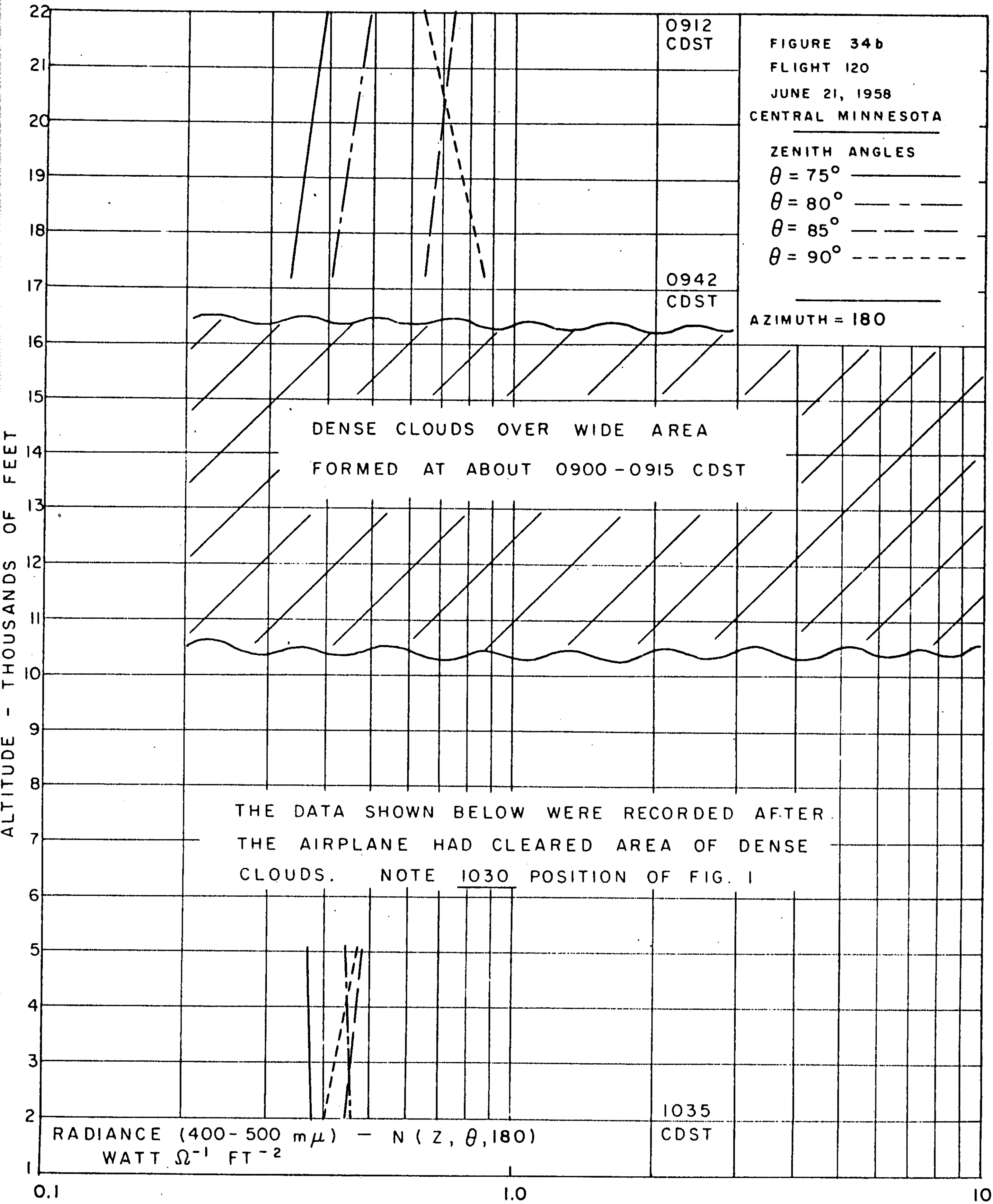
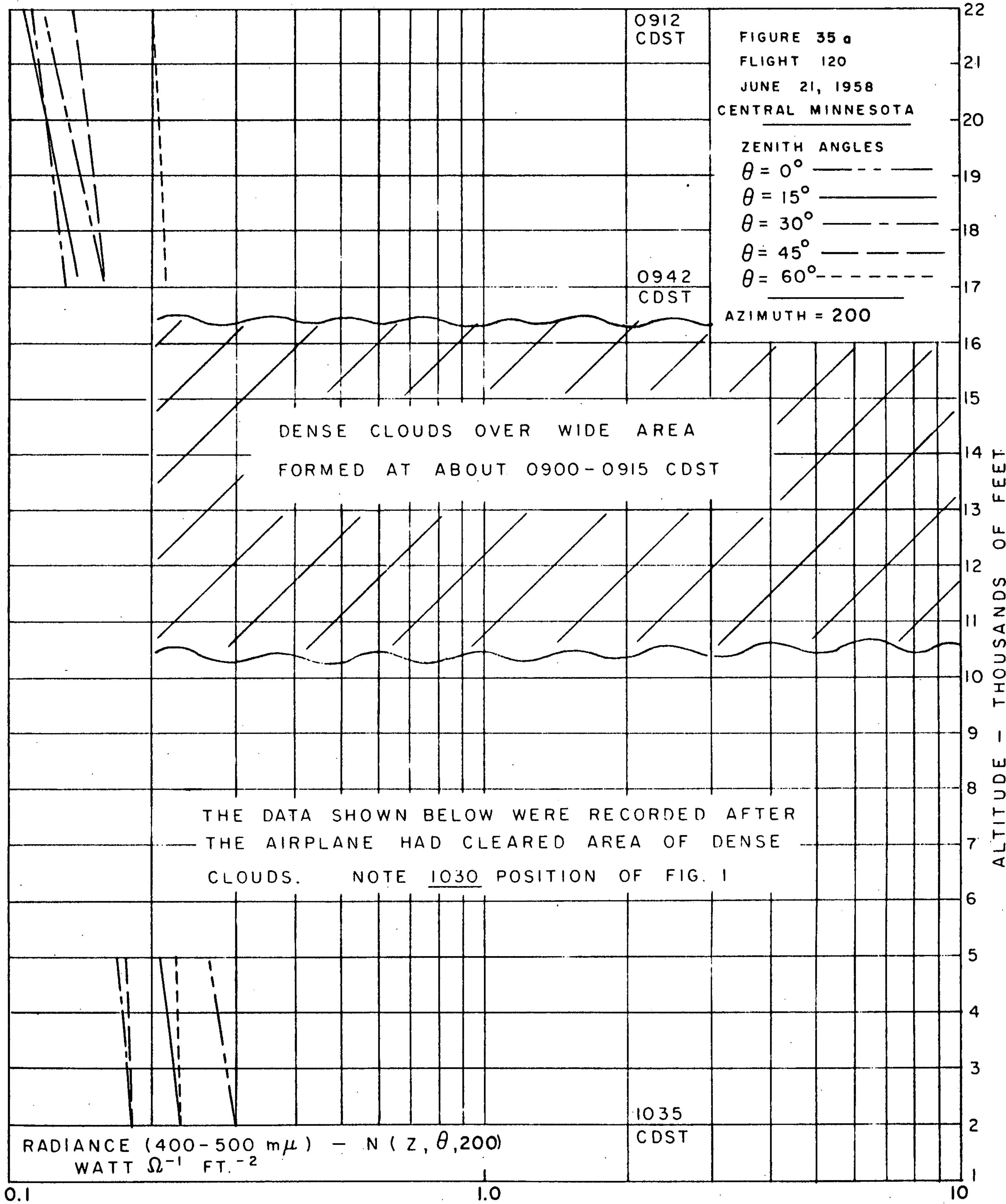


FIGURE 34b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 180
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) — N (Z, θ,180)
WATT Ω⁻¹ FT⁻²
ALTITUDE - THOUSANDS OF FEET
0.1
1.0
10
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1


0912
CDST
FIGURE 35 a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 200
0942
CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
RADIANCE (400-500 mμ) — N (Z, θ,200)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
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7
8
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10
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16
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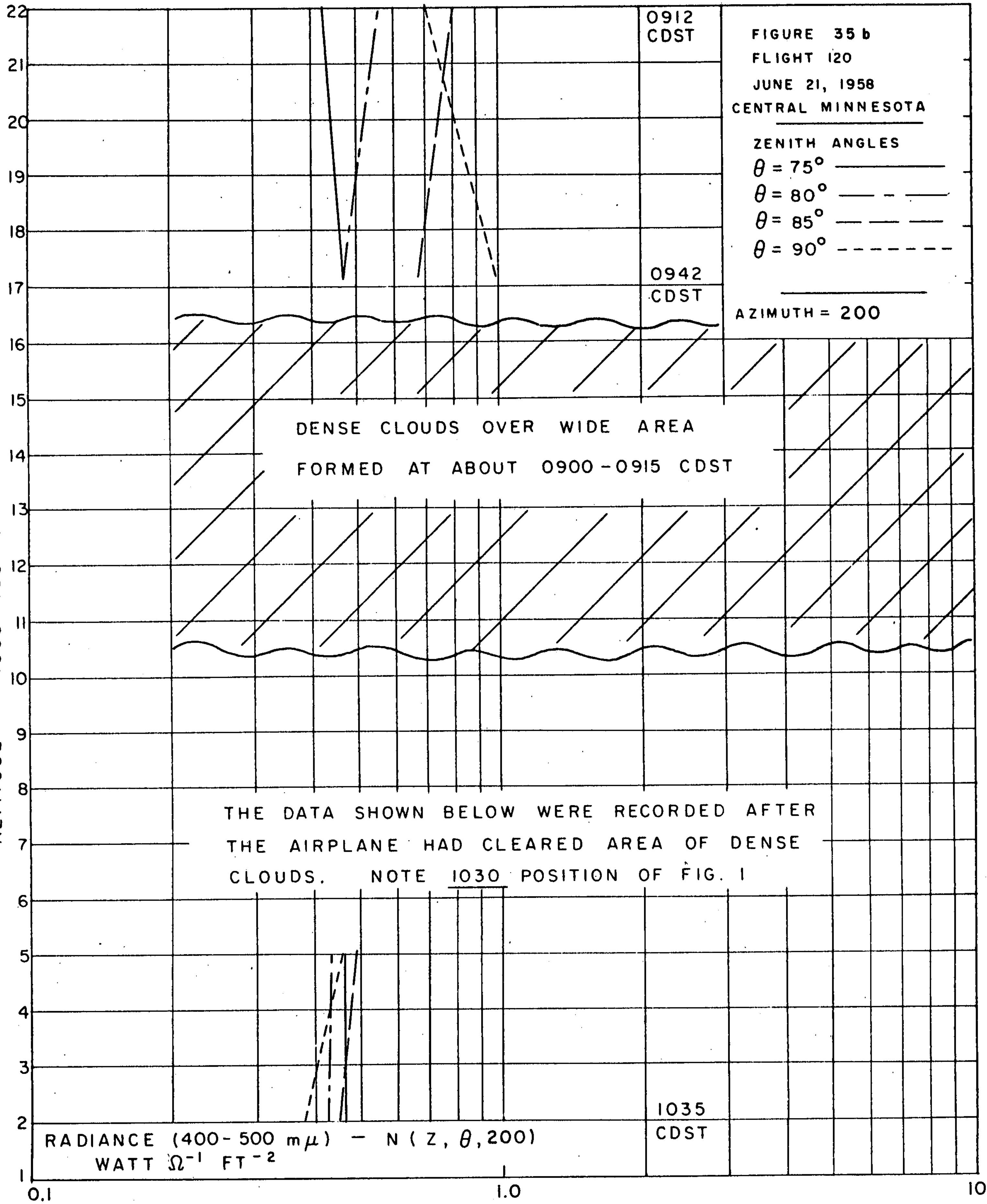
21
22


0912
CDST
0942
CDST
1035
CDST
FIGURE 35 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 200
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N (Z, θ, 200)
WATT Ω⁻¹ FT⁻²
0.1
1.0
10

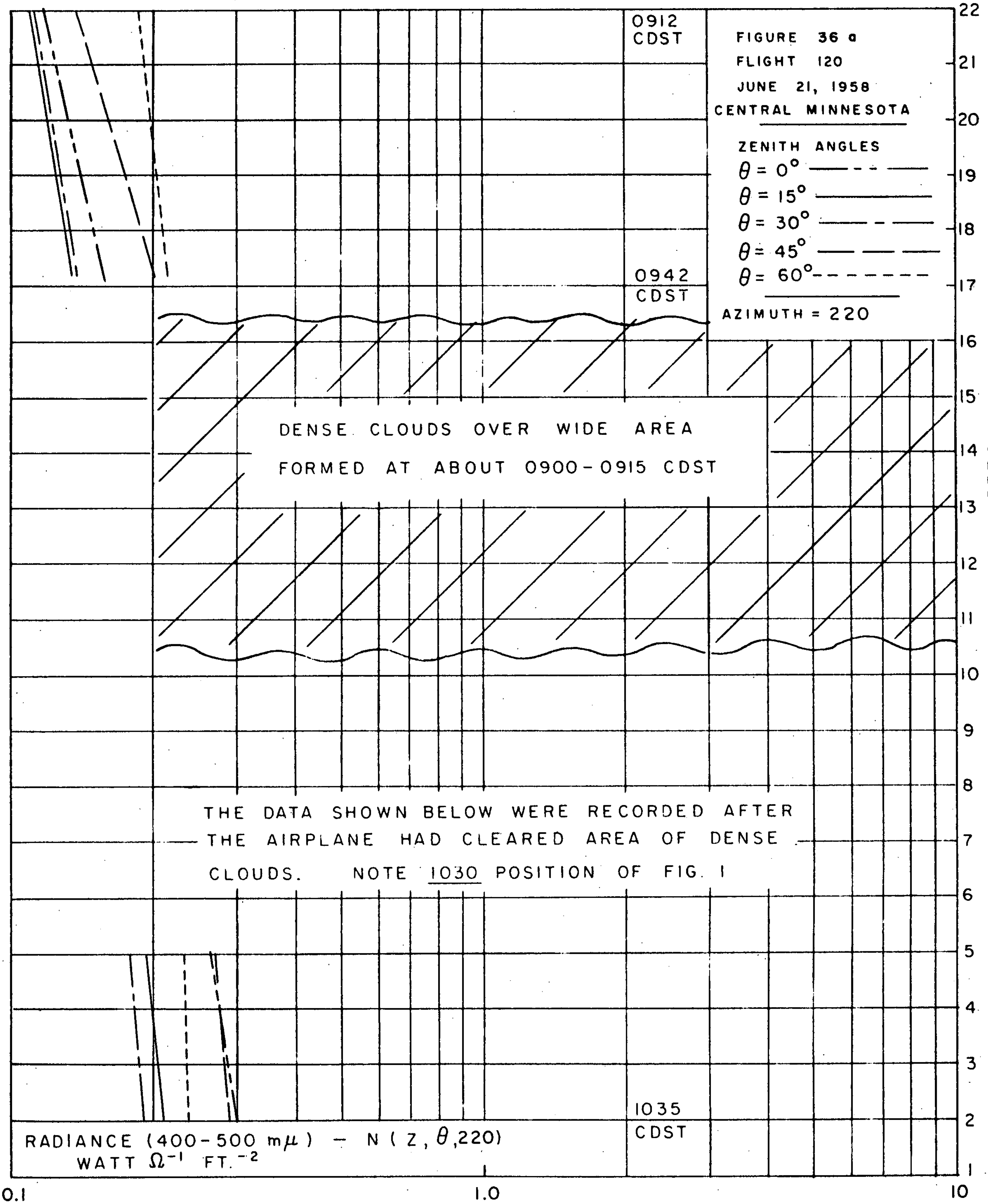


FIGURE 36 a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 220
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) - N (Z, θ,220)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

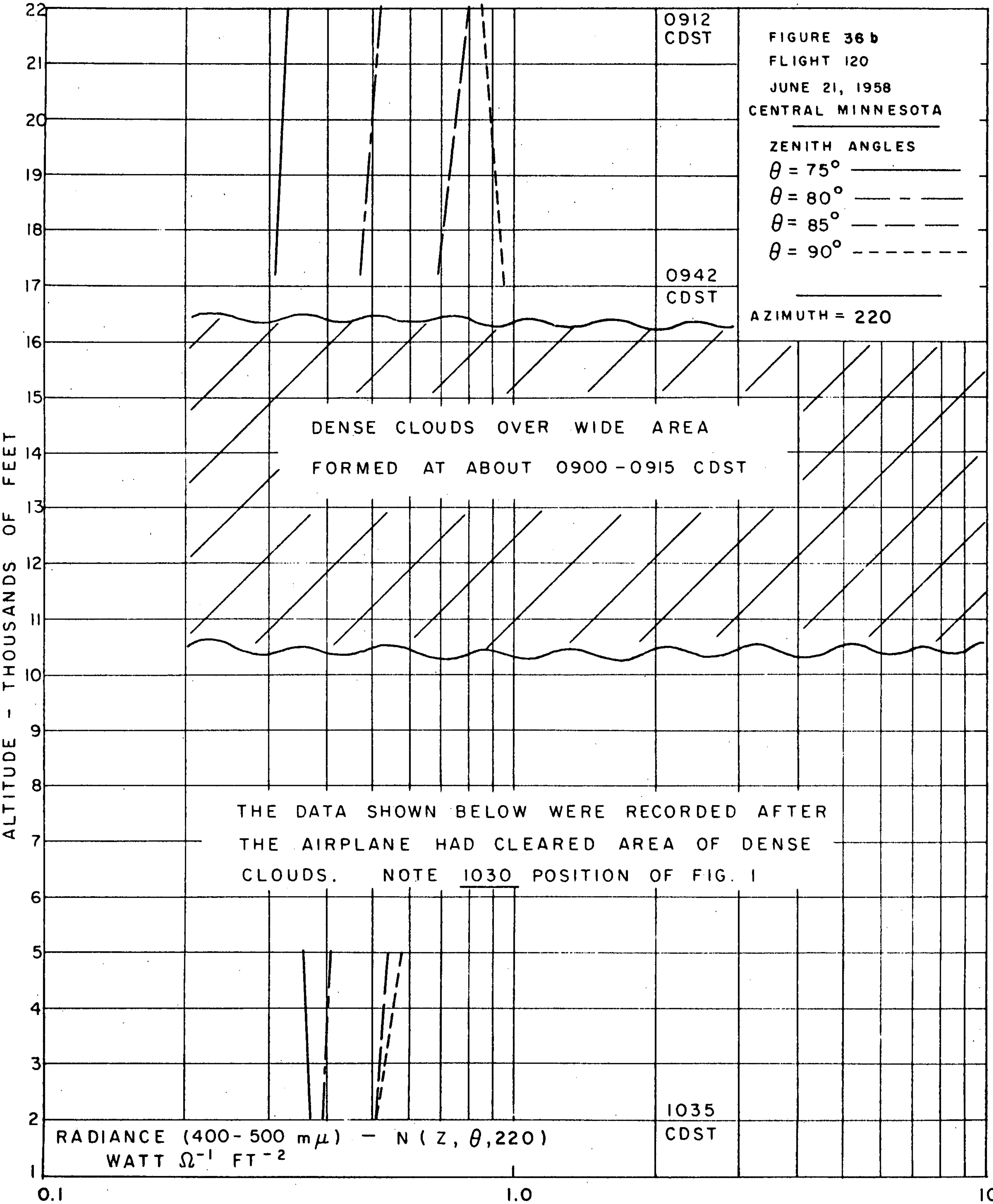


FIGURE 36 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 220
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) - N (Z, θ, 220)
WATT Ω⁻¹ FT⁻²
0.1
1.0
10
1
2
3
4
5
6
7
8
9
10
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12
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16
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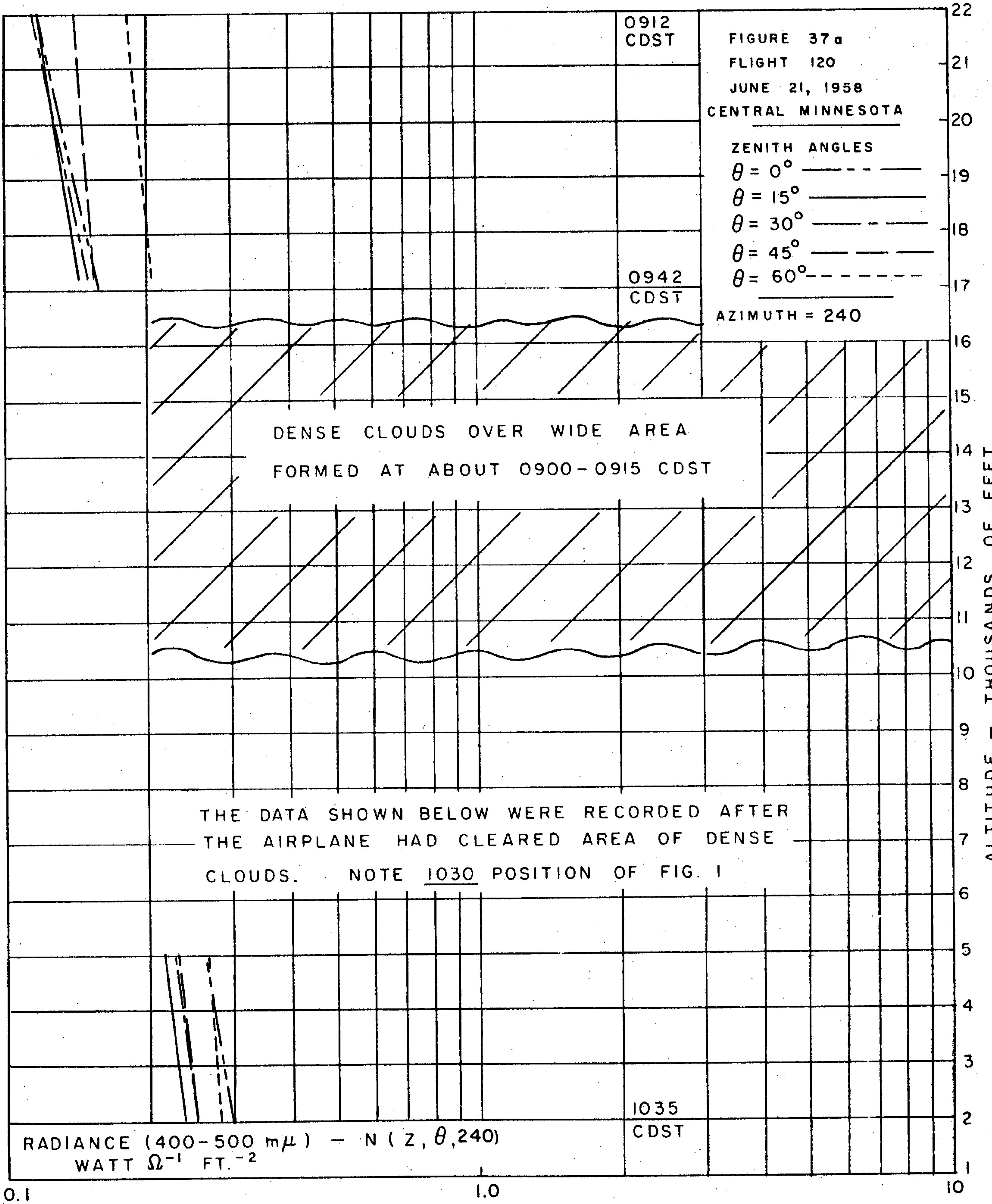
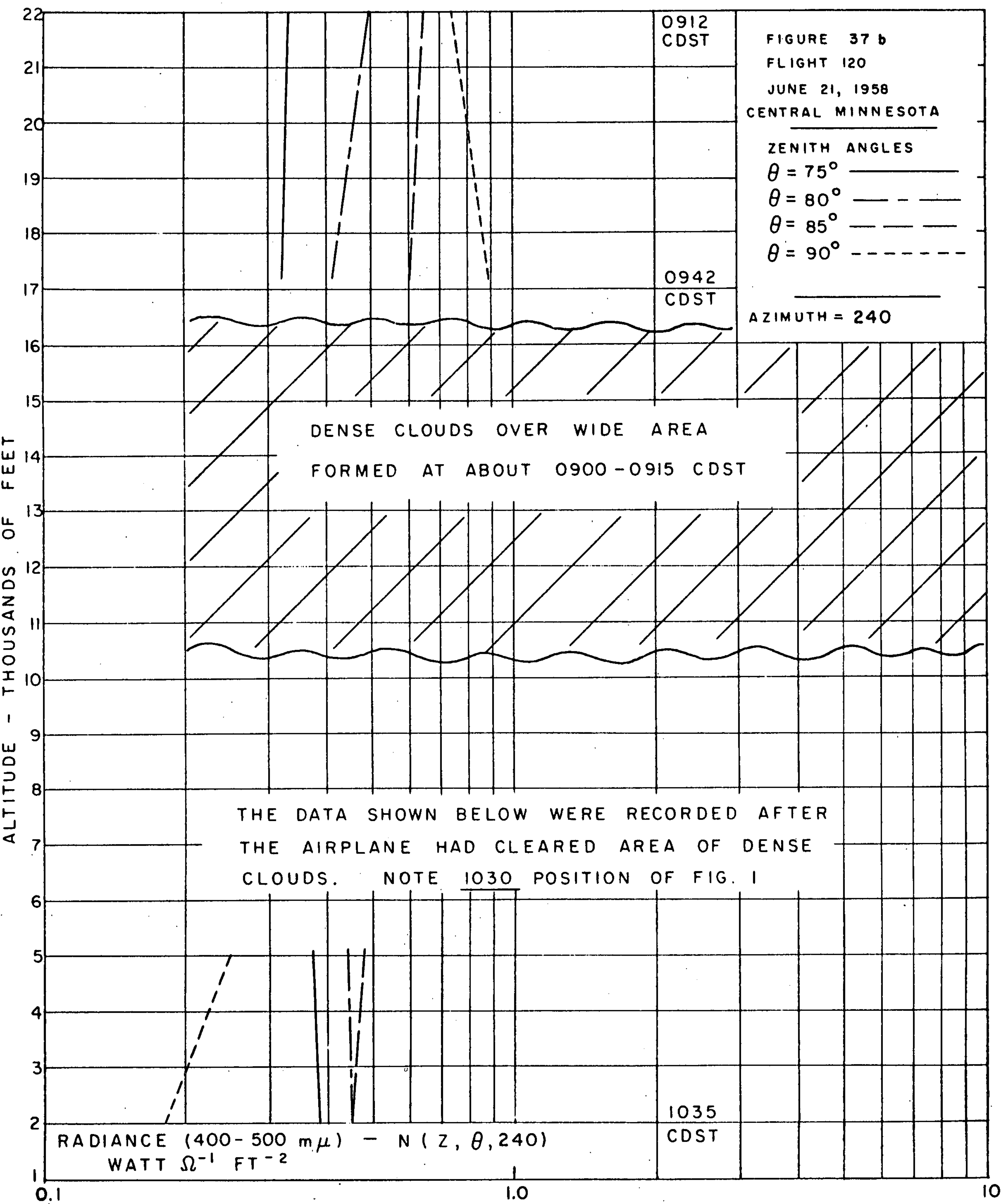
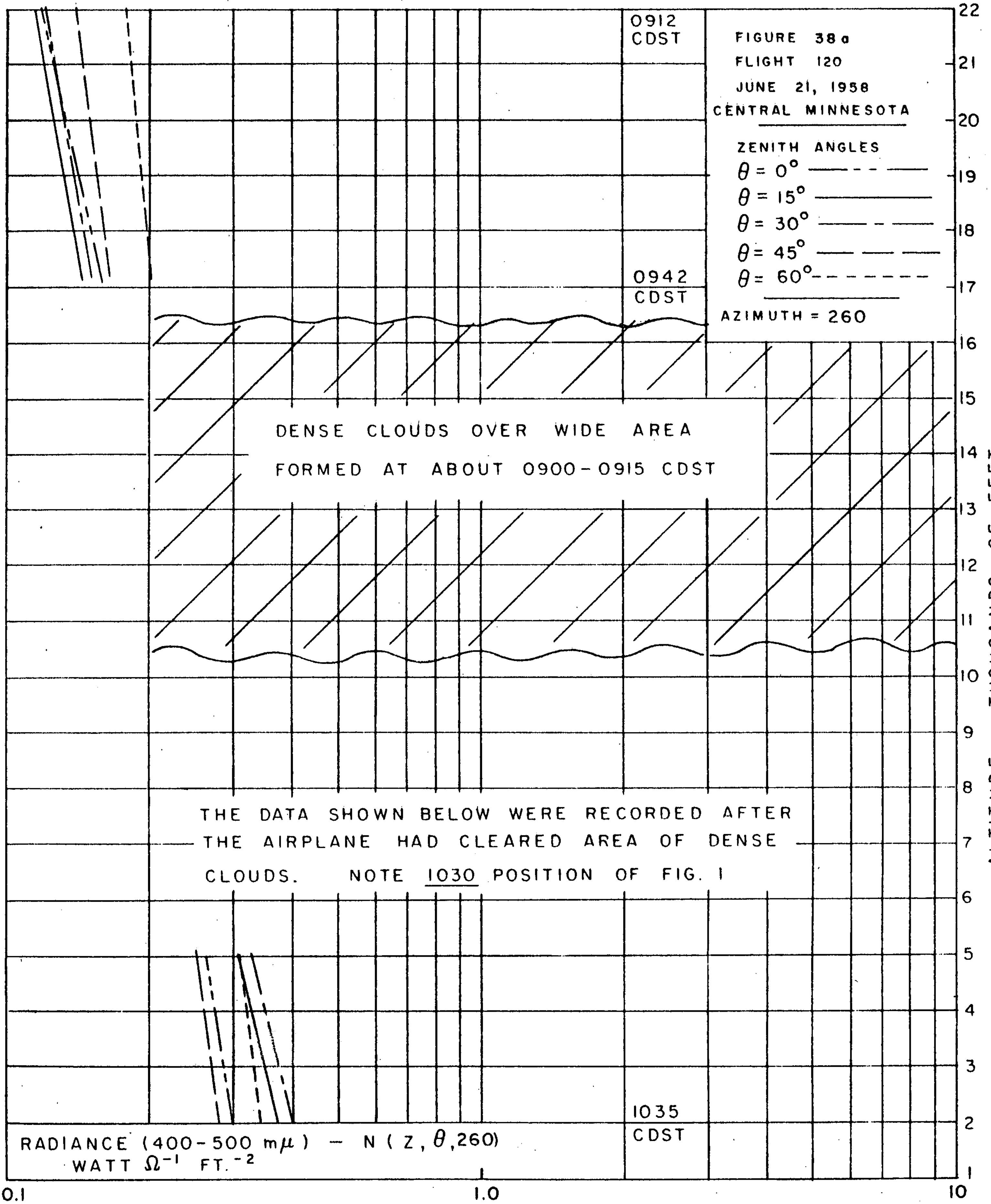
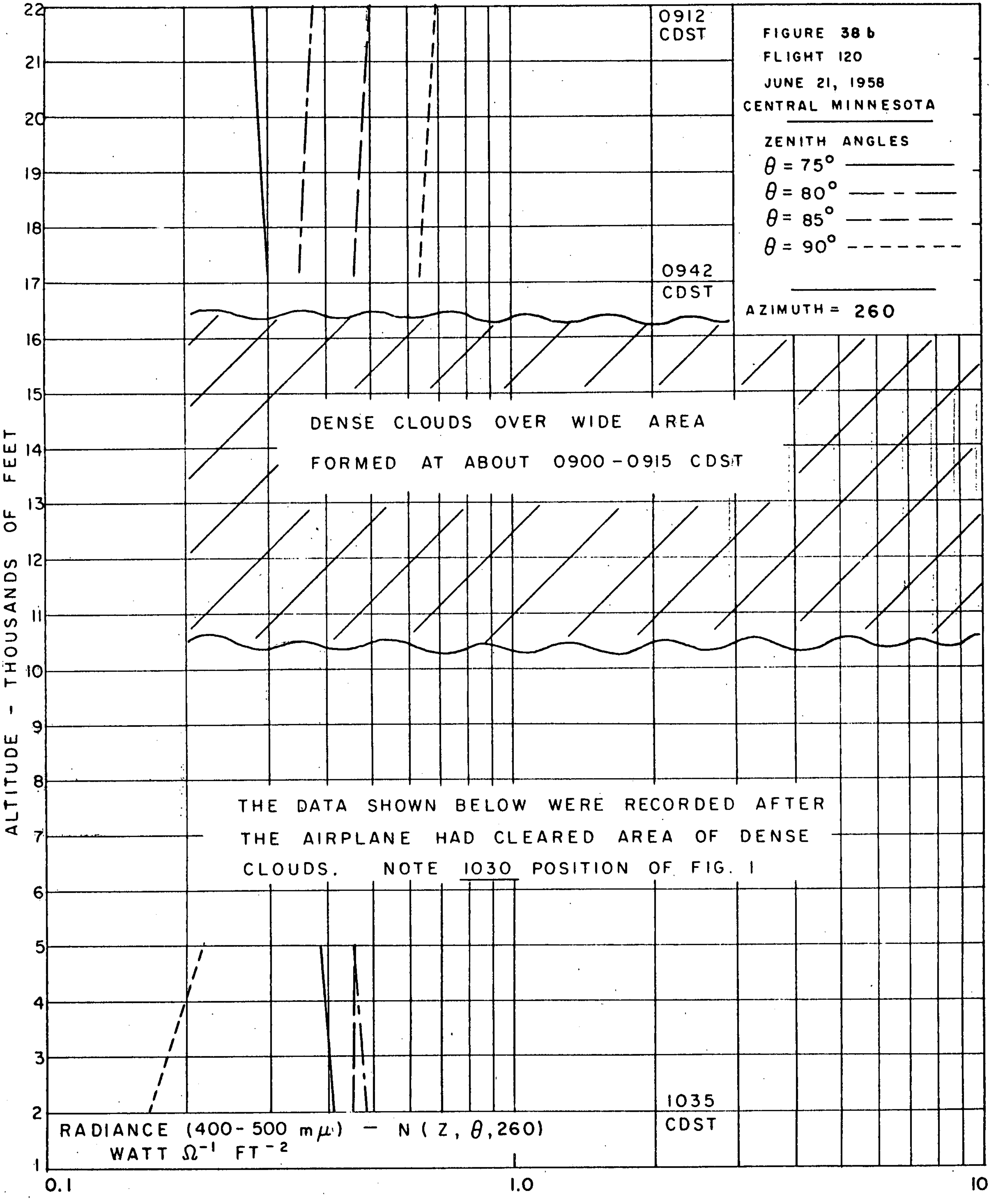
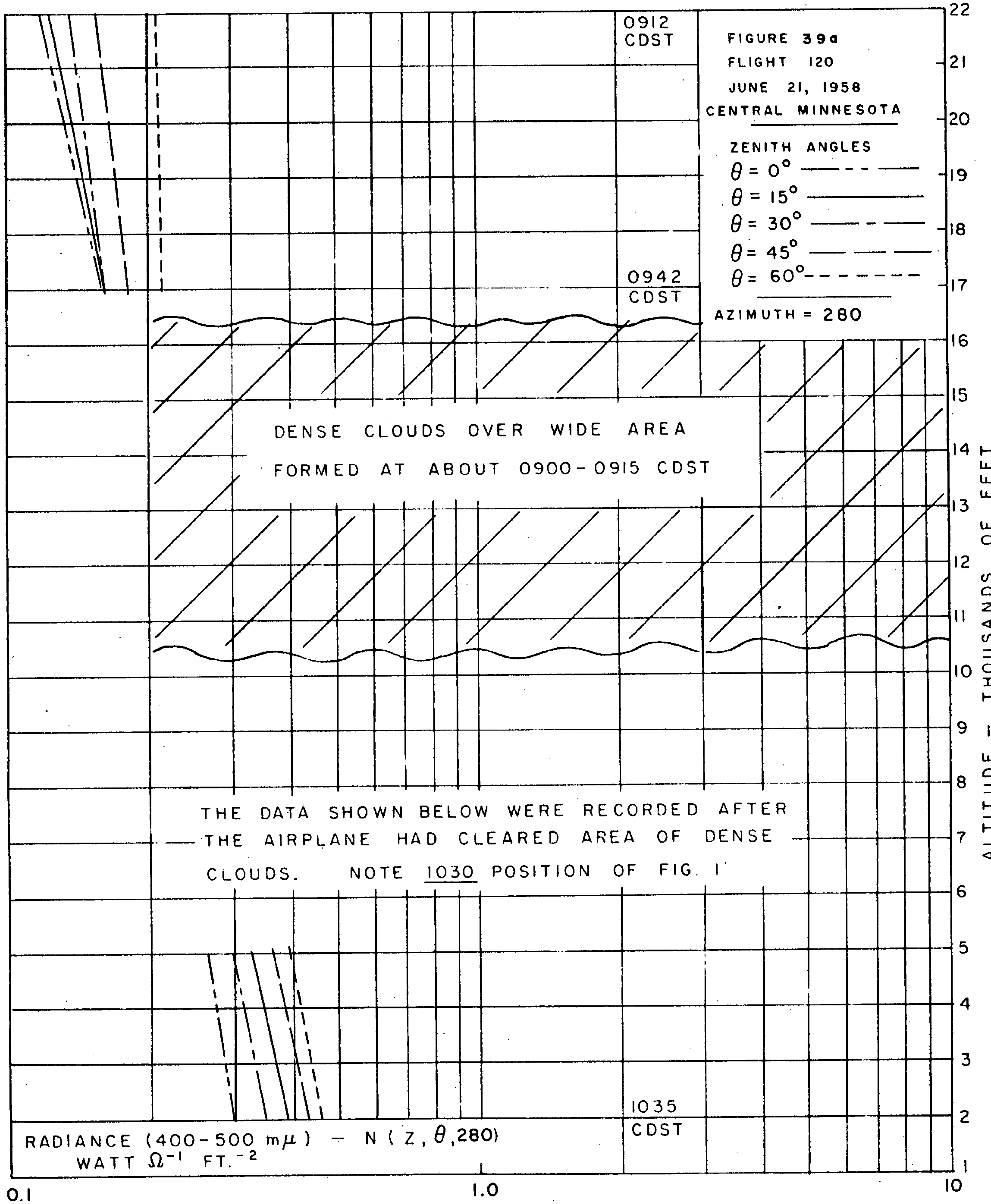
18
19
20
21
22


0912
CDST
FIGURE 37a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 240
0942
CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
RADIANCE (400-500 mμ) - N (Z, θ,240)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE - THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22


0912
CDST
FIGURE 37 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
0942
CDST
AZIMUTH = 240
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) — N (Z, θ, 240)
WATT Ω⁻¹ FT⁻²
0.1
1.0
10


0912
CDST
FIGURE 38a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 260
0942
CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
RADIANCE (400-500 mμ) — N (Z, θ, 260)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE — THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1


0912
CDST
FIGURE 38 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
0942
CDST
AZIMUTH = 260
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
RADIANCE (400-500 mμ) — N (Z, θ, 260)
WATT Ω⁻¹ FT⁻²
ALTITUDE - THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0.1
1.0
10


0912
CDST
FIGURE 39a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 280
0942
CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035
CDST
RADIANCE (400-500 mμ) — N (Z, θ,280)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ALTITUDE — THOUSANDS OF FEET

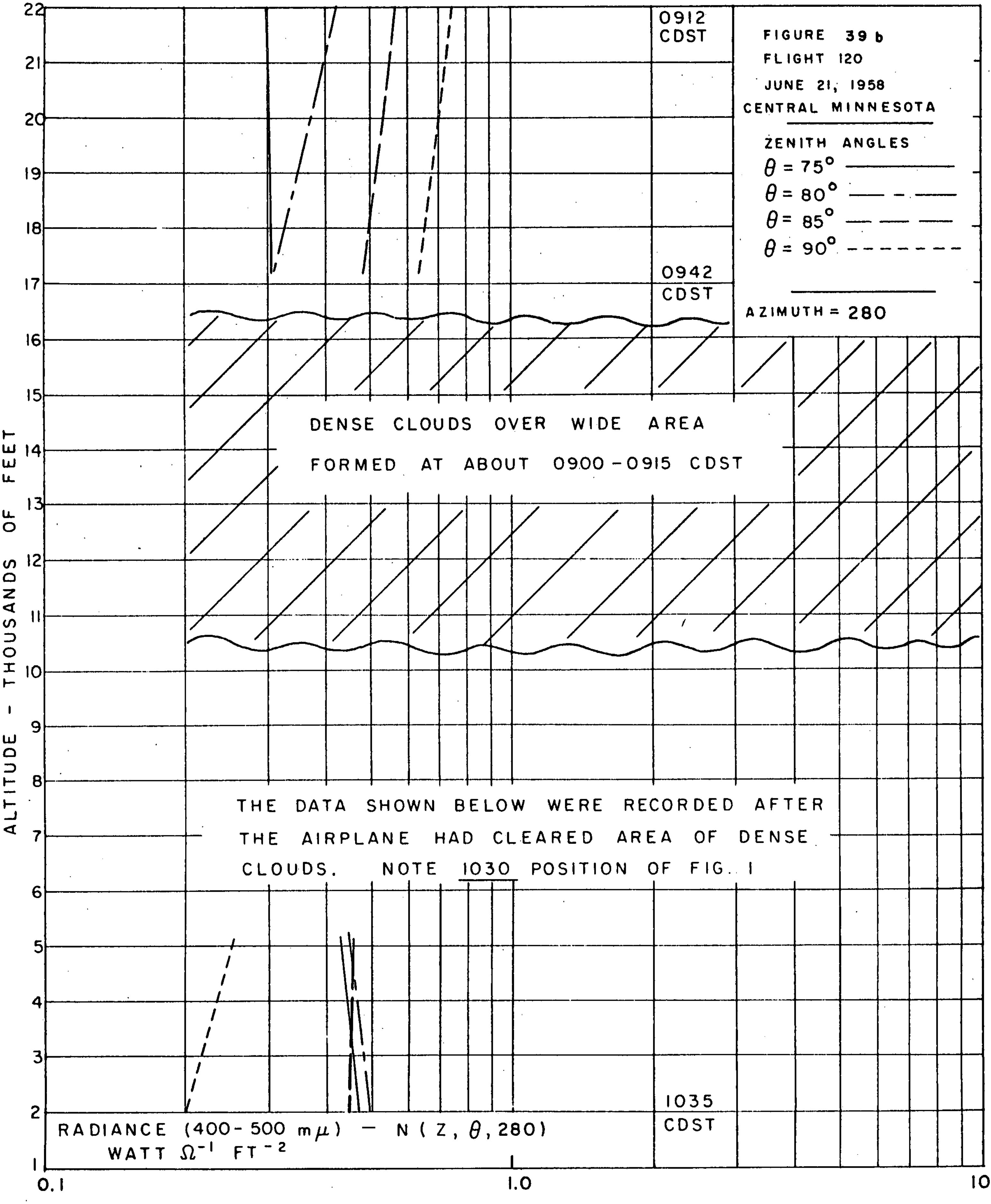
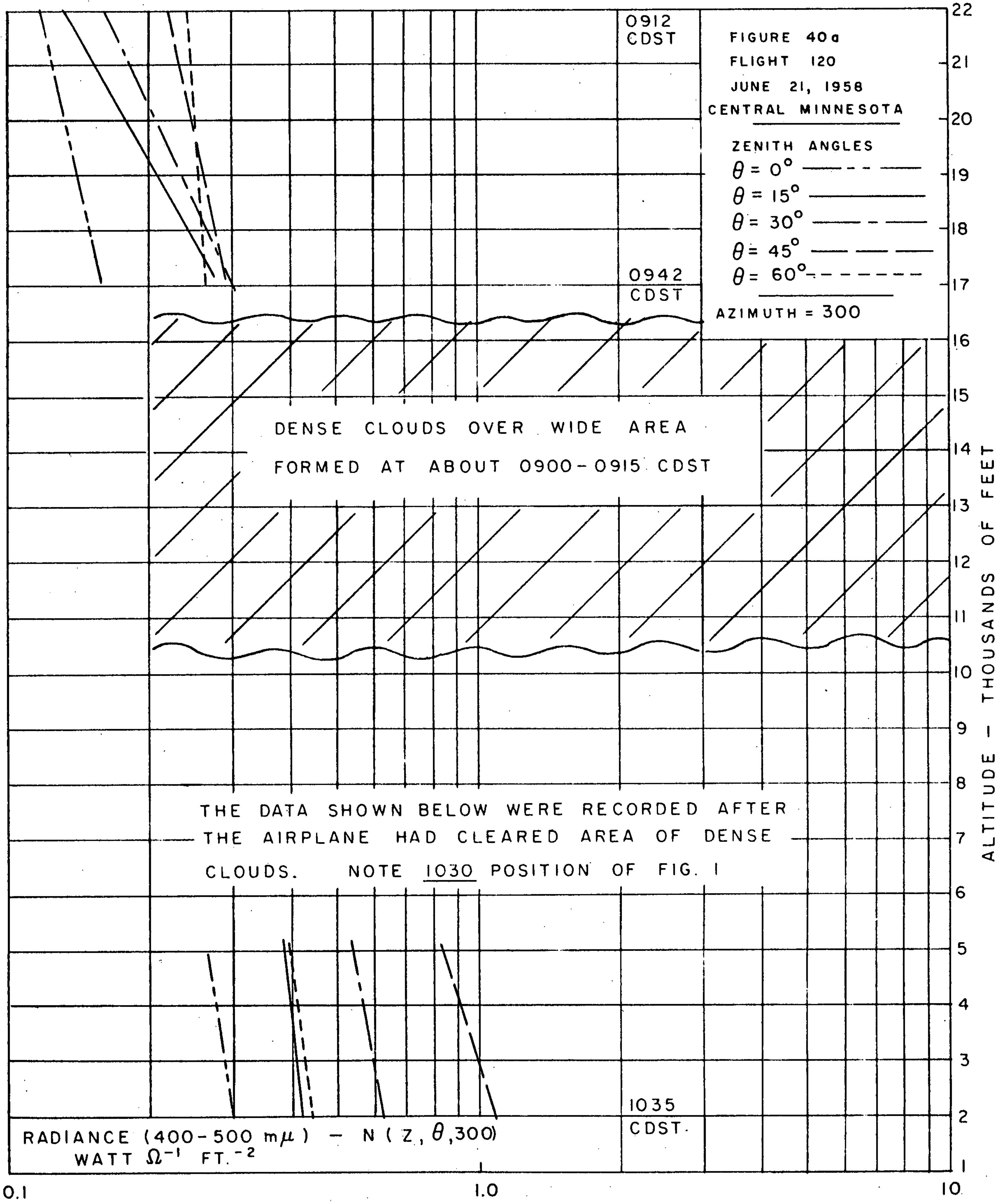
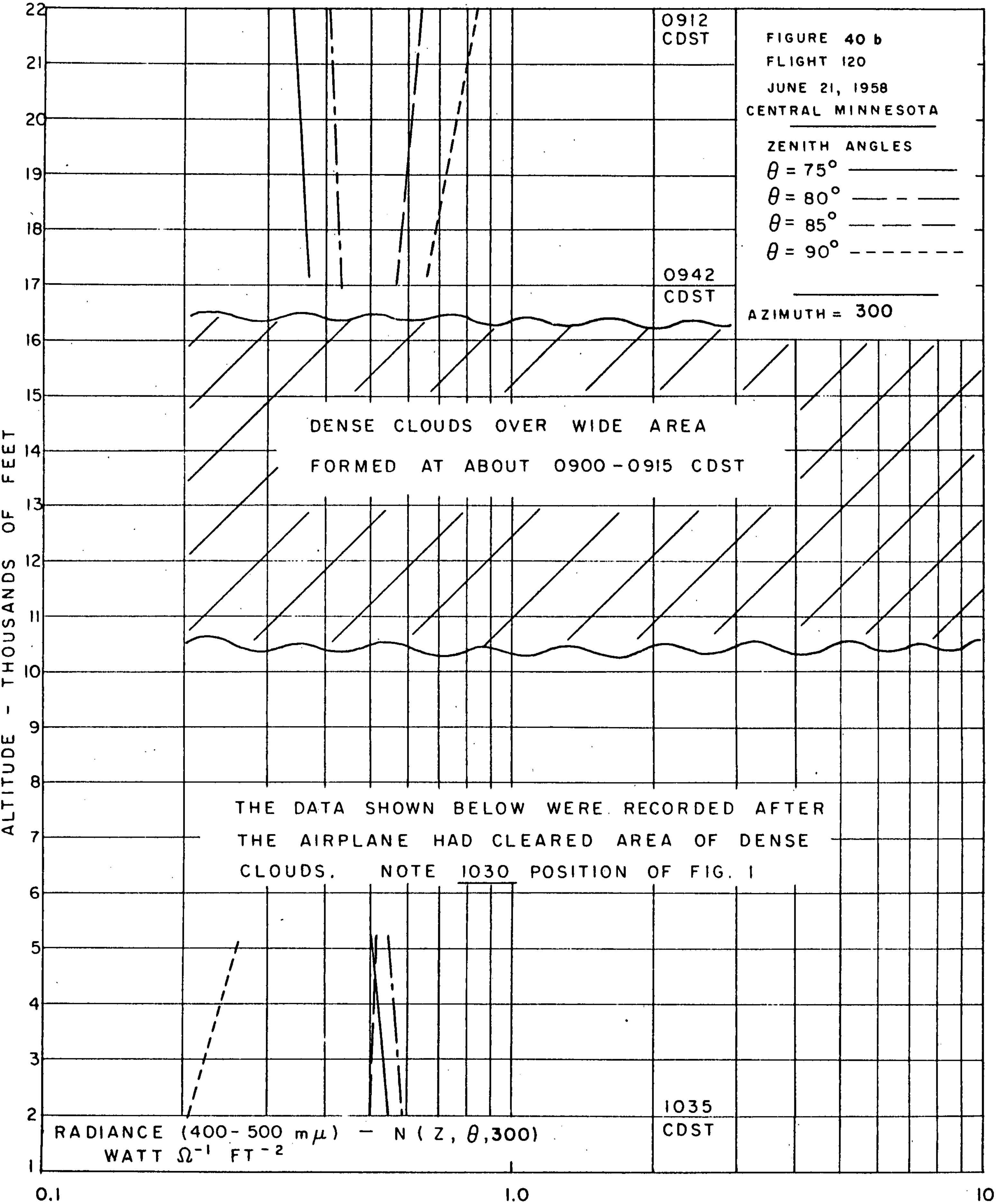


FIGURE 39 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 280
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900 - 0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) — N (Z, θ, 280)
WATT Ω⁻¹ FT⁻²
0.1
1.0
10


0912
CDST
FIGURE 40a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 300
0942
CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER
THE AIRPLANE HAD CLEARED AREA OF DENSE
CLOUDS. NOTE 1030 POSITION OF FIG. I
1035
CDST
RADIANCE (400-500 mμ) – N (Z, θ,300)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE – THOUSANDS OF FEET
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1


0912 CDST
FIGURE 40 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 300
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
ALTITUDE - THOUSANDS OF FEET
RADIANCE (400-500 mμ) — N (Z, θ,300)
WATT Ω⁻¹ FT⁻²
0.1
1.0
10

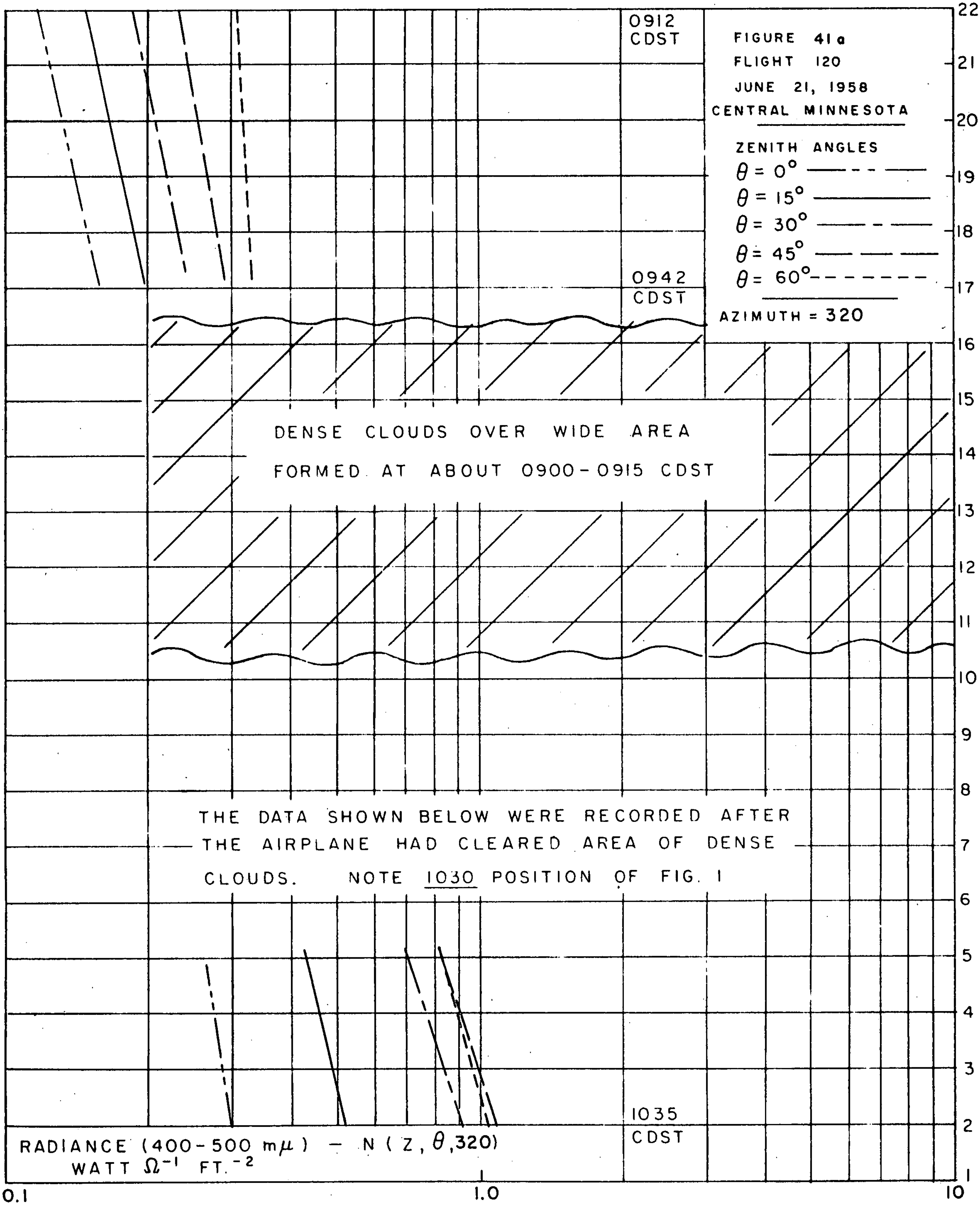


FIGURE 41a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 320
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) — N (Z, θ, 320) WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE — THOUSANDS OF FEET
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

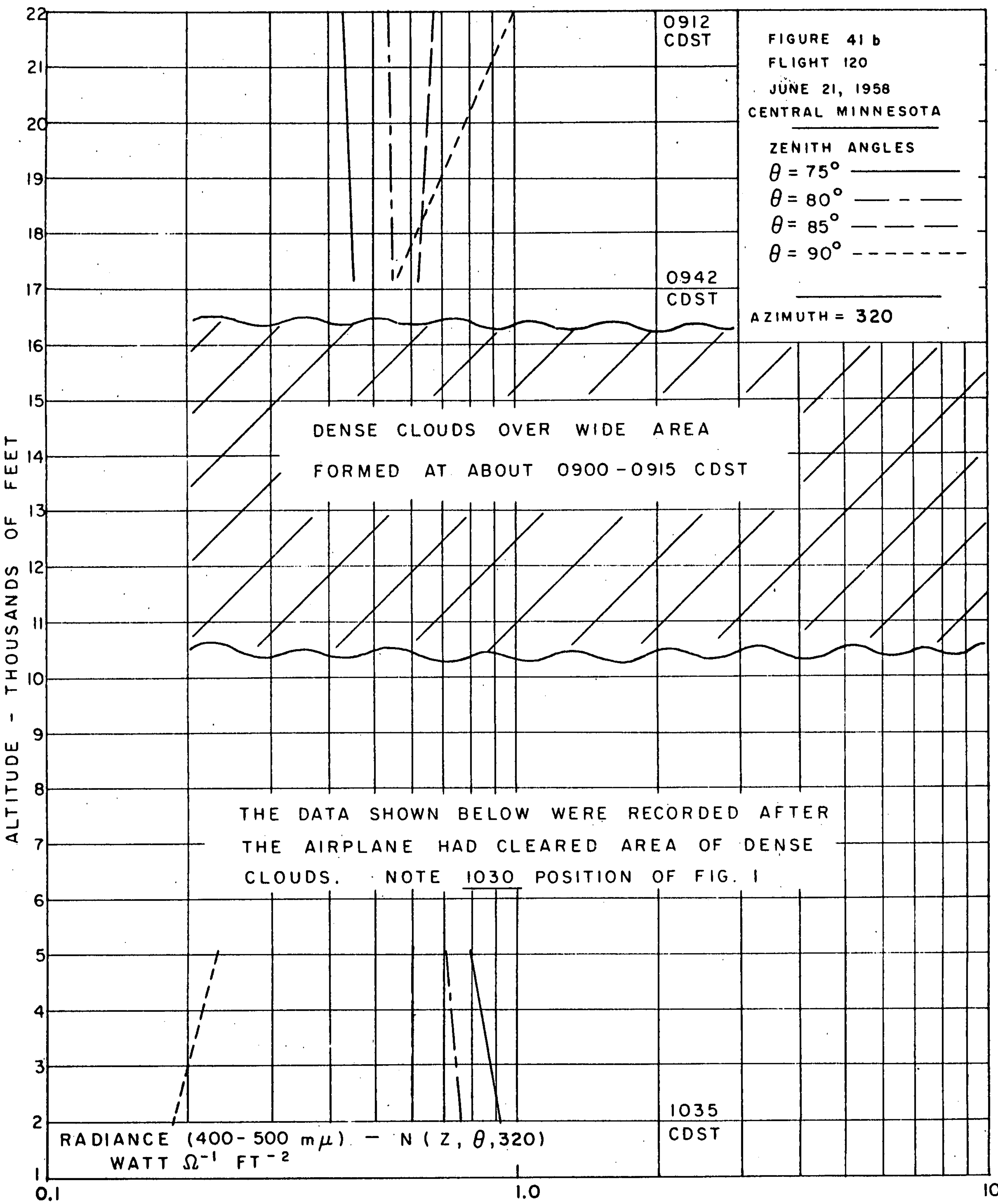
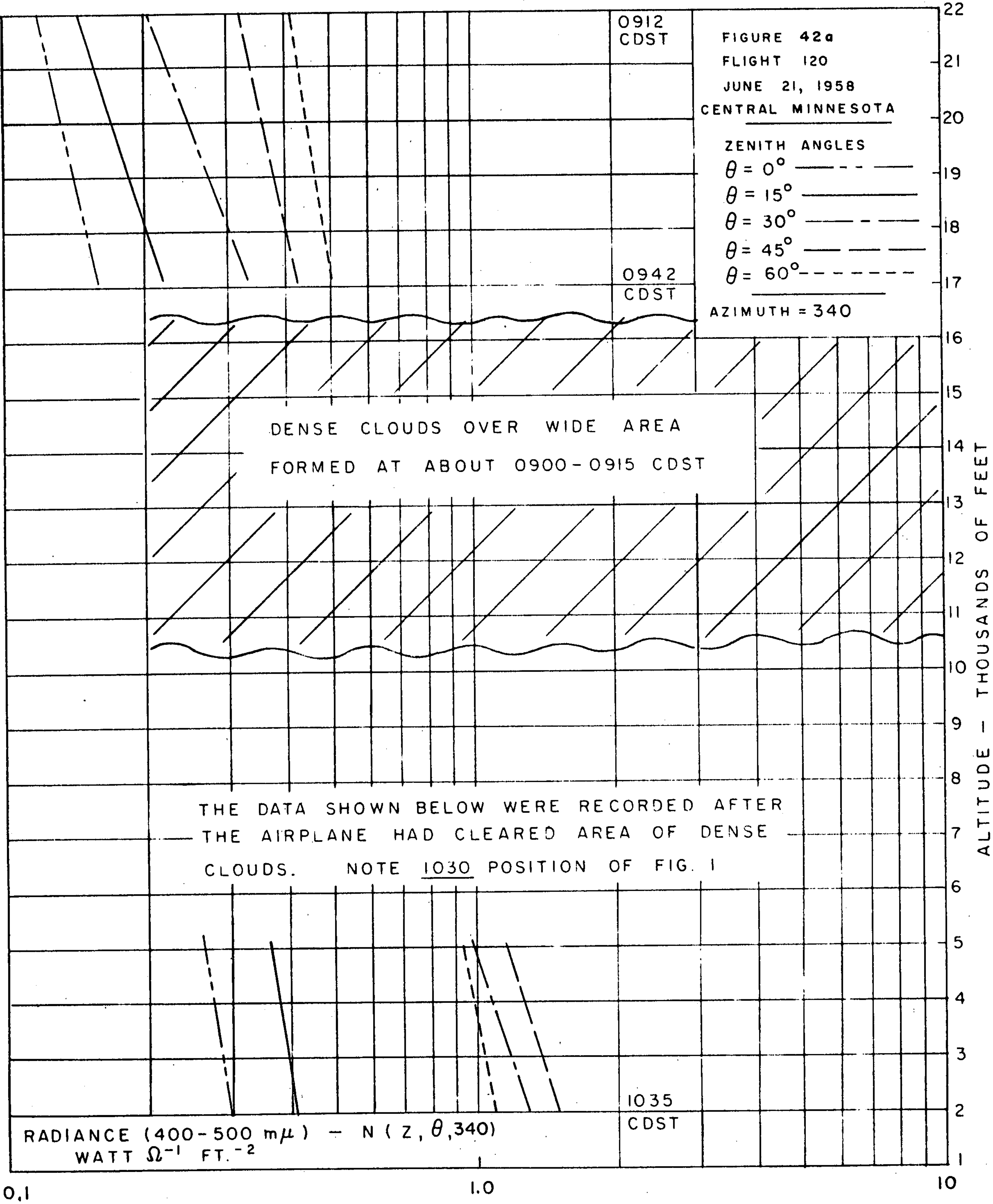


FIGURE 41 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 320
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) — N (Z, θ, 320)
WATT Ω⁻¹ FT⁻²
ALTITUDE - THOUSANDS OF FEET
0.1
1.0
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22


0912 CDST
FIGURE 42a
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 0°
θ = 15°
θ = 30°
θ = 45°
θ = 60°
AZIMUTH = 340
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) – N (Z, θ,340)
WATT Ω⁻¹ FT.⁻²
0.1
1.0
10
ALTITUDE – THOUSANDS OF FEET
1
2
3
4
5
6
7
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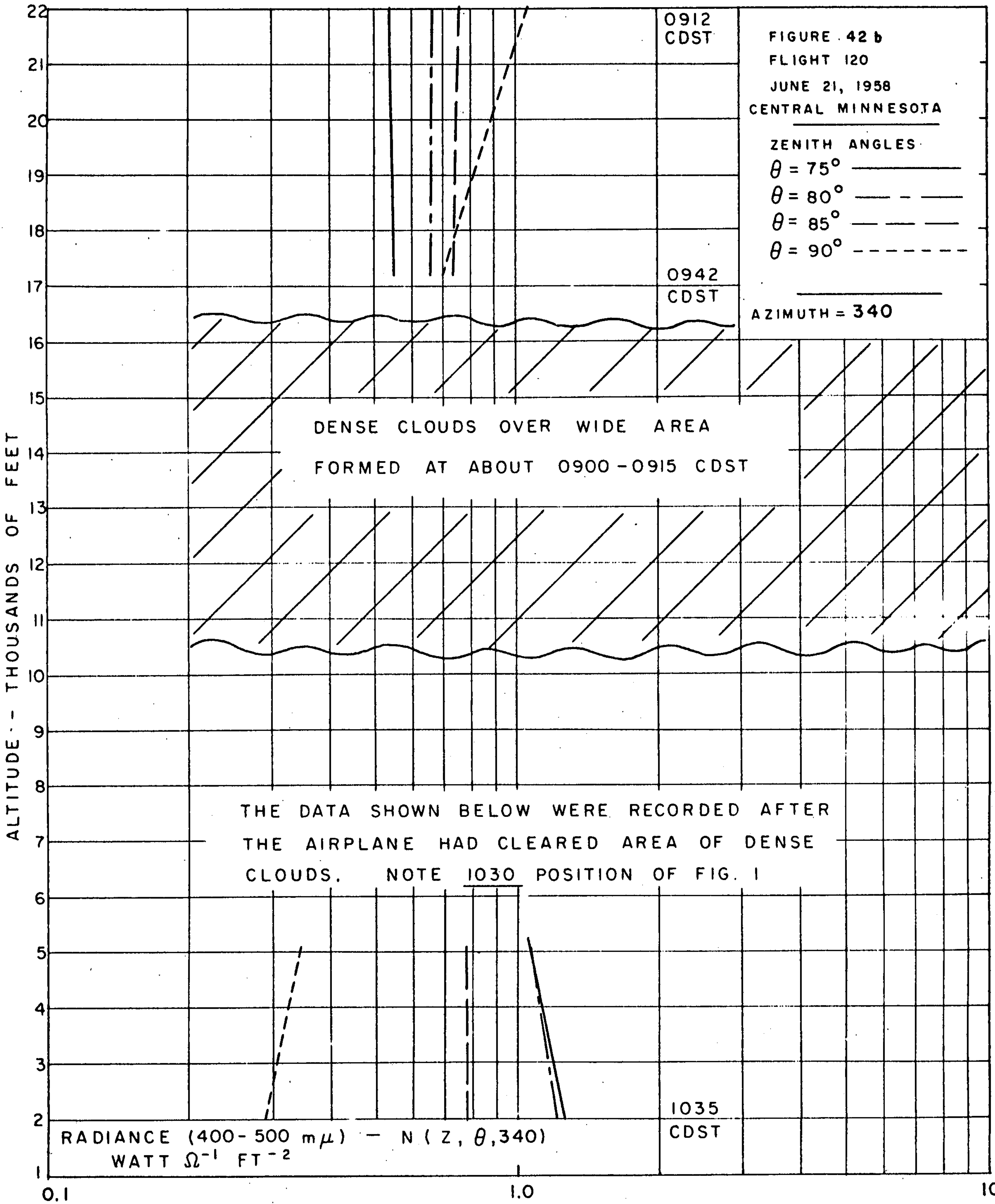
FIGURE 42 b
FLIGHT 120
JUNE 21, 1958
CENTRAL MINNESOTA
ZENITH ANGLES
θ = 75°
θ = 80°
θ = 85°
θ = 90°
AZIMUTH = 340
0912 CDST
0942 CDST
DENSE CLOUDS OVER WIDE AREA
FORMED AT ABOUT 0900-0915 CDST
THE DATA SHOWN BELOW WERE RECORDED AFTER THE AIRPLANE HAD CLEARED AREA OF DENSE CLOUDS. NOTE 1030 POSITION OF FIG. 1
1035 CDST
RADIANCE (400-500 mμ) — N (Z, θ,340)
WATT Ω⁻¹ FT⁻²
ALTITUDE - THOUSANDS OF FEET
0.1
1.0
10
1
2
3
4
5
6
7
8
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2. Boileau, A.R., "Atmospheric Optical Measurements during High Altitude Balloon Flight, Part II," SIO Ref. 61-1, Scripps Institution of Oceanography , University of California, San Diego, July 1961.

3. Duntley, S.Q., A.R. Boileau, and R.W. Preisendorfer, "Image Transmission by the Troposphere I," J. Opt. Soc. Am. 47, 499-506 (1957).

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