BRL

CONTRACT 169

REPORT NO. 9

UPPER ATMOSPHERE WINDS FROM GUN LAUNCHED VERTICAL PROBES

(Barbados, 15-16 February 1967)

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BRL CONTRACT 169 REPORT 9

UPPER ATMOSPHERE WINDS FROM GUN LAUNCHED VERTICAL PROBES

(Barbados, 15-16 February 1967)

Prepared for

U. S. Army
Ballistic Research Laboratories
Aberdeen Proving Ground, Maryland

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NOTE: The wind vector as given in this report is considered to point in the direction toward which the wind is blowing, (that is, a west wind is toward the west). Most meteorologists are accustomed to a 180° difference, (that is, a west wind is from the west).

INTRODUCTION

For several years upper atmospheric winds over the lower West Indies have been studied by firing high altitude ballistic probes from a specially modified sixteen-inch naval gun. The installation of a similar 16" gun at Yuma Proving Ground, Arizona, early in 1966 has made possible a similar study of winds in this region. These firings are being carried out by the U. S. Army Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, under the direction of Dr. Charles H. Murphy, and by the Space Research Institute of McGill University, Canada, under the direction of Dr. G. V. Bull.*

Atmospheric winds are studied by releasing chemical trails from the gun-fired probes during the upper portion of their trajectories. To date, the primary chemical which has been released is trimethyl aluminum (TMA). TMA produces a chemiluminescent glow in regions of the atmosphere above 85 kilometers, thus allowing the trails to be photographed while being distorted by upper atmosphere winds. The photographs are then reduced to provide wind information by Space Instruments Research, Inc. (SIR), using computer techniques.

The purpose of this report is to summarize results of these studies for the period from February 15 through February 16, 1967. A "Table of Trail Information" is given on page 13 and lists the trail number, shot number, date, time and altitude interval. Previous results for winds

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over Barbados, West Indies, are covered in Technical Reports No. 1, 2, 3, 5, and 8. Technical Reports No. 4, 6, and 7 cover previous results for winds over Yuma, Arizona.

DATA ACQUISITION

The chemical trails are formed almost vertically over the Island of Barbados (longitude 59.4°W, latitude 13.0°N) and extend from an altitude of approximately 85 kilometers through apogee. In some firings, TMA is also released on the down leg of the trajectory. To the unaided eye, the chemical release first appears as a straight white trail resembling a jet contrail. Within a minute or so, the trail is distorted into strange shapes by the upper atmospheric winds (see Figure 1) and fades from view within approximately fifteen minutes after initial release.

Space Instruments Research has established eight photographic triangulation stations on the Islands of Barbados, St. Vincent, Grenada, and Tobago, with two sites per island. These sites are located to the west and south of Barbados at distances of 190 to 290 kilometers (see Figure 2). While only one site on each of two islands is required for data reduction purposes, the eight sites have been found desirable because of cloud conditions in the area.

Equipment at each site, built by SIR, consists of a camera unit containing two seven-inch focal length cameras mounted on a concrete pedestal, and an electronic control unit. Cameras are automatically pulsed to take exposures of 3, 6 and 12 seconds duration every 30 seconds.

Since commercial power is either unreliable or unavailable at many site locations, SIR has developed a battery operated 115-volt power supply for the control equipment. The power supply is tuning-fork controlled and provides 60 cycle power with an accuracy of 0.005% for the camera programmer so that pictures can be taken simultaneously at each site. A

data block containing 24 tiny lights, mounted in each camera unit, records time, firing number, and site information in the corner of each frame of film.

A short wave radio net connecting all sites and the launch control center has been installed by SIR to enable the launch control officer to be informed of weather conditions on the islands and to synchronize picture taking operations with the firing of the gun. Most sites are operated by local personnel who have been trained by SIR.

During a typical night's operation, the gun is fired at one to two-hour intervals, from sunset to sunrise. Photographs are taken by all sites during the time that the trail is visible. The film is then returned to Atlanta for processing and data reduction.

DATA REDUCTION

Several computer programs have been developed which make it possible to calculate upper atmosphere winds from measurements made directly on the photographs of the luminous trails.

Since the method used is basically three-dimensional triangulation using spherical trigonometry, it is necessary to know precisely the direction each camera was pointed during a given firing. The direction is determined by first taking accurate measurements of the locations of several star images on the film, and then computing the azimuth and elevation of the optical axis of the camera by means of a computer program. This computer program makes use of the celestial coordinates of some 6,000 stars which have been stored on magnetic tape.

Wind speeds and directions are then determined from the location of the trail in space at a succession of known times. The location is found, using either a point location program or a trail location program, or both, and depends on the physical shape of the chemical release cloud.

Point location method. If the chemical release exhibits discrete points (resulting either from turbulence or from the nature of the release mechanism) and these points can be identified on films from two or more islands, the point location program can be used to calculate the position of each point in longitude, latitude, and altitude above sea level.

These calculations are made from data taken at successive times. A wind program is then used to calculate both vertical and horizontal winds from the motion of these points as a function of time.

Trail location method. Most of the chemical releases produce a smooth trail having few, if any, identifiable points. In such cases, film coordinates of a large number of incremental points along the film image of the trail are fed into the computer from data from two or more islands. The trail location program attempts to triangulate each point from one site with many points from another site, finally choosing points from both sites whose optical paths from camera into space form the closest spatial intersection. After doing many hundreds of such calculations, the computer is able to construct coordinates for a mathematical curve in the shape of the trail in space. Then, as with the point location program, winds can be determined from the motion of the curve with time. Here, however it must be assumed that vertical winds are essentially zero. This assumption is borne out by previous studies which have shown vertical winds in this altitude region to be of the order of a few meters per second compared to horizontal winds ranging up to 150 meters per second.

Corrections for variables such as atmospheric refraction, rotation of camera about optical axis, and camera focal length, are incorporated into the programs to maintain high accuracy. Focal length and camera rotation are, in fact, calculated from measurements of the positions of star images on the films.

INTERPRETATION OF DATA

Following the "Table of Trail Information," horizontal wind velocities are presented in tabular form and in plots of wind speed, direction, and components.

Winds were calculated at altitude intervals of one kilometer. Points on the various plots show the actual computed result, as listed in the table preceding the plot. A curve has been fitted to each set of points to aid in detecting wind patterns and to indicate reliability of the plotted results. Each curve has been drawn with a knowledge of intermediate results leading to the wind calculations and of the consistency of the winds as calculated between each of the five or more time intervals used. In cases where point-to-point curve fitting was not thought to reflect actual variations in wind speed, direction, or components, a more appropriate smooth curve has been drawn. Otherwise, the curves are fitted directly to the data points. Results of certain portions of the trails are at times less accurate than others due to the spatial orientation of those trail segments relative to the available photographic stations. Less accurate data can also result from photographs obscured by haze and clouds and from trails of short duration.

Wind speed plot. This plot shows the speed of the wind in meters per second as a function of height in kilometers above sea level.

Wind direction plot. The wind vector is considered to point in the direction toward which the wind is moving. The direction plot shows the direction of this vector in degrees clockwise from north as seen from above. Thus, a wind direction toward the east would be 90 degrees.

Wind components plot. While plots of wind direction and speed do completely describe the wind vector, it has been found helpful in studying wind patterns to present the north-south (N-S) and east-west (E-W) velocity components of the vector. In the north-south plot, north is positive; south is negative. In the east-west plot, east is positive; west negative. Components are plotted in meters per second versus height in kilometers.

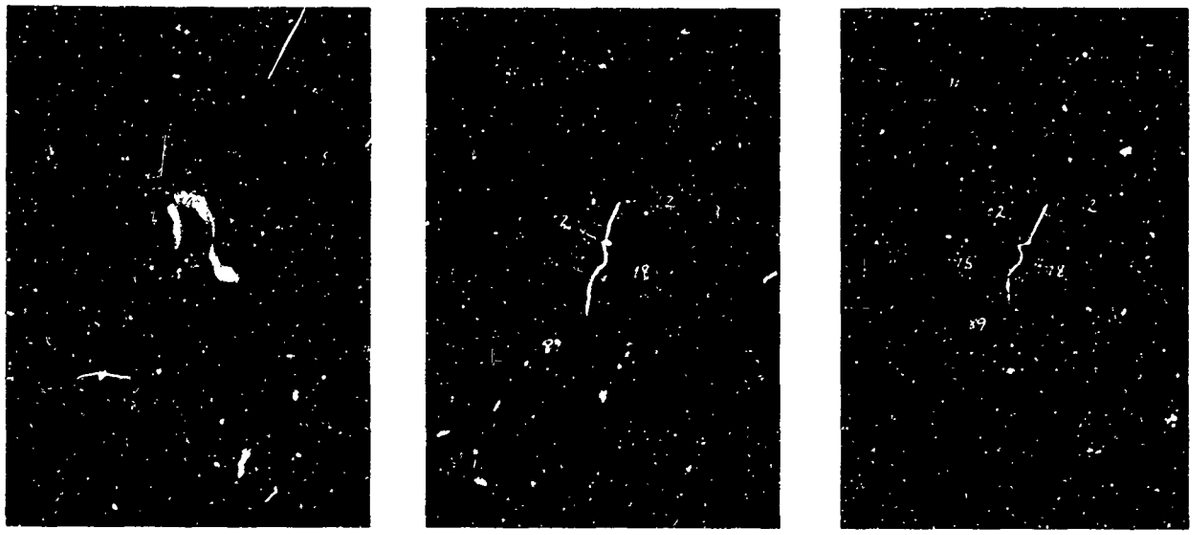
The wind direction and components described above are referenced to true north. In addition, components have been calculated relative to magnetic north for comparison with other ionospheric phenomena. These components are not plotted but are listed in the tabulations preceding each set of plots.

Throughout this report, where shorter notation was desirable, "Up" or "U" and "Down" or "D" have replaced uptrail and downtrail, respectively.

Figure 1

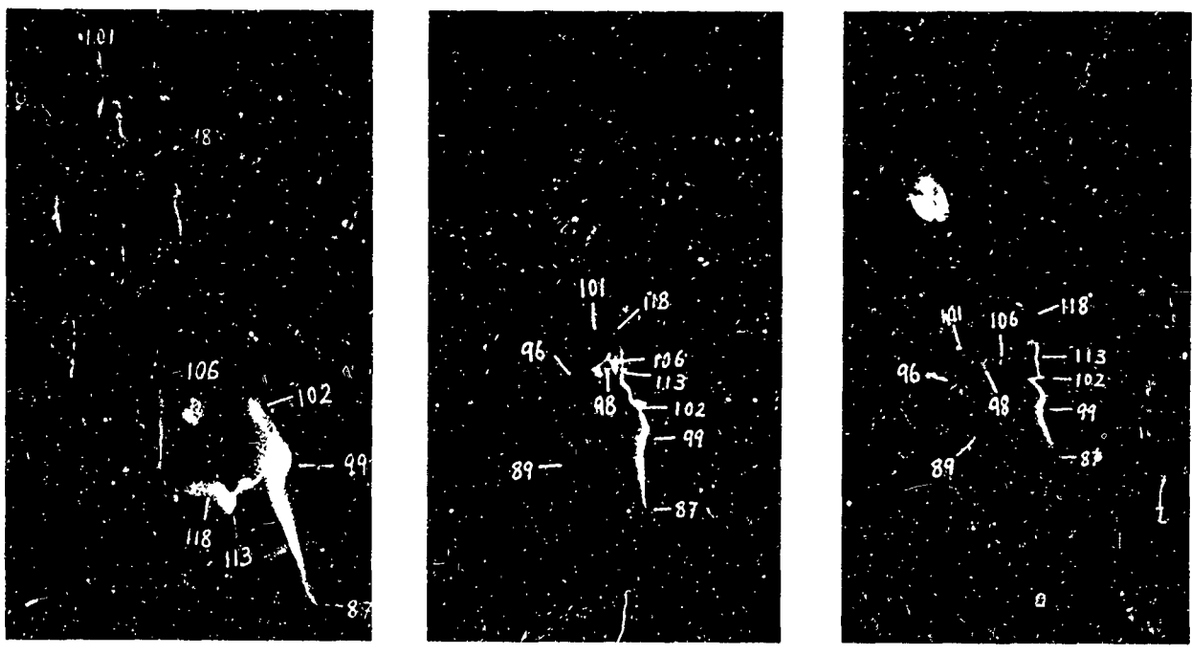
PHOTOGRAPHS OF FIRING DUBLIN

Photographs Taken 142 Seconds After Firing



Barbados St. Vincent Grenada

Photographs Taken 222 Seconds After Firing

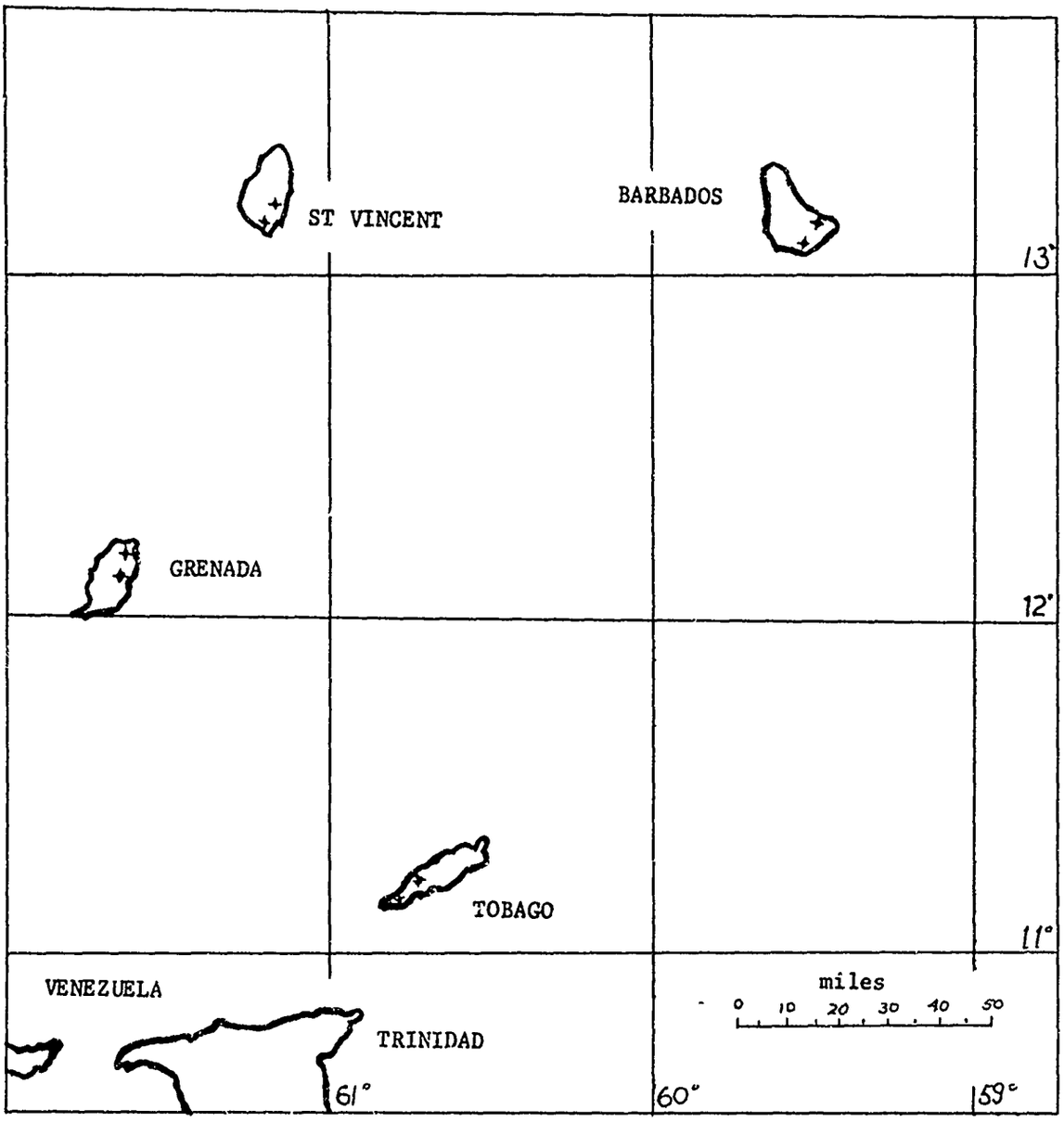


Barbados St. Vincent Grenada

This set of pictures was taken at completion of the downtrail. The uptrail shows continued effects of the winds, while the lower portion is new and only slightly distorted. Stars can be seen in the background of these pictures. The positions of these stars are used to determine the exact direction each camera was aimed.

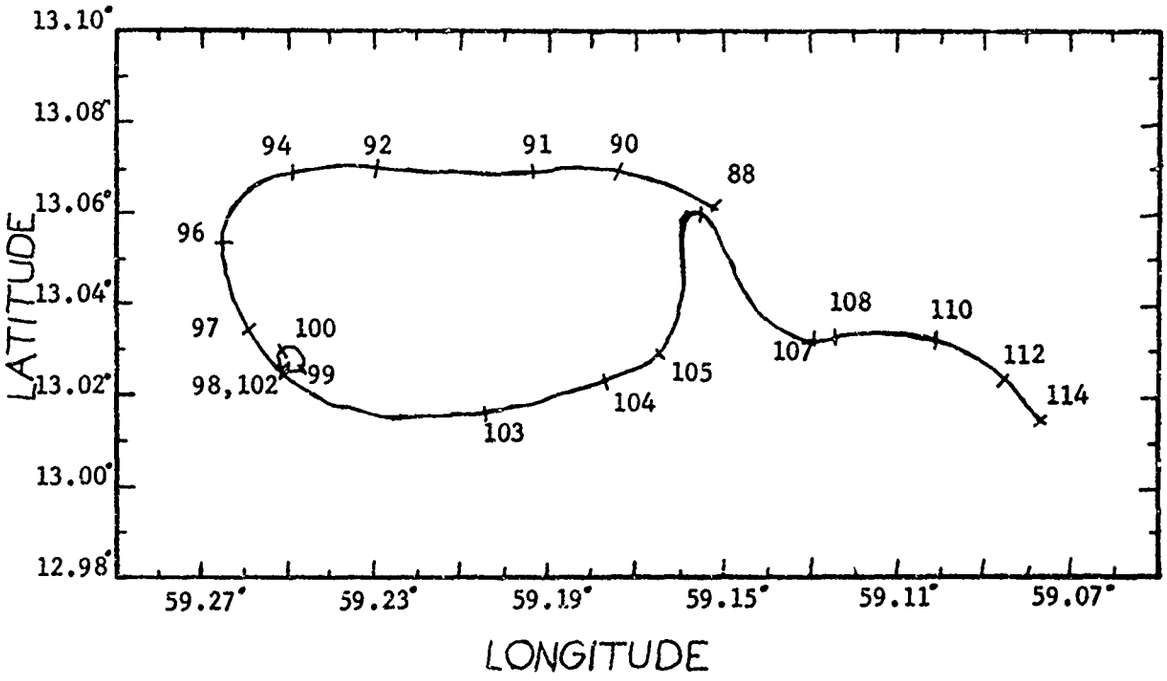
Fig. 2

Location of S.I.R. photographic stations



Two stations are located on each of the four islands, as shown. While only one station on each of any two islands is sufficient for determination of winds by triangulation, several stations were found necessary because of prevalent cloud conditions in the area. Accuracy of the data reduction is also increased by use of films from more than two islands.

TRAIL POSITION – DUBLIN



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8. Williamson, L. E., and Kennedy, B., Meteorological Shell for Standard Artillery Pieces - A Feasibility Study, Atmospheric Sciences Laboratory, ECOM-5161, October 1967.

TABLE OF TRAIL INFORMATION

Trail No.	Trail Name	Date	Time(AST)	Altitudes (Km)
B59	Belfast	15 February 1967	21:17:00	89-123
B60	Cork	15 February 1967	22:45:00	89-101
B61	Dublin	15 February 1967	23:56:00	88-117
B62	Carvagh	16 February 1967	01:05:00	89-116
B63	Hollywood	16 February 1967	02:10:00	88-109
B64	Kerry	16 February 1967	03:23:00	93-116
B65	Limerick	16 February 1967	04:17.00	95-110
B66	Newry	16 February 1967	05:20:00	106-112

TABULATIONS AND PLOTS

EIGHT TMA TRAILS - 15-16 FEBRUARY 1967

NOTE: The wind vector as given in this report is considered to point in the direction toward which the wind is blowing, (that is, a west wind is toward the west.) Most meteorologists are accustomed to a 180^{o} difference, (that is, a west wind is from the west.)

TRAIL NO. B59 BELFAST [redacted]
15 FEBRUARY 1967

BARBADOS
UP TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
89.0	295.4	20.8	8.9	-18.8	12.5	-16.6
90.0	274.4	37.5	2.9	-37.4	10.4	-36.0
91.0	259.0	61.3	-11.7	-60.2	0.8	-61.3
92.0	244.9	48.8	-20.7	-44.2	-11.3	-47.5
93.0	237.3	43.6	-23.6	-36.7	-15.7	-40.7
94.0	237.8	42.2	-22.5	-35.7	-14.8	-39.5
95.0	245.5	43.6	-18.1	-39.6	-9.7	-42.5
96.0	258.3	37.6	-7.6	-36.8	0.0	-37.6
97.0	270.3	36.1	0.2	-36.1	7.5	-35.3
98.0	278.7	33.8	5.1	-33.4	11.8	-31.7
99.0	281.5	35.3	7.0	-34.5	13.9	-32.4
100.0	285.5	37.4	10.0	-36.0	17.1	-33.2
101.0	291.6	36.1	13.3	-33.6	19.8	-30.2
102.0	300.7	37.4	19.1	-32.2	25.2	-27.6
103.0	321.2	49.6	38.6	-31.1	44.1	-22.6
104.0	344.5	42.6	41.1	-11.4	42.6	-2.8
105.0	343.8	31.4	30.2	-8.7	31.3	-2.4
106.0	317.3	32.8	24.1	-22.2	28.1	-16.8
107.0	321.6	44.8	35.1	-27.9	40.0	-20.2
108.0	338.1	39.0	36.2	-14.5	38.4	-6.8
109.0	3.2	42.9	42.8	2.4	41.4	11.0
110.0	45.9	44.6	31.0	32.0	23.9	37.6
111.0	87.1	57.9	3.0	57.9	-8.8	57.3
112.0	99.9	77.9	-13.4	76.7	-28.7	72.4
113.0	106.3	96.3	-27.1	92.4	-45.3	85.0
114.0	108.4	111.3	-35.1	105.6	-55.8	96.3
115.0	112.3	117.1	-44.5	108.4	-65.6	97.1
116.0	112.4	121.9	-46.4	112.7	-68.3	100.9
117.0	115.3	118.8	-50.8	107.5	-71.6	94.9
118.0	123.7	113.0	-62.7	94.0	-80.5	79.3
119.0	122.9	121.5	-66.0	102.0	-85.3	86.5
120.0	122.0	130.5	-69.2	110.7	-90.2	94.3
121.0	122.0	137.5	-72.9	116.6	-95.1	99.4
122.0	125.7	139.9	-81.7	113.5	-103.1	94.5
123.0	129.0	143.0	-90.0	111.2	-110.7	90.6

TRAIL NO. B59 BELFAST

BARBADOS 15 FEBRUARY 1967 [redacted]

DOWN TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
88.0	63.3	12.8	5.7	11.4	3.3	12.3
89.0	283.6	36.0	8.5	-35.0	15.4	-32.5
90.0	274.2	39.9	2.9	-39.8	10.9	-38.4
91.0	269.0	30.1	-0.5	-30.1	5.6	-29.6
92.0	253.2	23.4	-6.8	-22.4	-2.1	-23.3
93.0	239.6	42.1	-21.3	-36.3	-13.5	-39.9
94.0	240.3	41.6	-20.6	-36.2	-12.8	-39.6
95.0	242.6	37.9	-17.5	-33.7	-10.3	-36.6
96.0	260.0	40.5	-7.0	-39.9	1.3	-40.5
97.0	271.6	40.0	1.1	-39.9	9.2	-38.8
98.0	280.5	38.4	7.0	-37.8	14.5	-35.6
99.0	282.0	42.8	8.9	-41.8	17.2	-39.1
100.0	287.7	43.7	13.3	-41.6	21.5	-38.0
101.0	298.8	44.1	21.3	-38.7	28.7	-33.6
102.0	308.9	54.8	34.4	-42.6	42.3	-34.7
103.0	323.0	61.4	49.1	-36.9	55.6	-26.2
104.0	336.1	50.2	45.9	-20.4	49.1	-10.7
105.0	335.9	32.1	29.3	-13.1	31.4	-6.9
106.0	303.7	35.0	19.4	-29.1	24.9	-24.6
107.0	304.9	43.4	24.9	-35.6	31.6	-29.8
108.0	326.9	48.7	40.8	-26.6	45.4	-17.8
109.0	352.1	43.5	43.2	-5.2	43.4	3.7
110.0	39.9	37.7	28.9	24.2	23.4	29.6
111.0	86.6	63.6	3.7	63.5	-9.3	62.9
112.0	97.8	77.4	-10.5	76.7	-25.9	73.0
113.0	106.9	95.6	-27.8	91.5	-45.8	83.9
114.0	108.6	112.4	-36.0	106.5	-56.9	97.0
115.0	115.3	119.1	-50.9	107.7	-71.7	95.1
116.0	114.6	123.0	-51.2	111.9	-72.9	99.2
117.0	114.8	126.2	-52.9	114.6	-75.1	101.5

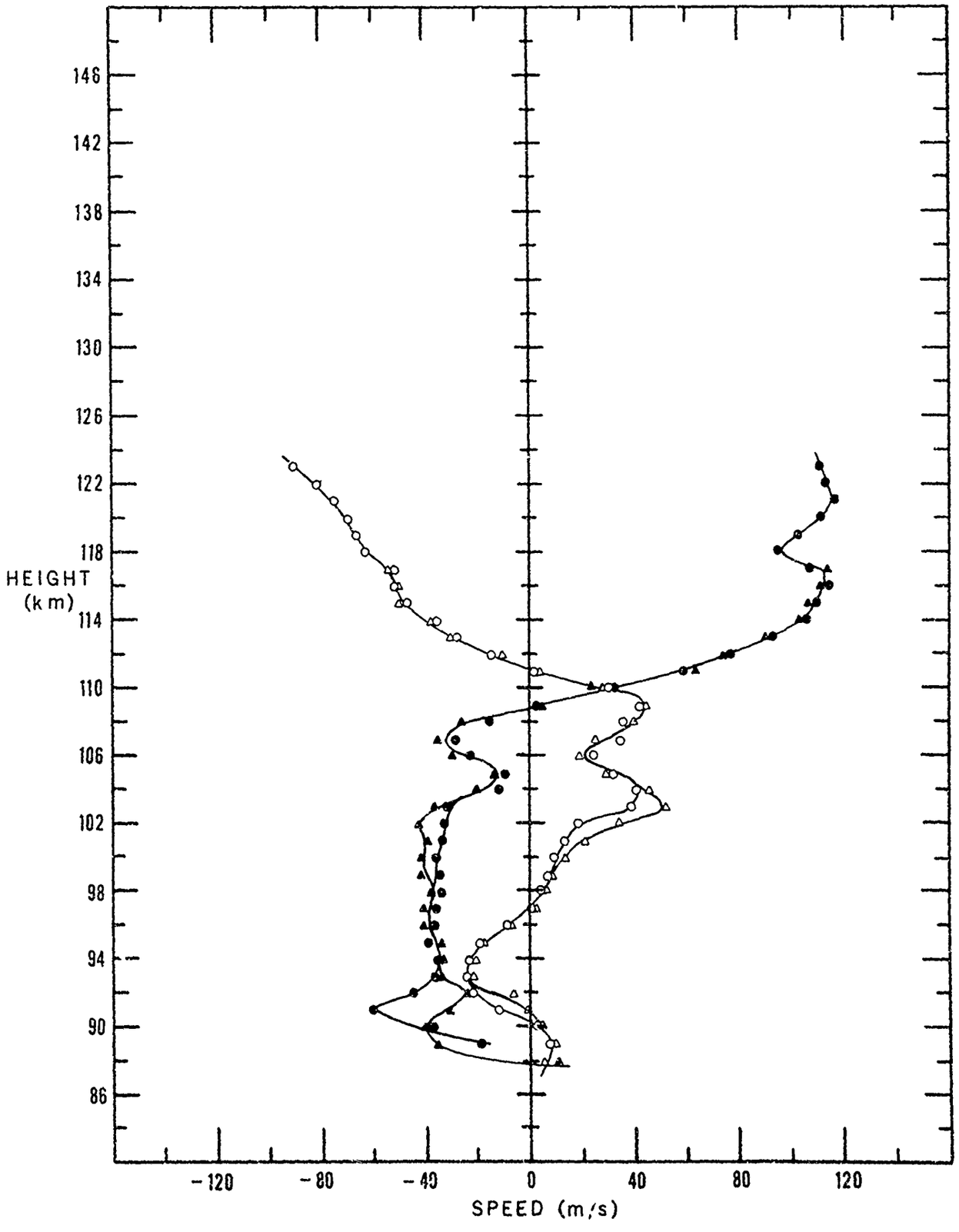
WIND COMPONENTS

	UP	DOWN
N-S	o	Δ
E-W	•	▲

TRAIL NO. B59 BELFAST

15 FEBRUARY 1967 21:17:00 AST

H.A.R.P. BARBADOS



WIND SPEED

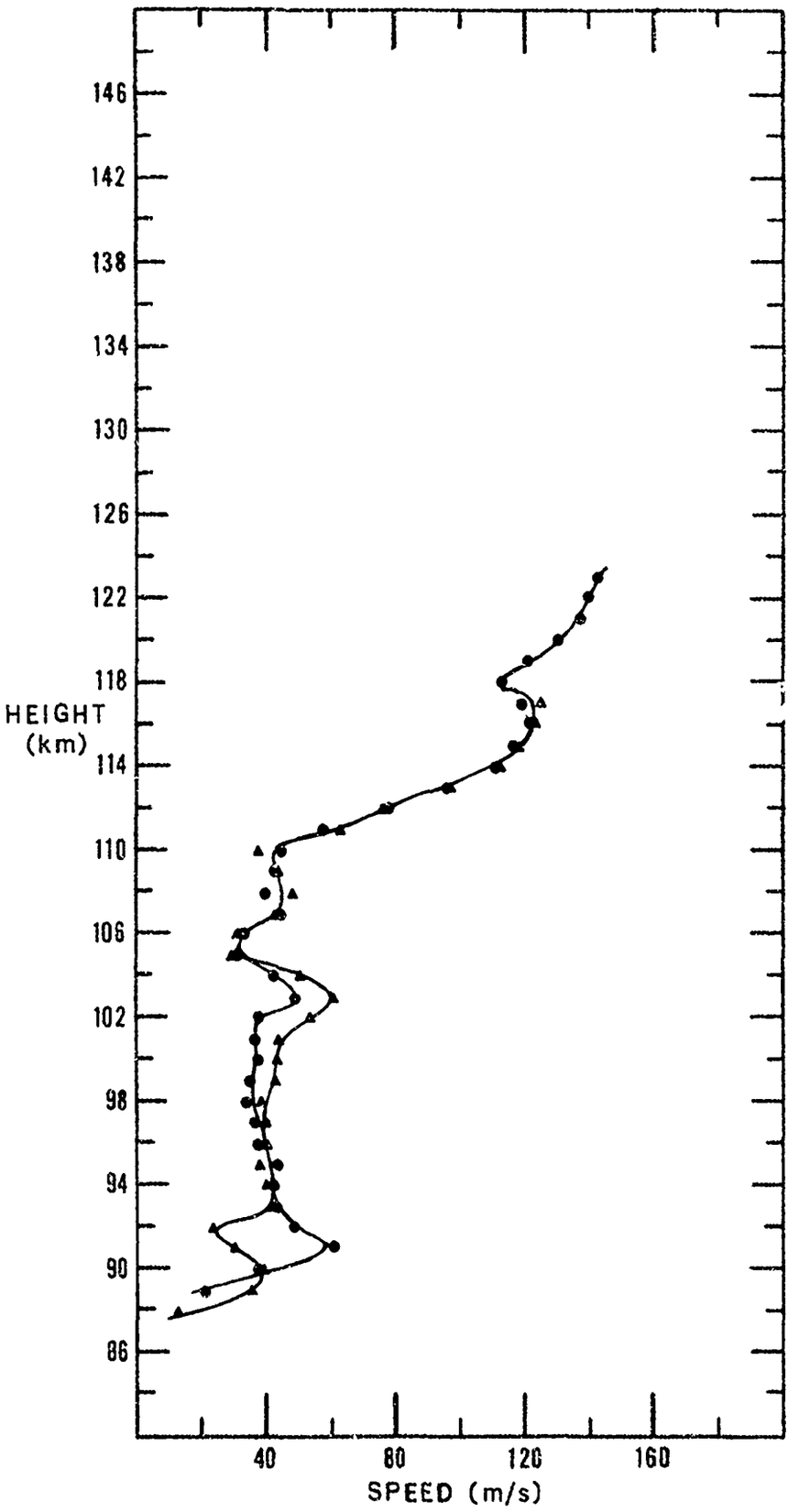
● UP

▲ DOWN

TRAIL NO. B59 BELFAST

15 FEBRUARY 1967 21:17:00 AST

H.A.R.P. BARBADOS



WIND DIRECTION

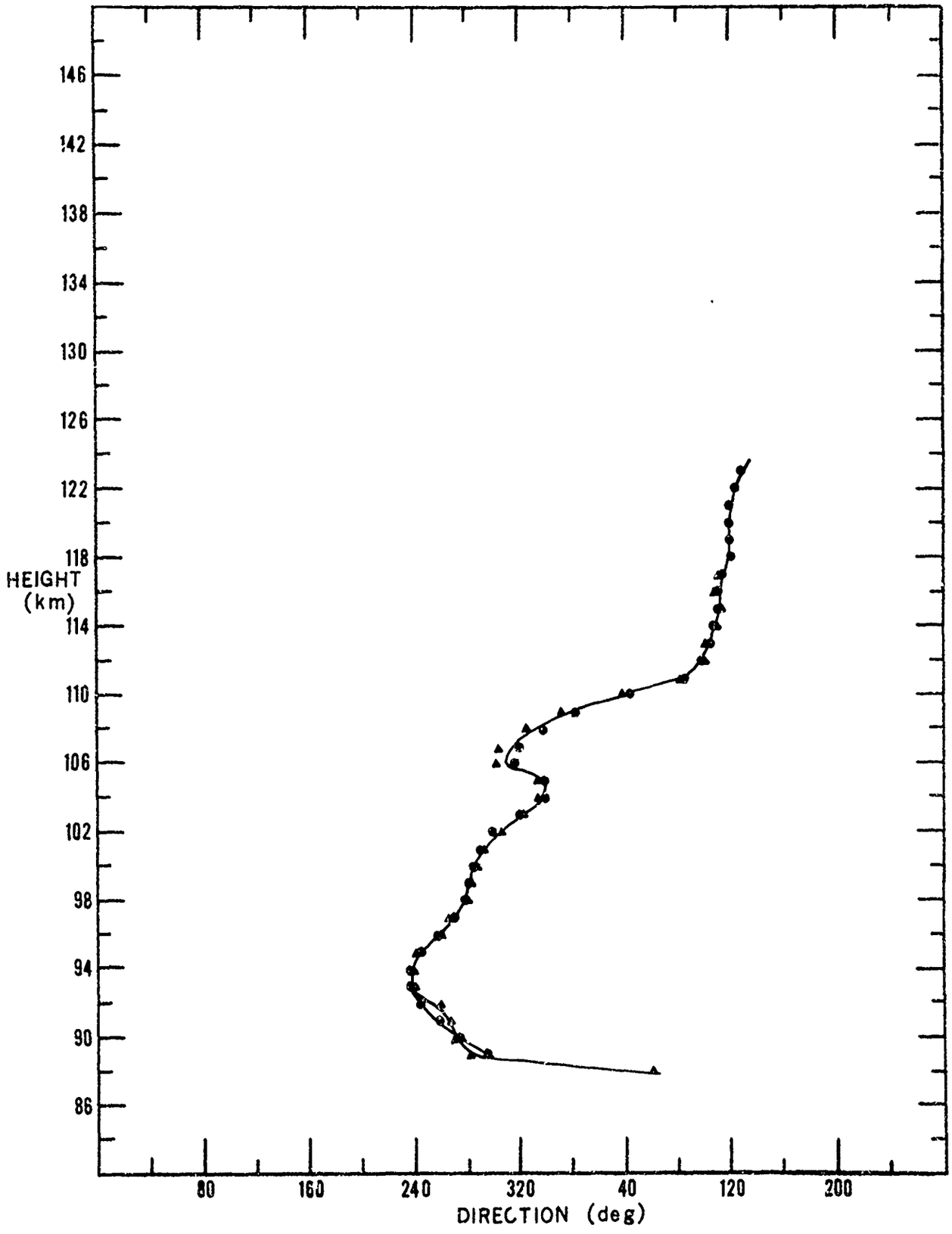
• UP

▲ DOWN

TRAIL NO. B59 BELFAST

15 FEBRUARY 1967 21:17:00 AST

H.A.R.P. BARBADOS



TRAIL NO. 980 CORR

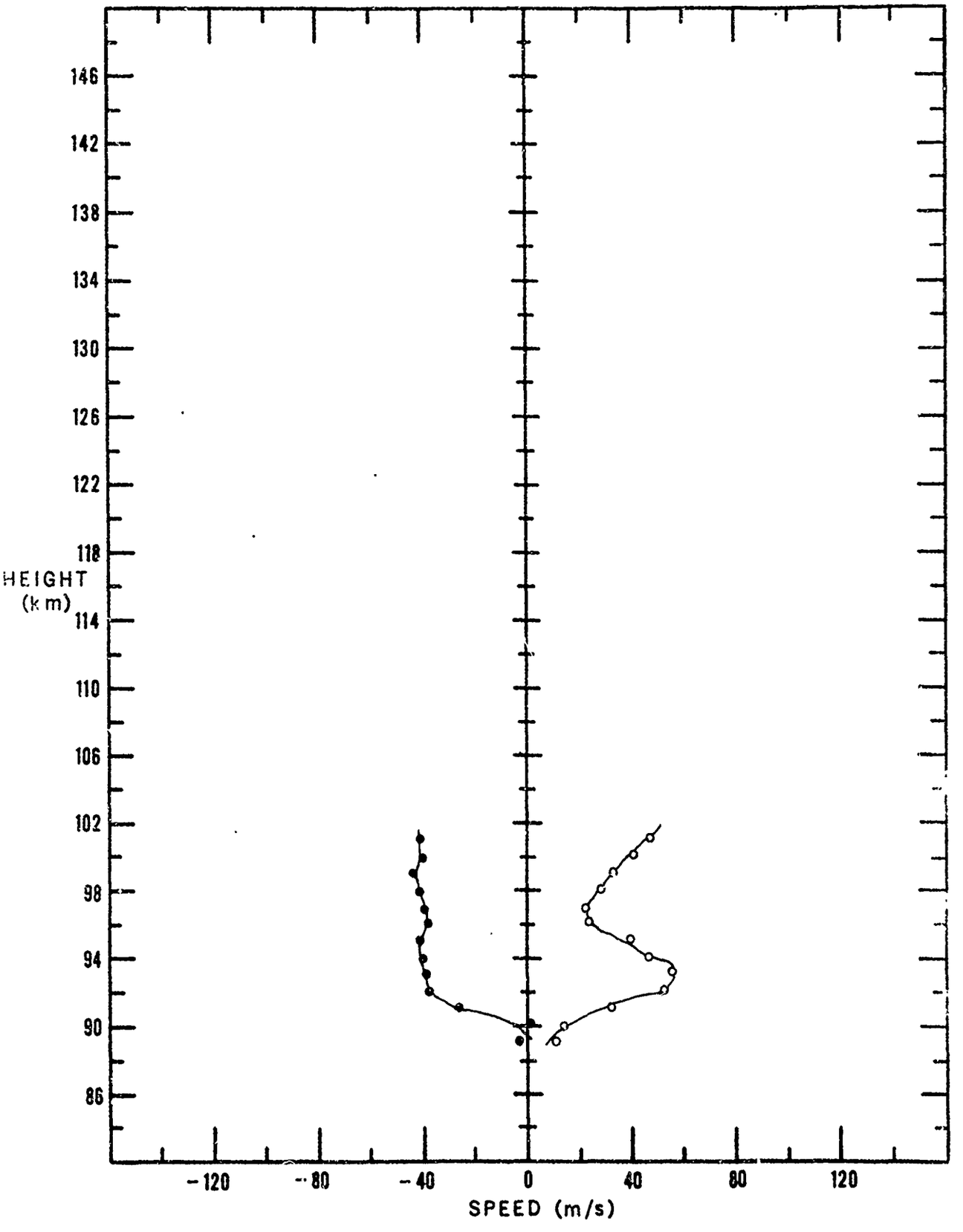
BARBADOS 15 FEBRUARY 1967 22-45-00 AST
UP TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
89.0	357.8	12.1	12.1	-0.5	11.9	2.0
90.0	8.3	16.2	16.0	2.3	15.2	5.5
91.0	325.0	42.3	34.6	-24.2	38.8	-16.7
92.0	326.3	65.9	54.8	-36.5	61.1	-24.6
93.0	327.0	68.4	57.3	-37.2	63.7	-24.8
94.0	321.7	63.6	49.9	-39.4	56.9	-28.4
95.0	315.3	57.9	41.2	-40.7	48.6	-31.5
96.0	305.0	44.9	25.7	-36.7	32.6	-30.7
97.0	303.3	45.4	24.9	-38.0	32.1	-32.1
98.0	307.0	50.9	30.6	-40.6	38.2	-33.5
99.0	310.0	55.3	35.6	-42.4	43.5	-34.3
100.0	317.7	57.2	42.3	-38.6	49.3	-29.2
101.0	320.7	63.1	48.8	-40.0	55.9	-29.3

TRAIL NO. B60 CORK

15 FEBRUARY 1967 22:45:00 AST

H.A.R.P. BARBADOS



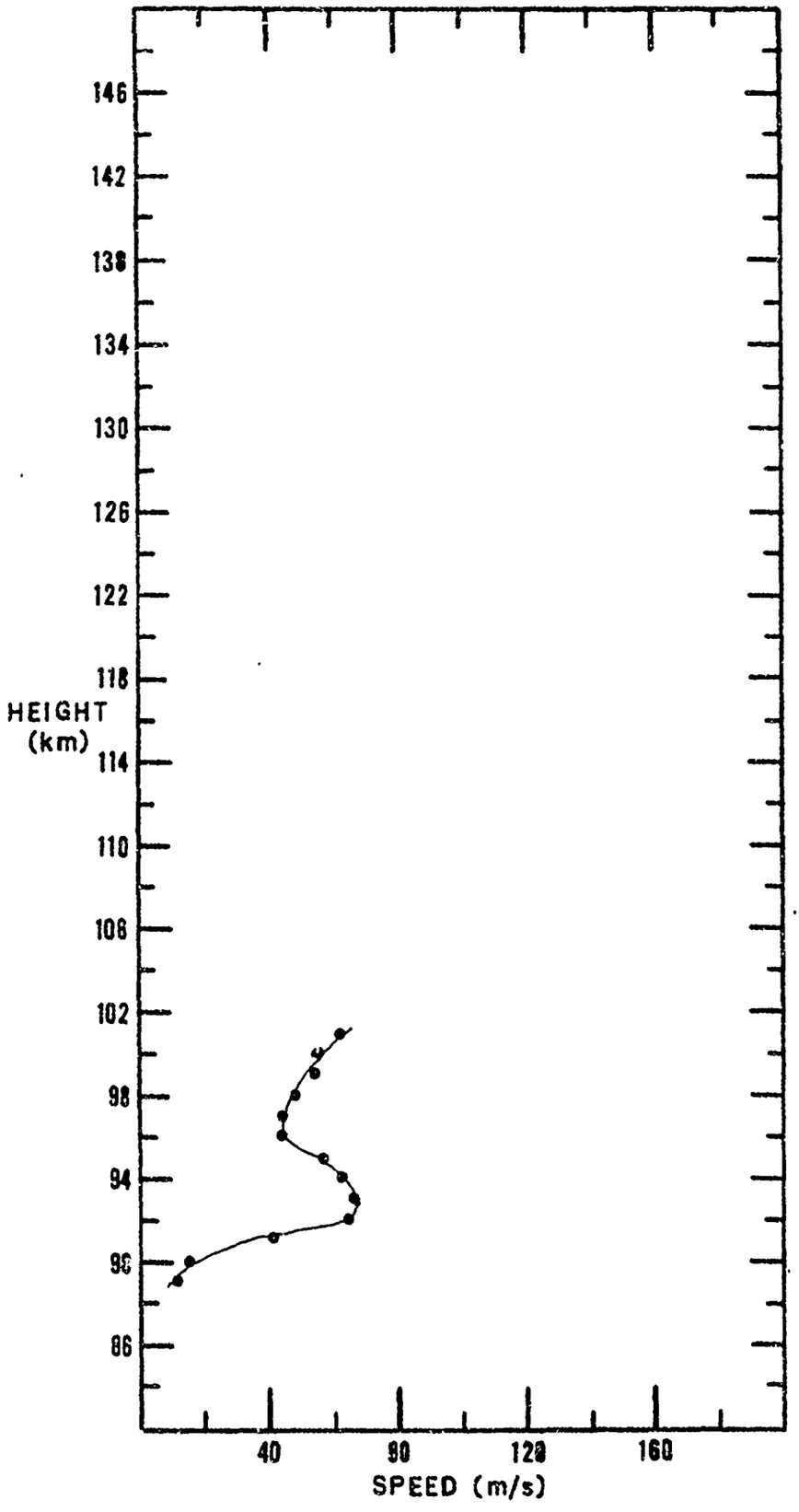
WIND SPEED

• UP

TRAIL NO. B60 CORK

15 FEBRUARY 1967 22:45:00 AST

H.A.R.P. BARBADOS



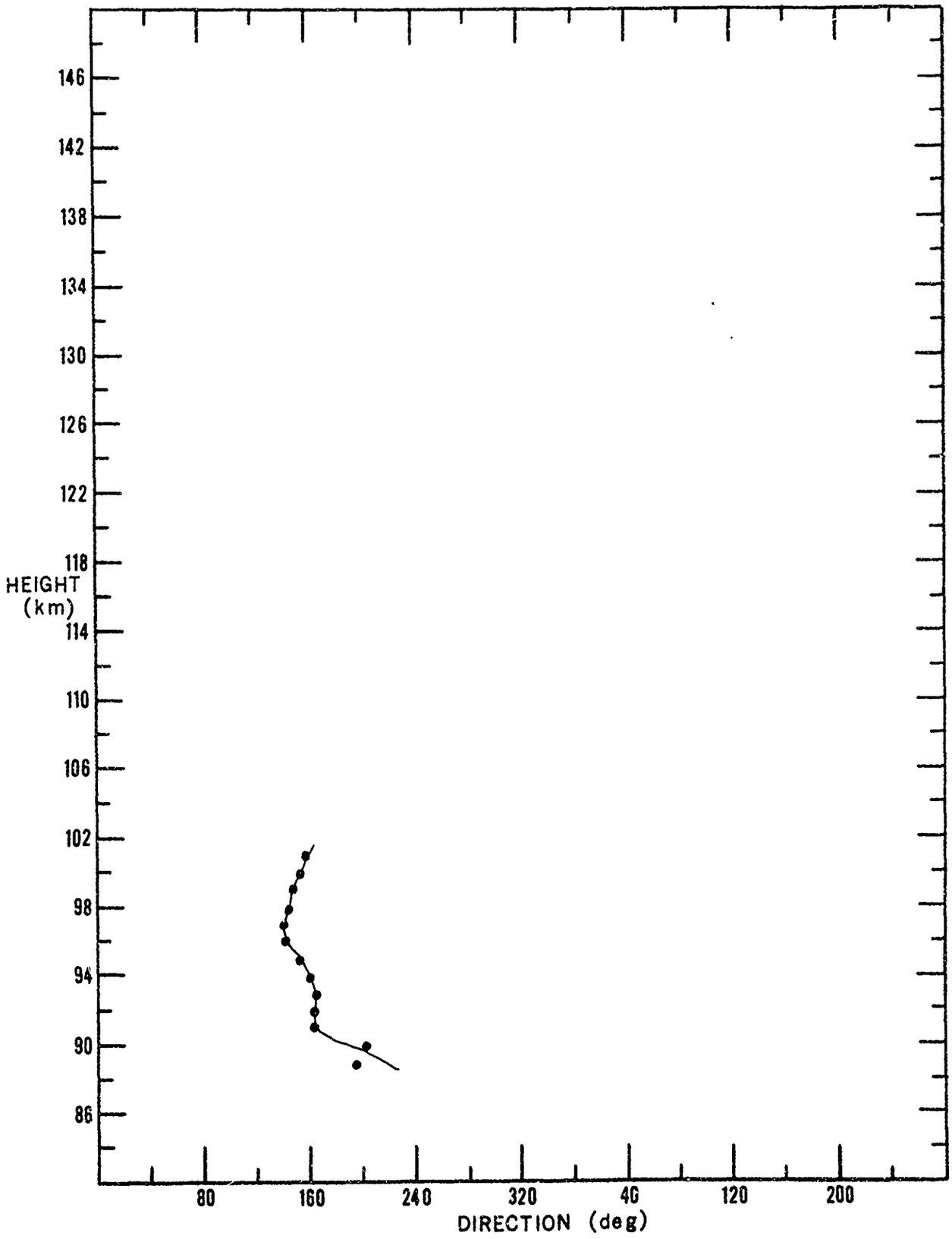
TRAIL NO. B60 CORK

15 FEBRUARY 1967 22:45:00 AST

H.A.R.P. BARBADOS

WIND DIRECTION

• UP



TRAIL NO. B61 DUBLIN

BARBADOS 15 FEBRUARY 1967 [redacted]

UP TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
88.0	49.2	34.0	22.2	25.7	16.5	29.7
89.0	34.0	35.4	29.4	19.8	24.8	25.4
90.0	12.7	34.1	33.3	7.5	31.1	14.1
91.0	348.2	32.4	31.7	-6.6	32.4	0.0
92.0	324.0	39.0	31.6	-23.0	35.6	-16.1
93.0	313.2	47.3	32.3	-34.5	38.6	-27.2
94.0	310.4	52.7	34.2	-40.2	41.7	-32.4
95.0	265.6	78.9	34.5	-71.0	48.2	-62.5
96.0	294.9	75.2	31.6	-68.3	44.8	-60.5
97.0	279.1	71.1	11.3	-70.2	25.3	-66.4
98.0	268.3	64.6	-1.9	-64.6	11.3	-63.6
99.0	268.8	62.0	-1.2	-62.0	11.4	-61.0
100.0	280.8	63.0	11.8	-61.9	24.1	-58.2
101.0	277.4	75.5	9.7	-74.9	24.7	-71.4
102.0	265.9	72.1	-5.1	-71.9	9.6	-71.4
103.0	262.6	28.9	-3.7	-28.6	2.2	-28.8
104.0	282.9	7.6	1.7	-7.4	3.2	-6.9
105.0	36.1	13.4	10.8	7.9	9.0	9.9
106.0	52.1	21.1	12.9	16.6	9.3	18.9
107.0	60.2	28.2	14.0	24.5	8.7	26.8
108.0	65.6	35.0	14.4	31.9	7.6	34.2
109.0	68.2	43.1	16.0	40.0	7.5	42.4
110.0	70.4	51.0	17.1	48.0	7.0	50.5
111.0	73.1	57.7	16.7	55.2	5.1	57.4
112.0	74.2	65.7	17.9	63.2	4.7	65.5
113.0	77.5	69.7	15.1	68.1	1.0	69.7
114.0	77.6	75.8	16.2	74.0	0.8	75.7
115.0	78.7	71.9	14.1	70.5	-0.5	71.9
116.0	80.4	75.0	12.5	74.0	-2.8	75.0
117.0	76.7	75.3	17.3	73.3	2.0	75.3

TRAIL NO. 861 DUBLIN

BARBADOS 15 FEBRUARY 1967 [redacted]

DOWN TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
88.0	37.9	37.6	29.7	23.1	24.4	28.7
89.0	62.5	41.4	36.7	19.1	32.1	26.2
90.0	342.3	34.7	33.1	-10.6	34.6	-3.7
91.0	335.5	34.7	31.6	-14.4	33.9	-7.7
92.0	318.4	42.2	31.5	-28.0	36.5	-21.0
93.0	306.6	52.9	31.5	-42.5	39.5	-35.2
94.0	306.6	56.4	33.6	-45.3	42.1	-37.5
95.0	297.9	68.2	31.9	-60.2	43.5	-52.5
96.0	284.7	85.1	21.5	-82.3	37.8	-76.2
97.0	284.6	74.7	18.8	-72.3	33.1	-67.0
98.0	267.9	66.7	-2.4	-66.7	11.2	-65.8
99.0	266.6	64.6	-3.9	-64.4	9.3	-63.8
100.0	269.3	62.0	-0.8	-62.0	11.8	-60.9
101.0	275.6	77.1	7.5	-76.7	22.9	-73.6
102.0	269.7	74.0	-0.4	-74.0	14.6	-72.5
103.0	266.0	34.5	-2.4	-34.4	4.6	-34.2
104.0	339.5	12.4	11.6	-4.3	12.2	-1.9
105.0	41.8	19.8	14.8	13.2	11.8	15.9
106.0	56.5	27.6	15.2	23.1	10.2	25.7
107.0	65.9	31.7	12.9	28.9	6.8	30.9
108.0	72.0	34.7	10.7	33.0	3.8	34.5
109.0	77.0	47.7	10.8	46.5	1.1	47.7
110.0	75.4	56.3	14.2	54.5	2.8	56.2
111.0	77.2	66.6	14.7	65.0	1.2	66.6
112.0	79.6	66.9	12.0	65.8	-1.6	66.9
113.0	84.3	73.0	7.3	72.6	-7.6	72.6
114.0	87.8	74.3	2.8	74.3	-12.4	73.3
115.0	92.2	81.9	-3.2	81.8	-19.7	79.4
116.0	93.9	86.8	-5.9	86.6	-23.4	83.6
117.0	96.8	85.2	-10.0	84.6	-27.0	80.8

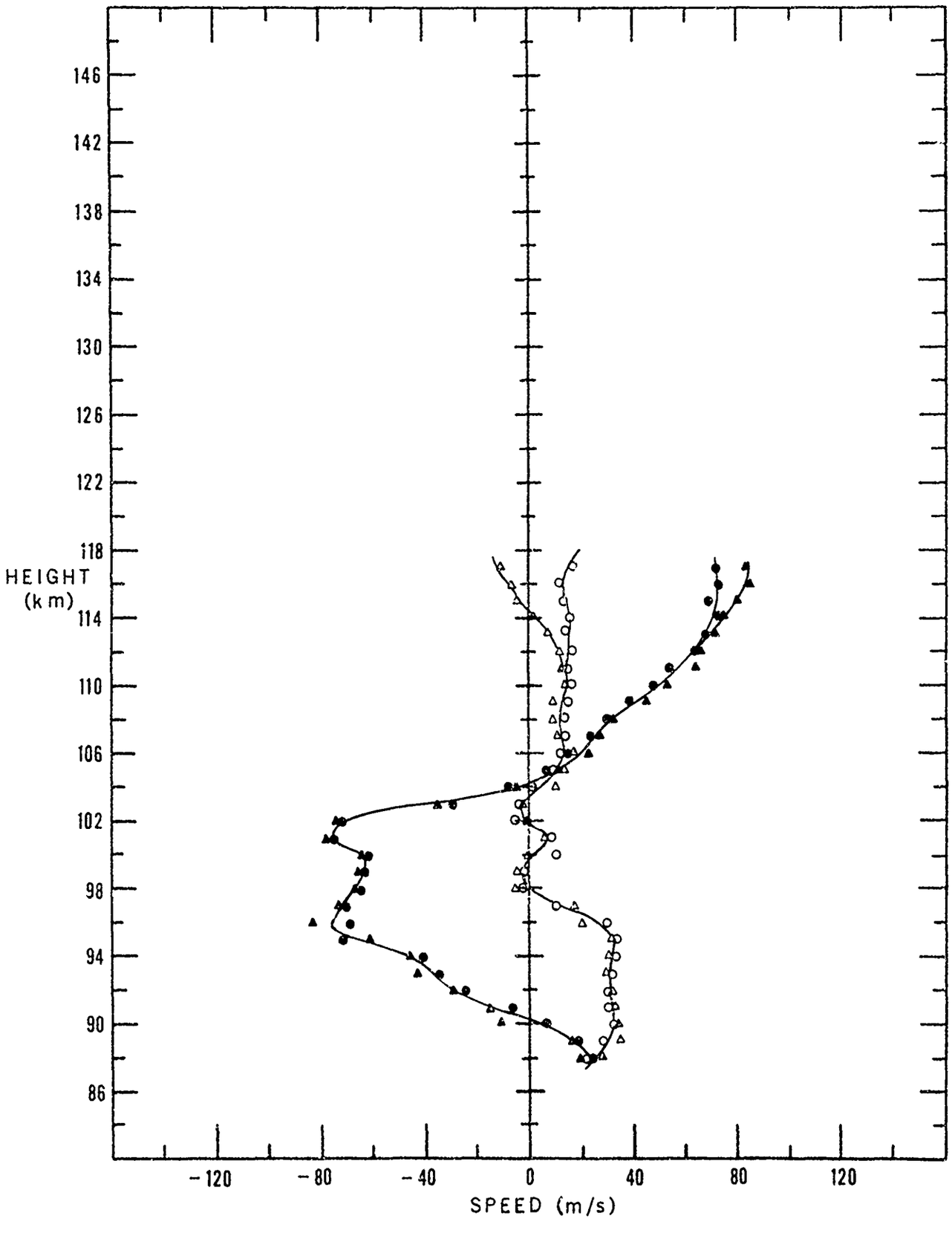
WIND COMPONENTS

	UP	DOWN
N–S	o	△
E–W	●	▲

TRAIL NO. B61 DUBLIN

15 FEBRUARY 1967 23:56:00 AST

H.A.R.P. BARBADOS



WIND DIRECTION

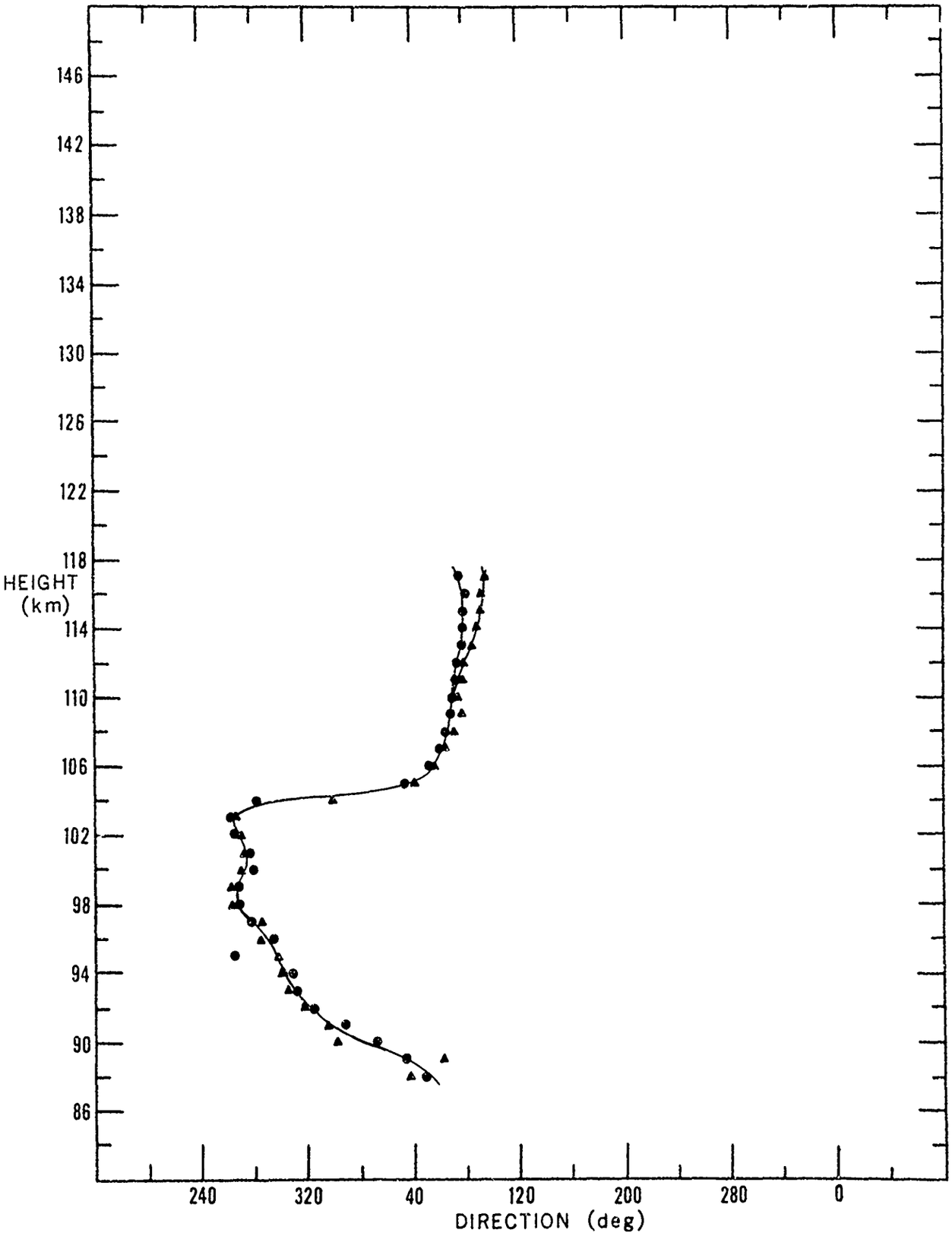
• UP

▲ DOWN

TRAIL NO. B61 DUBLIN

15 FEBRUARY 1967 23:56:00 AST

H.A.R.P. BARBADOS



WIND SPEED

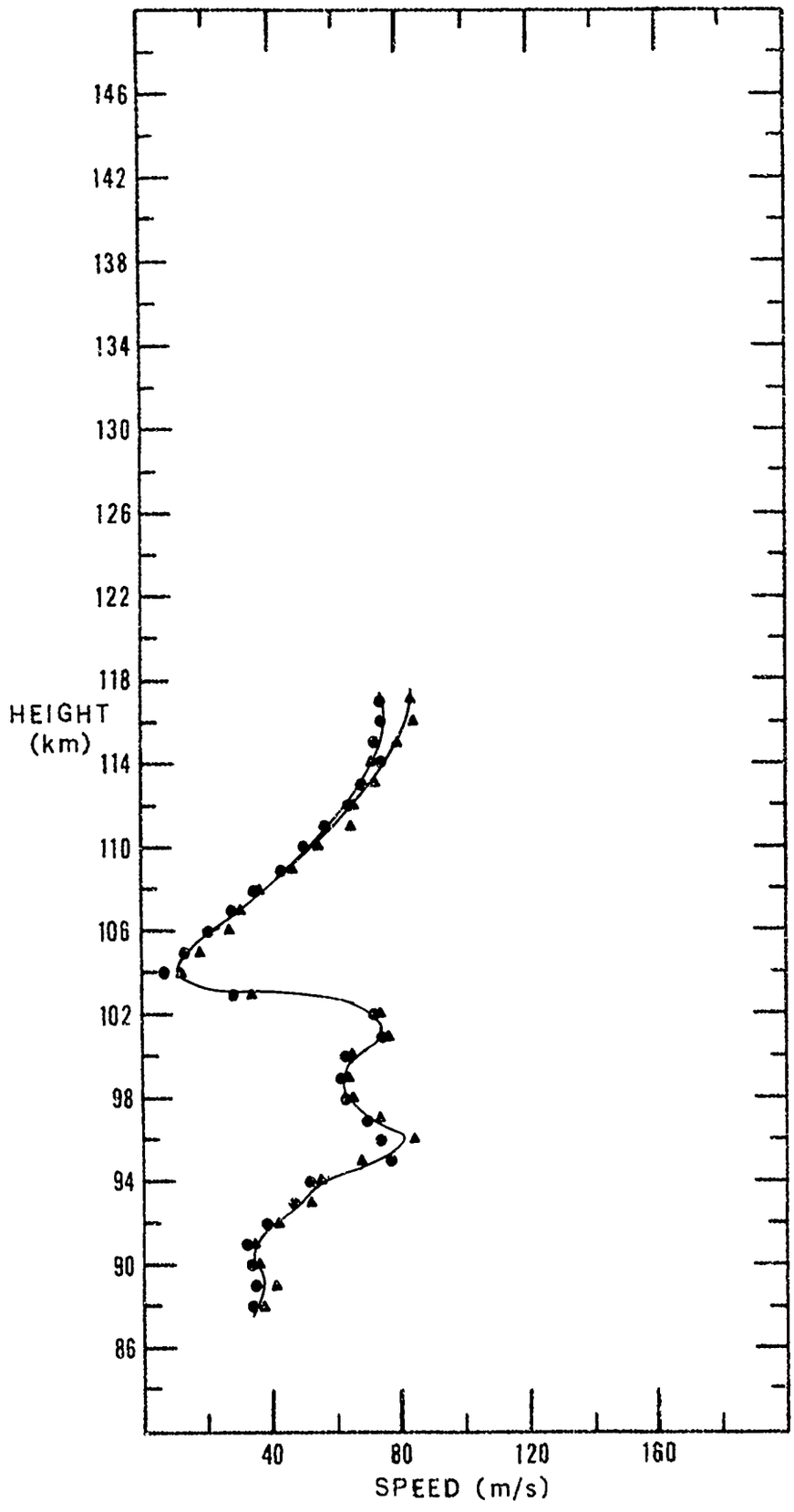
● UP

▲ DOWN

TRAIL NO. B61 DUBLIN

15 FEBRUARY 1967 23:56:00 AST

H.A.R.P. BARBADOS



TRAIL NO. B62 GARVAGH

BARBADOS 15 FEBRUARY 1967 [redacted]

DOWN TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
89.0	305.1	56.2	32.3	-46.0	41.0	-38.5
90.0	276.1	51.2	5.5	-50.9	15.7	-48.7
91.0	275.3	46.2	4.3	-46.0	13.6	-44.2
92.0	275.6	39.8	3.9	-39.6	11.9	-38.0
93.0	277.4	46.5	6.0	-46.2	15.3	-44.0
94.0	282.9	53.9	12.0	-52.5	22.4	-49.0
95.0	286.9	58.7	17.1	-56.2	28.2	-51.6
96.0	283.8	63.0	15.0	-61.2	27.1	-56.9
97.0	269.8	70.7	-0.2	-70.7	14.2	-69.3
98.0	258.9	66.3	-12.7	-65.0	0.8	-66.2
99.0	249.3	61.6	-21.8	-57.6	-9.6	-60.8
100.0	269.5	58.3	-0.5	-58.3	11.4	-57.2
101.0	287.9	33.7	10.3	-32.0	16.6	-29.2
102.0	302.6	11.2	6.0	-9.4	7.8	-8.0
103.0	346.1	4.4	4.3	-1.1	4.4	-0.2
104.0	51.3	14.1	8.8	11.0	6.4	12.6
105.0	65.1	19.5	8.2	17.7	4.4	19.0
106.0	69.4	28.7	10.1	26.9	4.4	28.4
107.0	68.0	40.5	15.2	37.6	7.2	39.9
108.0	75.7	47.5	11.7	46.0	2.1	47.4
109.0	71.9	56.2	17.4	53.4	6.2	55.8
110.0	77.6	44.5	9.6	43.5	0.6	44.5
111.0	74.6	39.6	10.5	38.2	2.5	39.5
112.0	61.7	32.5	15.5	28.6	9.4	31.2
113.0	45.8	30.9	21.5	22.1	16.6	26.0
114.0	354.3	33.1	32.9	-3.3	32.9	3.5
115.0	354.6	32.1	32.0	-3.0	31.9	3.6
116.0	354.1	33.1	33.0	-3.4	33.0	3.4

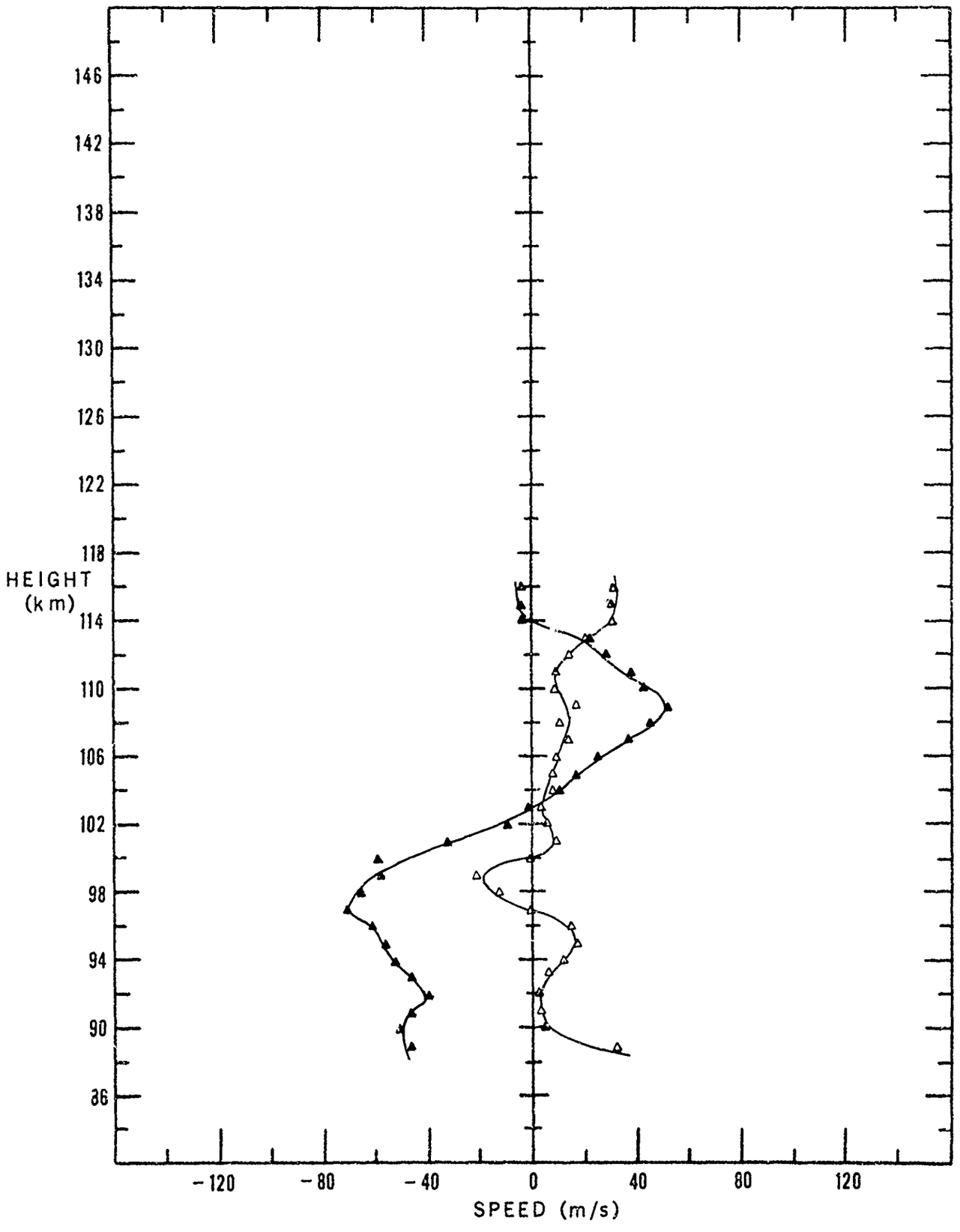
WIND COMPONENTS

	UP	DOWN
N–S	o	Δ
E–W	•	▲

TRAIL NO. B62 GARVAGH

16 FEBRUARY 1967 01:05:00 AST

H.A.R.P. BARBADOS



WIND SPEED

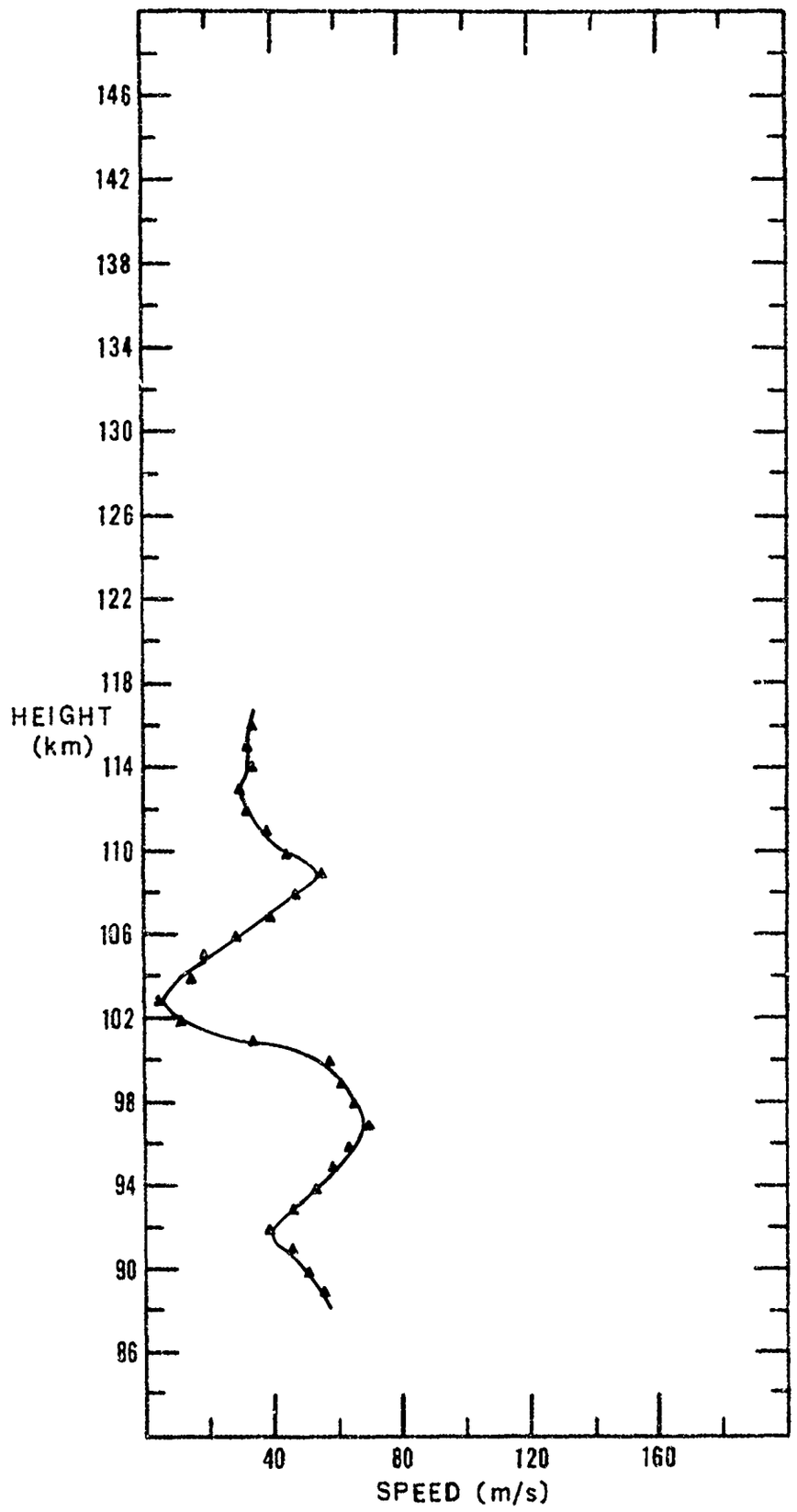
• UP

▲ DOWN

TRAIL NO. B62 GARVAGH

16 FEBRUARY 1967 01:05:00 AST

H.A.R.P. BARBADOS



WIND DIRECTION

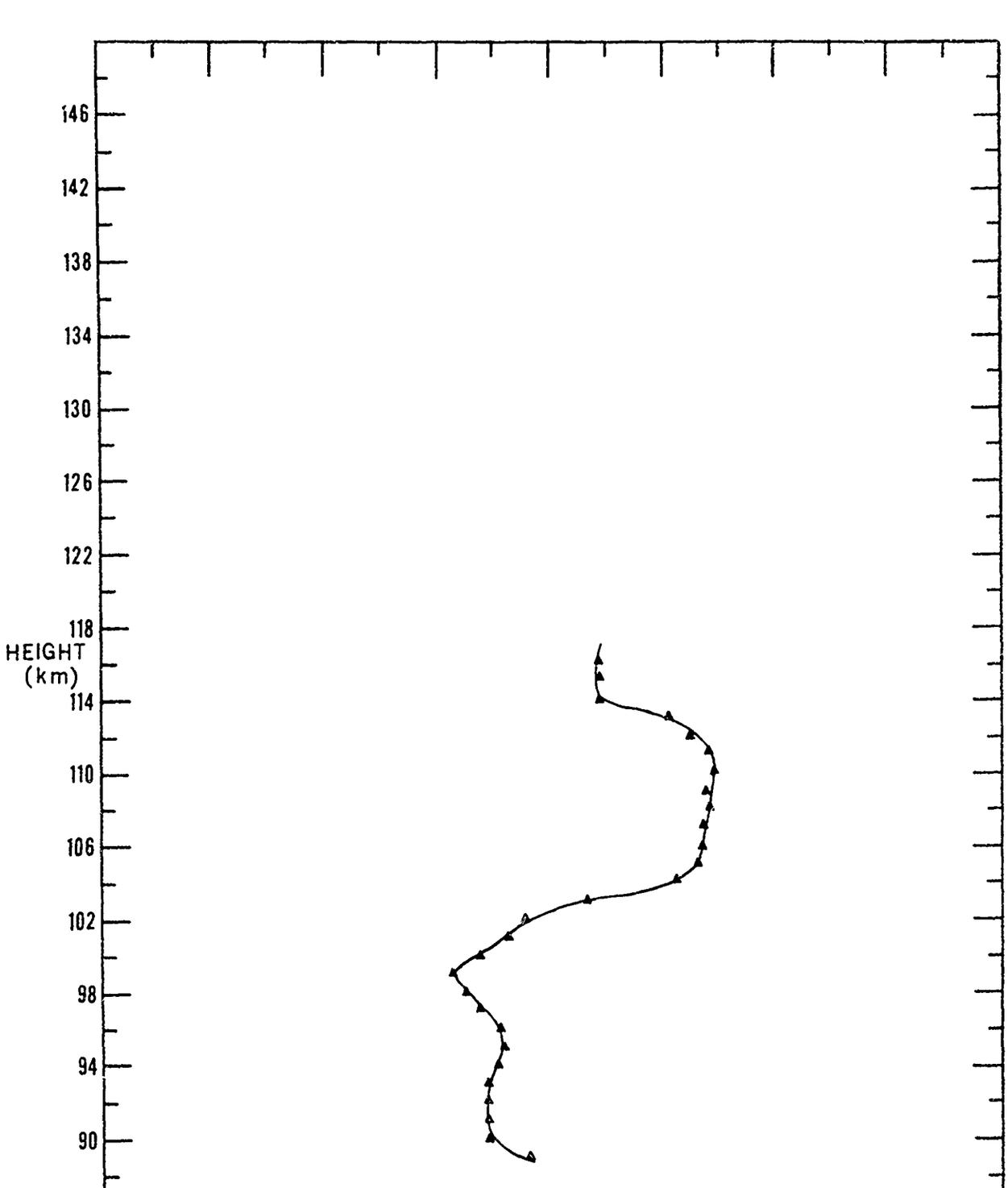
• UP

▲ DOWN

TRAIL NO. B62 GARVAG:!

16 FEBRUARY 1967 01:05:00 AST

H.A.R.P. BARBADOS



TRAIL NO. B63 HOLLYWOOD

BARBADOS 15 FEBRUARY 1967 [redacted]

HD TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
[illegible].0	352.1	62.6	62.1	-8.6	62.6	4.2
[illegible].0	347.5	81.8	79.9	-17.7	81.8	-1.1
90.0	312.2	78.2	52.5	-58.0	63.2	-46.1
[illegible].0	311.3	54.5	36.0	-41.0	43.6	-32.8
[illegible].1	304.2	45.5	25.6	-37.6	32.7	-31.6
93.0	296.0	45.6	20.0	-41.0	27.9	-36.1
94.0	306.2	40.4	23.9	-32.6	30.0	-27.1
[illegible].0	322.4	41.4	32.8	-25.3	37.3	-18.1
[illegible].0	321.2	55.8	43.5	-34.9	49.7	-25.3
[illegible].0	308.3	61.7	38.2	-48.4	47.2	-39.6
[illegible].0	303.6	63.2	35.0	-52.6	45.0	-44.4
99.0	297.1	52.6	24.0	-46.8	33.0	-40.9
100.0	282.0	49.2	10.3	-48.1	19.9	-45.0
[illegible].0	283.4	43.9	10.2	-42.7	18.7	-39.7
[illegible].0	310.3	36.7	23.8	-28.0	29.0	-22.6
[illegible].1	353.2	40.4	40.2	-4.8	40.3	3.5
[illegible].0	10.7	52.0	51.1	9.7	48.1	19.9
[illegible].0	19.1	54.0	51.0	17.7	46.3	27.7
[illegible].0	30.3	57.8	49.9	29.2	42.9	38.7
[illegible].0	43.6	65.1	47.1	44.9	37.0	53.5
[illegible].0	56.1	64.3	35.8	53.4	24.2	59.6
[illegible].0	43.9	29.6	21.4	20.5	16.8	24.4

TRAIL NO. B63 HOLLYWOOD

BARBADOS 15 FEBRUARY 1967 [redacted]

DOWN TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
102.0	348.1	43.2	42.3	-8.9	43.2	-0.1
103.0	18.6	44.9	42.5	14.3	38.7	22.6
104.0	35.7	54.3	44.1	31.7	36.7	40.0
105.0	50.5	70.0	44.5	54.1	32.6	62.0
106.0	62.9	67.2	30.6	59.8	17.8	64.8
107.0	69.0	50.1	18.0	46.8	8.1	49.5
108.0	73.7	39.8	11.2	38.2	3.2	39.7
109.0	72.0	31.8	9.8	30.2	3.5	31.6
110.0	12.0	21.1	20.6	4.4	19.3	8.5
111.0	329.3	51.0	43.9	-26.0	48.3	-16.5
112.0	333.9	64.1	57.6	-28.2	62.1	-15.9

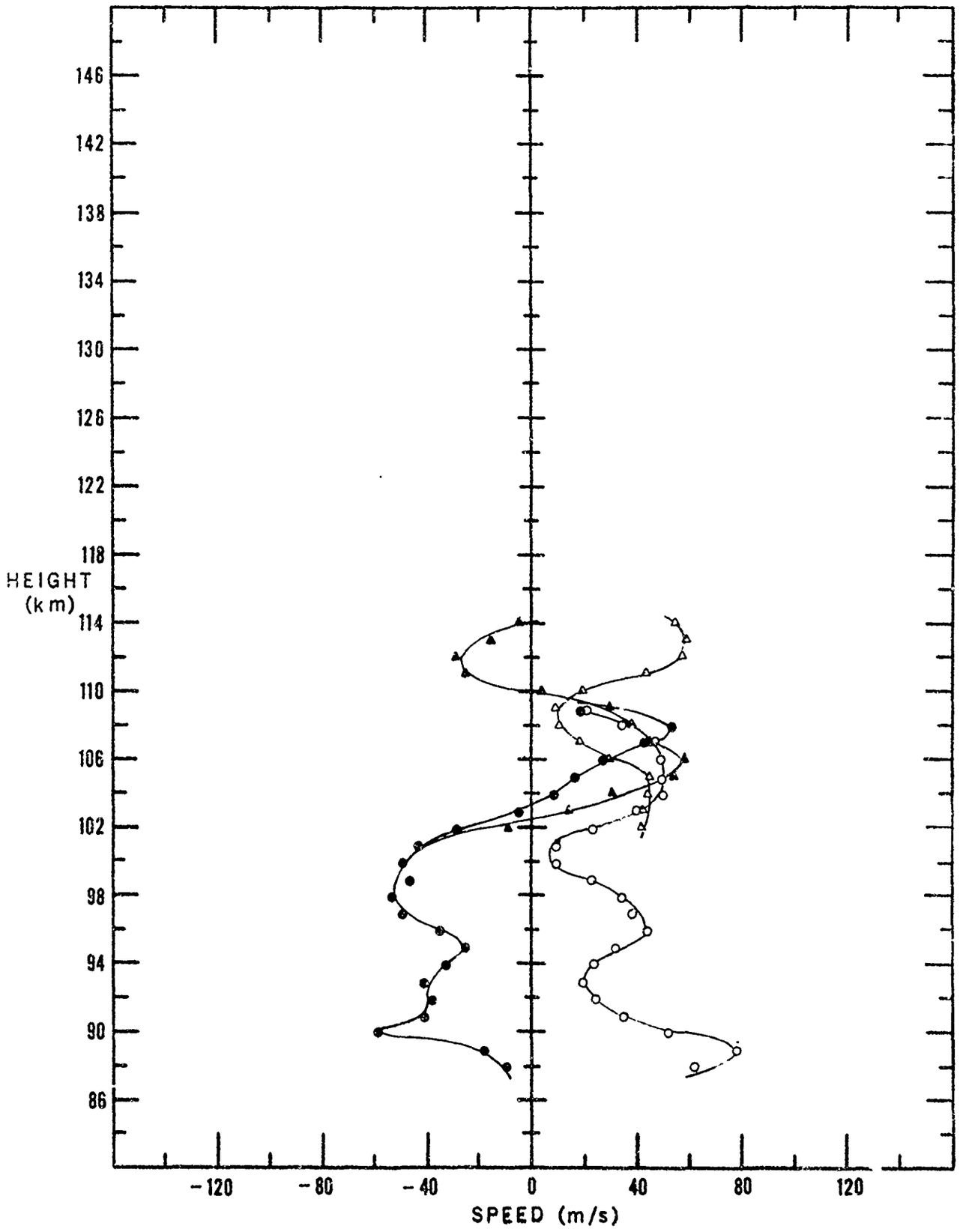
WIND COMPONENTS

	UP	DOWN
N-S	○	△
E-W	●	▲

TRAIL NO. B63 HOLLYWOOD

16 FEBRUARY 1967 02:10:00 AST

H.A.R.P. BARBADOS



WIND SPEED

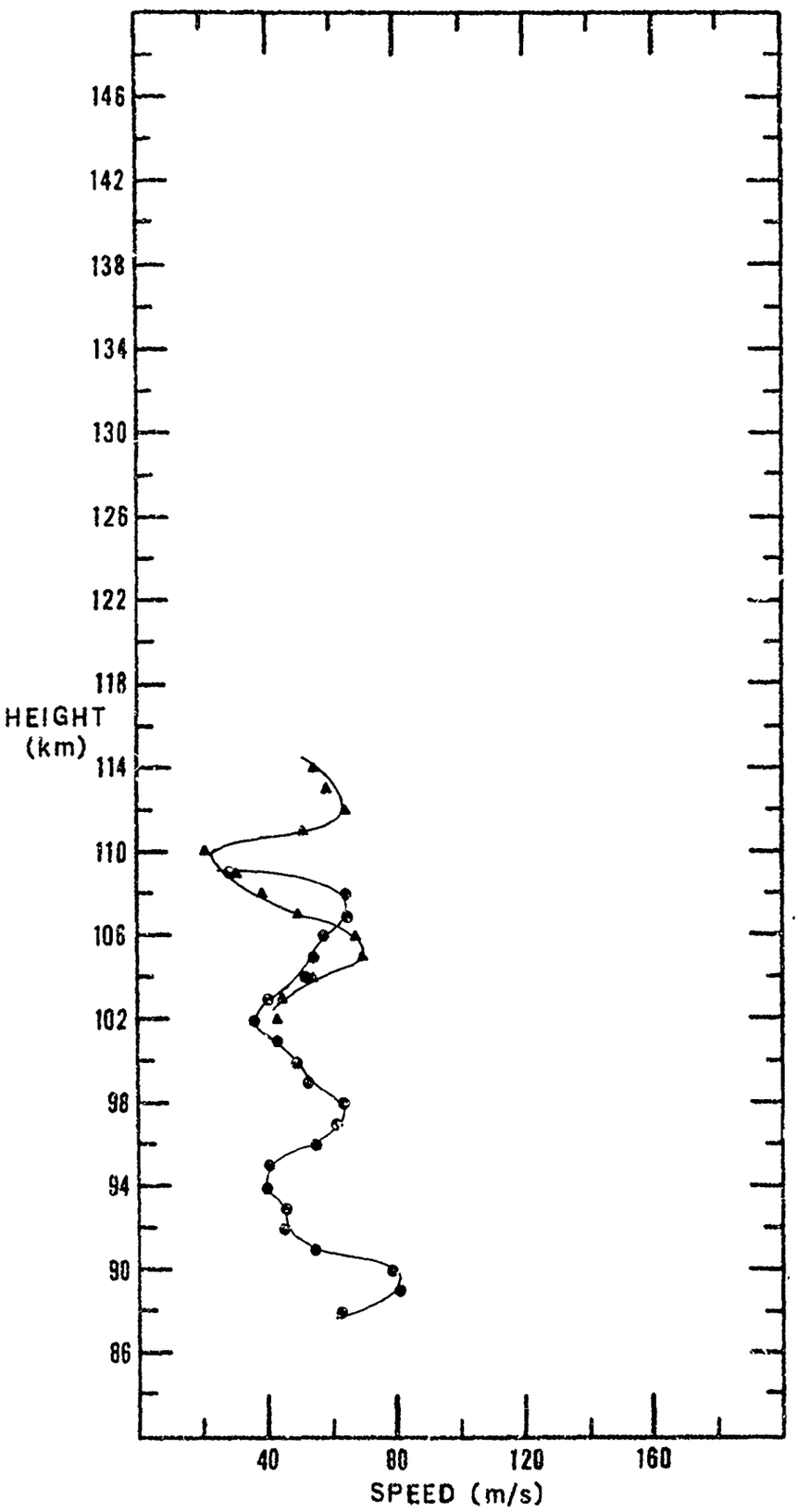
● UP

▲ DOWN

TRAIL NO. B63 HOLLYWOOD

16 FEBRUARY 1967 02:10:00 AST

H.A.R.P. BARBADOS



WIND DIRECTION

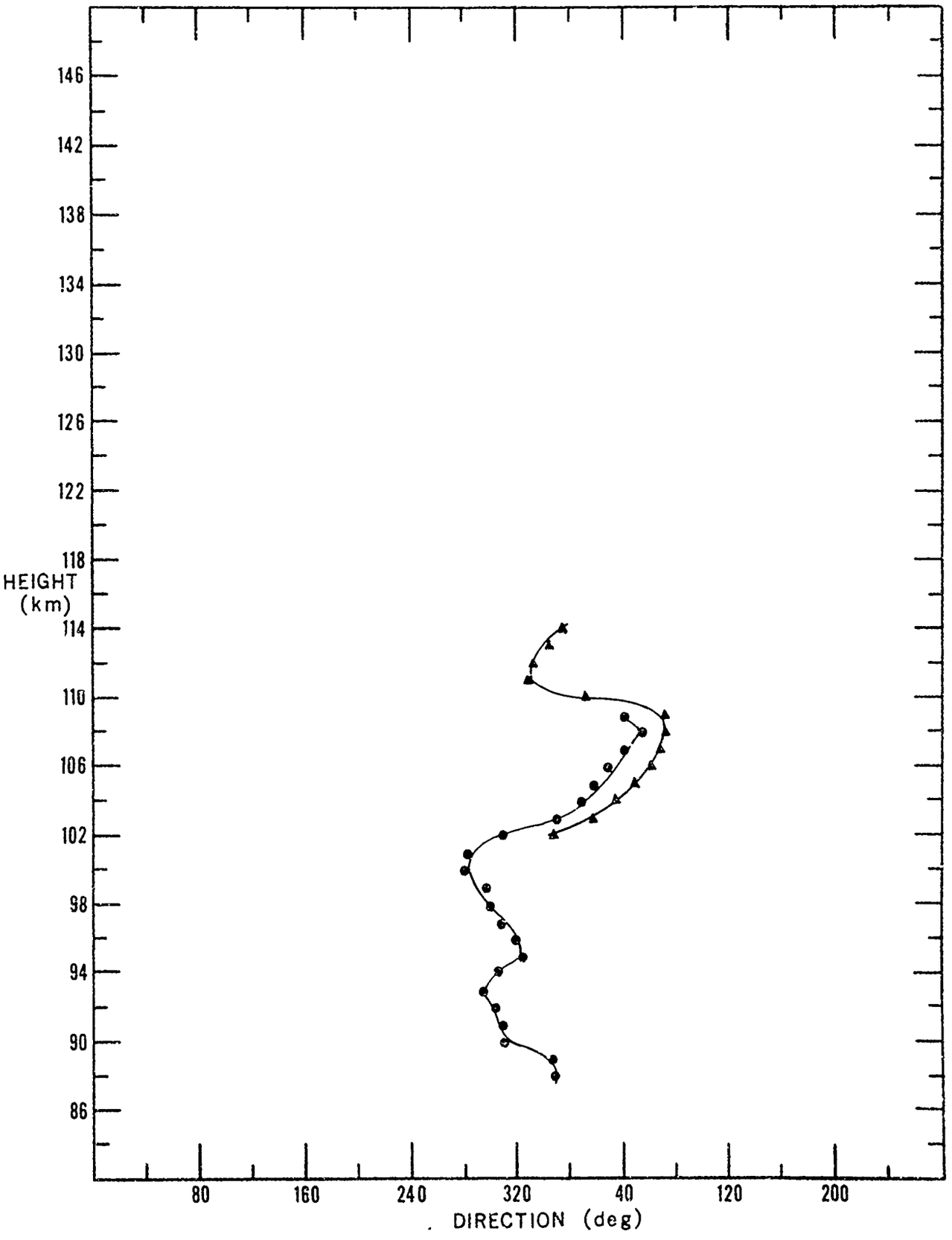
• UP

▲ DOWN

TRAIL NO. B63 HOLLYWOOD

16 FEBRUARY 1967 02:10:00 AST

H.A.R.P. BARBADOS



TRAIL NO. B64 KERRY 65 LIMERICK

BARBADOS 15 FEBRUARY 1967 [redacted]

UP TRAIL

TITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
3.0	293.9	61.3	24.8	-56.0	35.7	-49.8
4.0	298.6	71.8	34.4	-63.0	46.5	-54.7
5.0	289.7	84.0	28.3	-79.1	43.8	-71.7
6.0	285.6	89.8	24.1	-86.5	41.2	-79.8
7.0	291.2	78.0	28.2	-72.8	42.4	-65.6
8.0	300.3	64.2	32.4	-55.4	43.0	-47.7
9.0	317.3	54.3	39.9	-36.8	46.5	-27.9
0.0	11.8	48.6	47.5	10.0	44.5	19.4
1.0	30.7	57.5	49.4	29.3	42.4	38.7
2.0	35.8	62.9	51.1	36.8	42.6	46.4
3.0	33.3	70.6	59.0	38.8	49.9	50.0
4.0	43.1	78.4	57.2	53.6	45.1	64.1
5.0	46.4	83.4	57.5	60.4	44.0	70.8
6.0	47.9	85.2	57.2	63.2	43.2	73.5
07.0	47.4	86.3	58.4	63.5	44.3	74.0
08.0	46.7	90.4	62.0	65.8	47.3	77.0
09.0	34.0	77.7	64.1	43.9	53.8	56.0
10.0	356.1	76.7	76.5	-5.2	76.0	10.4
11.0	359.2	86.8	86.8	-1.2	85.2	16.5
12.0	358.9	104.5	104.4	-2.0	102.6	19.2
13.0	349.3	89.6	88.0	-16.6	89.5	1.6
14.0	345.3	91.6	88.6	-23.2	91.5	-4.7
15.0	341.3	90.1	85.3	-28.8	89.4	-10.9
16.0	338.0	89.5	83.0	-33.5	88.1	-15.9

TRAIL NO. B64 KERRY

WIND COMPONENTS

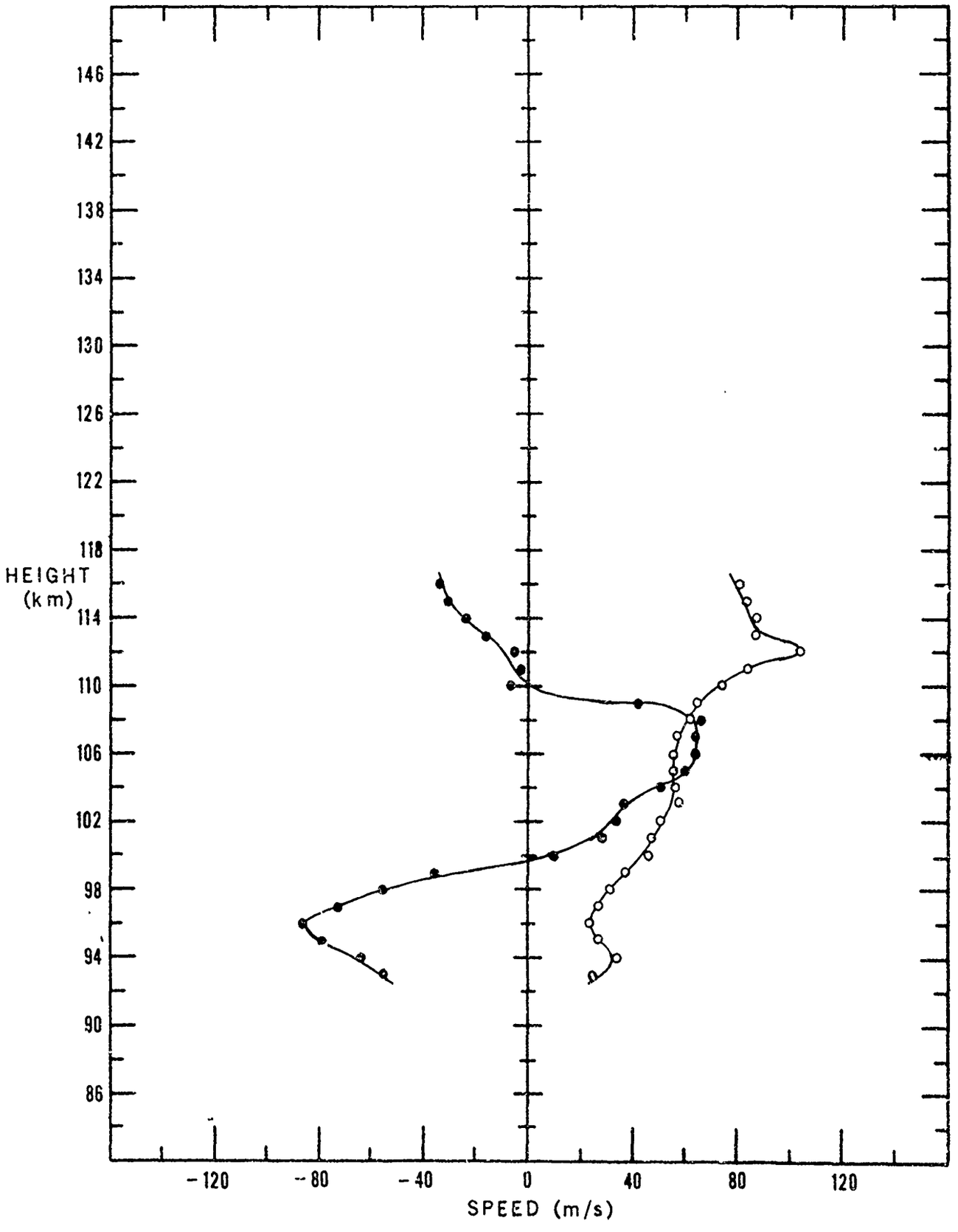
UP

N-S o

E-W •

16 FEBRUARY 1967 03:23:00 A S T

H.A.R.P. BARBADOS



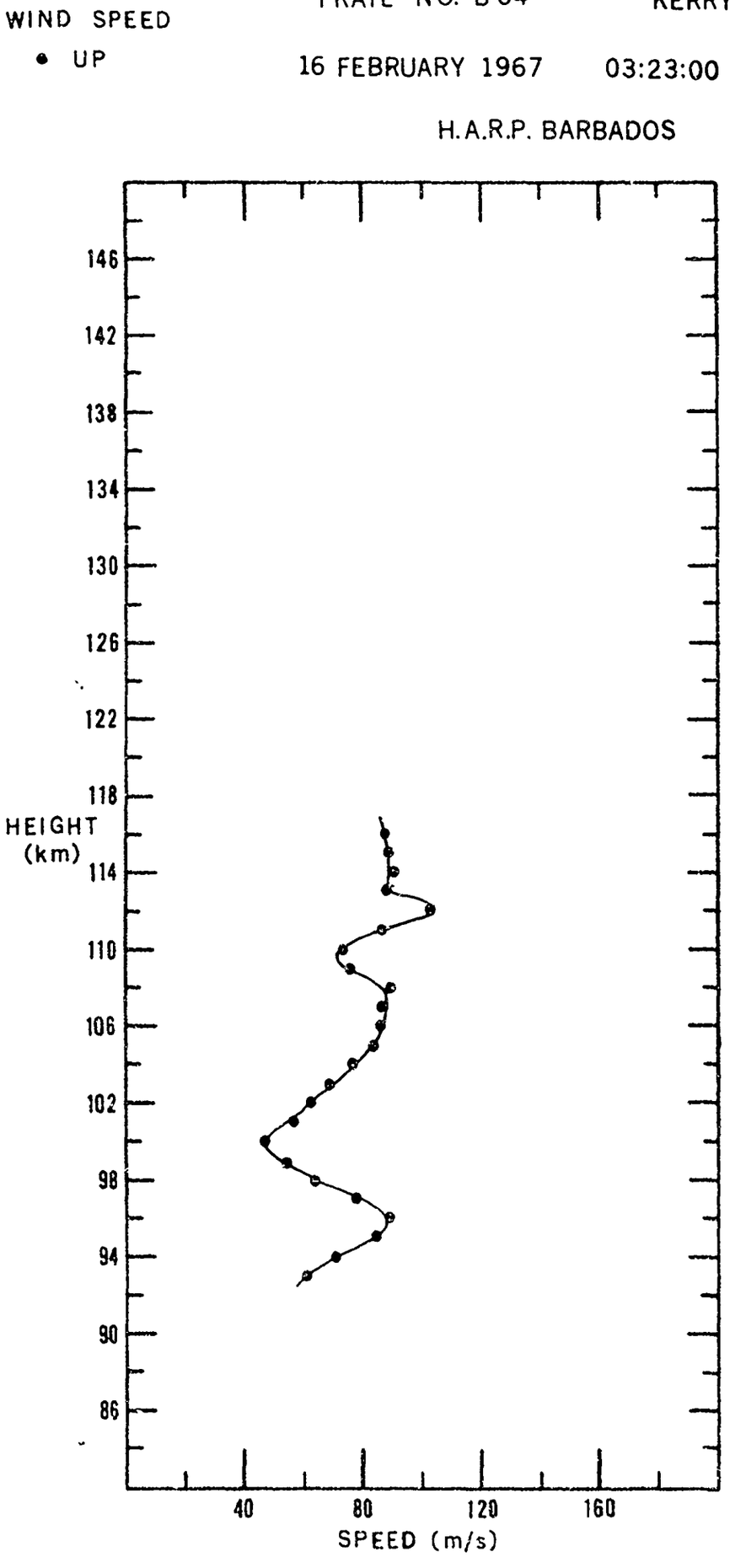
WIND SPEED

• UP

TRAIL NO. B 64 KERRY

16 FEBRUARY 1967 03:23:00 A S T

H.A.R.P. BARBADOS



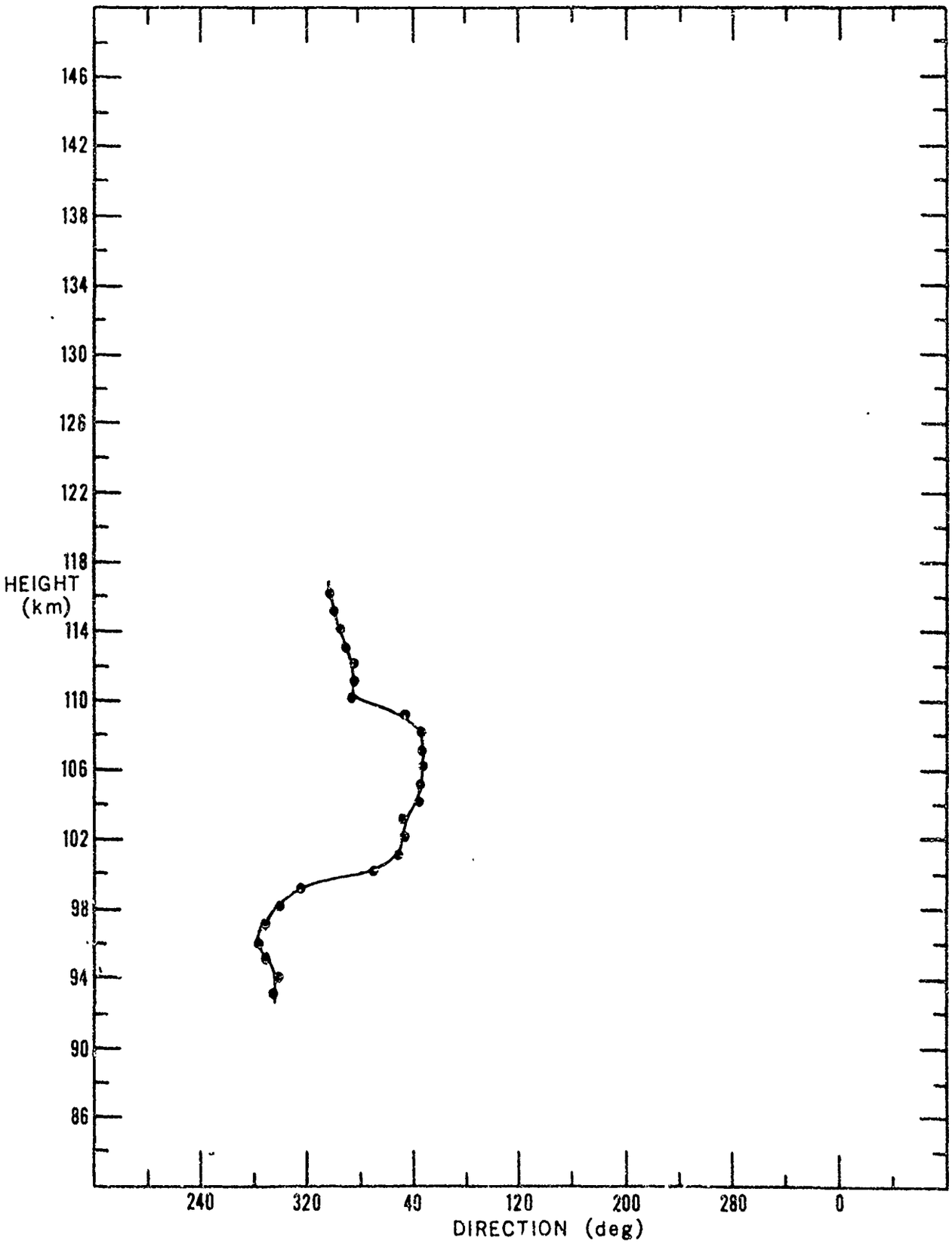
TRAIL NO. B 64 KERRY

WIND DIRECTION

• UP

16 FEBRUARY 1967 03:23:00 A S T

H.A.R.P. BARBADOS



TRAIL NO. B65 LIMERICK

BARBADOS 15 FEBRUARY 1967 [redacted]

UP TRAIL

TITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
95.0	302.6	106.7	57.5	-89.9	74.6	-76.3
96.0	326.9	79.4	66.5	-43.4	73.9	-29.0
97.0	342.7	64.7	61.8	-19.2	64.4	-6.2
98.0	356.4	60.7	60.6	-3.8	60.1	8.6
99.0	2.8	65.0	65.0	3.2	63.0	16.3
00.0	11.8	74.0	72.5	15.1	67.9	29.5
01.0	19.6	80.3	75.7	27.0	68.6	41.8
02.0	31.8	86.5	73.5	45.6	62.7	59.6
03.0	47.1	90.4	61.5	66.2	46.8	77.3
04.0	52.7	96.0	58.2	76.4	41.5	86.6
05.0	53.8	82.3	48.6	66.4	34.1	74.9
06.0	32.9	51.2	43.0	27.8	36.5	36.0
07.0	359.4	61.7	61.7	-0.6	60.5	11.9
08.0	331.2	78.4	68.7	-37.8	74.9	-23.1
09.0	343.1	97.7	93.5	-28.4	97.3	-8.8
10.0	352.0	107.1	106.1	-14.8	106.9	7.1

TRAIL NO. B65 LIMERICK [redacted]

BARBADOS 15 FEBRUARY 1967

DOWN TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
95.0	333.0	66.0	58.8	-30.0	63.7	-17.4
96.0	335.0	71.0	64.3	-29.9	69.0	-16.2
97.0	346.7	65.4	63.6	-15.1	65.3	-1.9
98.0	1.0	63.0	63.0	1.1	61.5	13.9
99.0	25.2	60.0	54.3	25.5	48.0	36.0
100.0	32.8	66.6	55.9	36.1	47.4	46.7
101.0	38.8	74.0	57.7	46.4	47.1	57.2
102.0	45.3	83.9	59.0	59.6	45.7	70.3
103.0	48.3	92.4	61.5	69.0	46.2	80.1
104.0	52.3	91.4	55.9	72.3	40.0	82.1
105.0	54.4	83.3	48.5	67.7	33.7	76.1
106.0	43.7	61.1	44.2	42.2	34.7	50.3
107.0	11.9	57.7	56.5	11.9	52.9	23.1

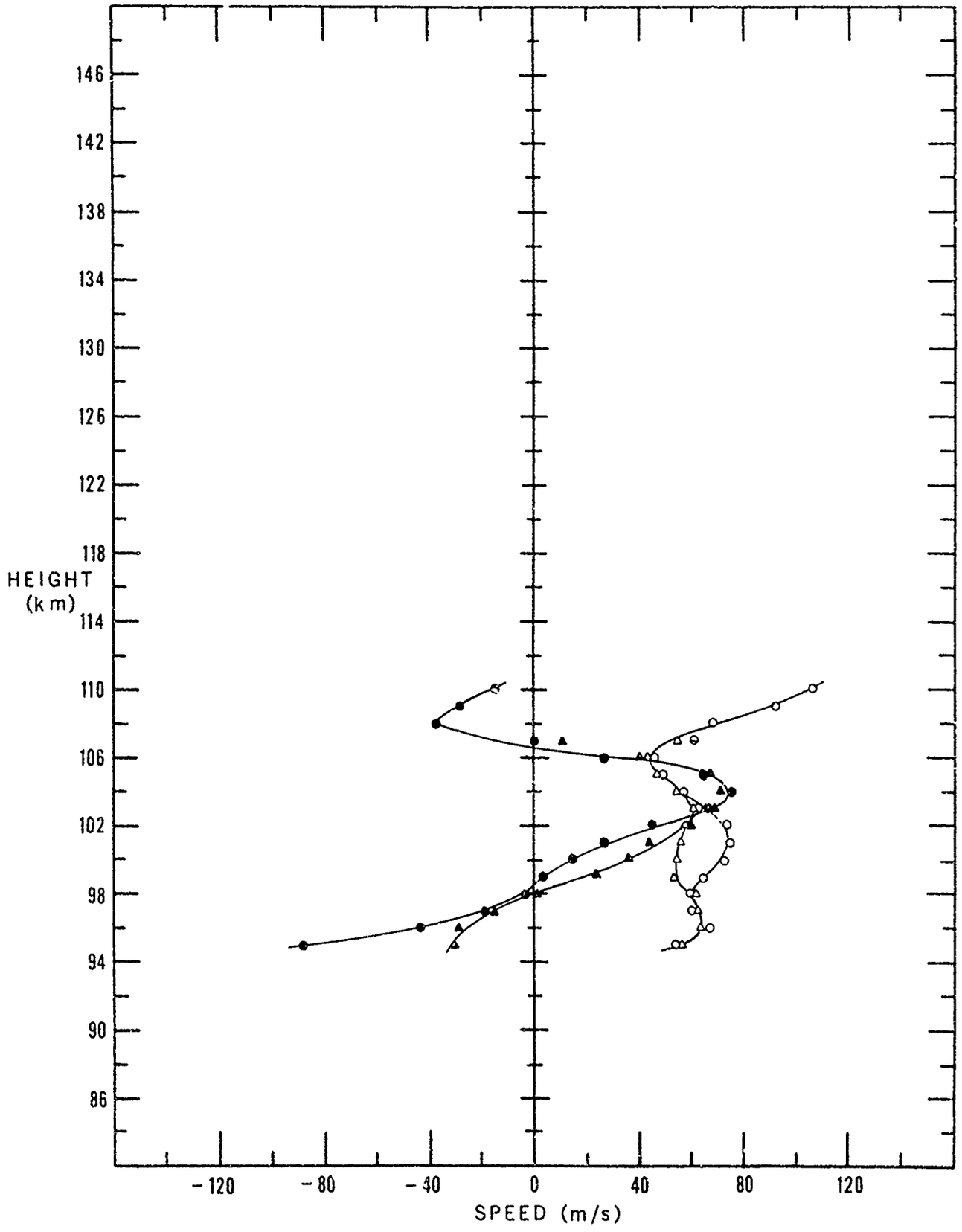
WIND COMPONENTS

	UP	DOWN
N–S	o	△
E–W	●	▲

TRAIL NO. B65 LIMERICK

16 FEBRUARY 1967 04:17:00 AST

H.A.R.P. BARBADOS



WIND SPEED

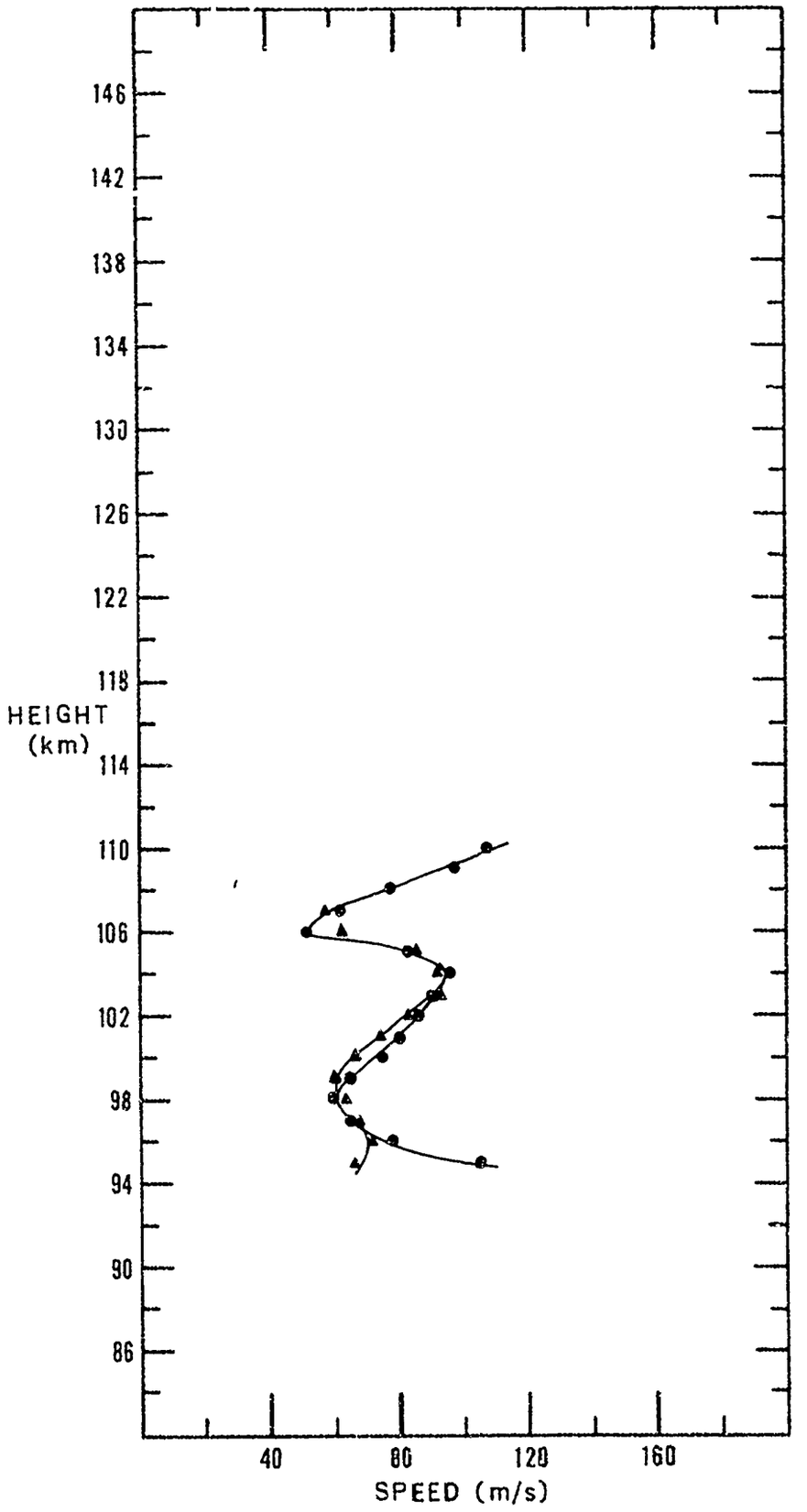
● UP

▲ DOWN

TRAIL NO. B65 LIMERICK

16 FEBRUARY 1967 04:17:00 AST

H.A.R.P. BARBADOS



WIND DIRECTION

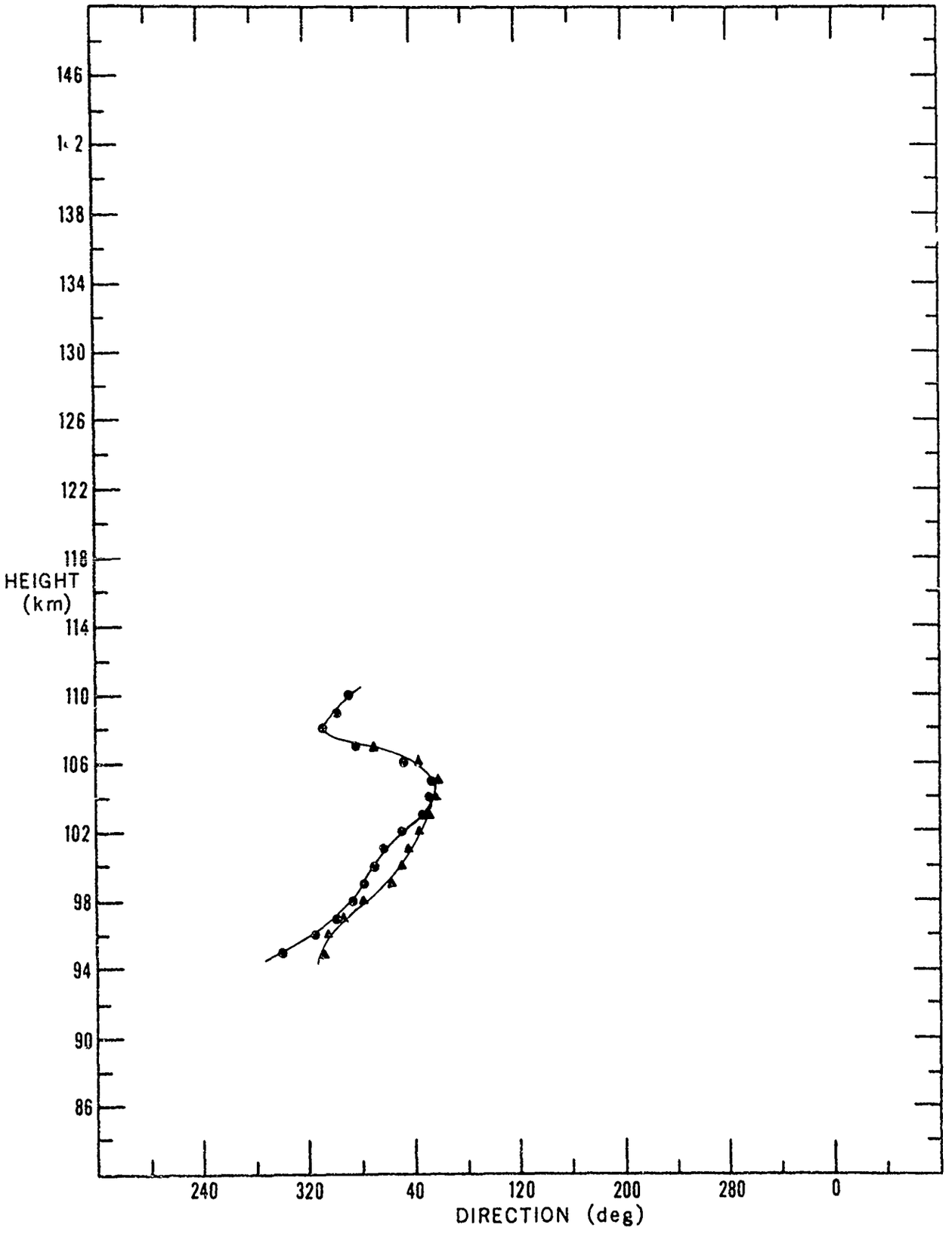
• UP

▲ DOWN

TRAIL NO. B65 LIMERICK

16 FEBRUARY 1967 04:17:00 AST

H.A.R.P. BARBADOS



TRAIL NO. B66 NEWRY

BARBADOS 15 FEBRUARY 1967 [redacted]

UP TRAIL

ALTITUDE (KM)	WIND HEADING (DEG)	WIND VELOCITY (M/S)	WIND COMPONENTS (M/S) GEOGRAPHIC N-S	GEOGRAPHIC E-W	MAGNETIC N-S	MAGNETIC E-W
106.0	52.5	12.6	7.7	10.0	5.5	11.4
107.0	27.8	18.7	16.5	8.7	14.4	11.9
108.0	320.3	53.1	40.8	-33.9	46.8	-24.9
109.0	337.0	70.8	65.2	-27.7	69.5	-13.9
110.0	352.1	81.9	81.1	-11.2	81.7	5.5
111.0	3.5	103.5	103.3	6.4	8.2	0
112.0	19.3	115.2	108.8	38.1	8.7	0

TRAIL NO. B66 NEWRY

16 FEBRUARY 1967 05:20:00 AST

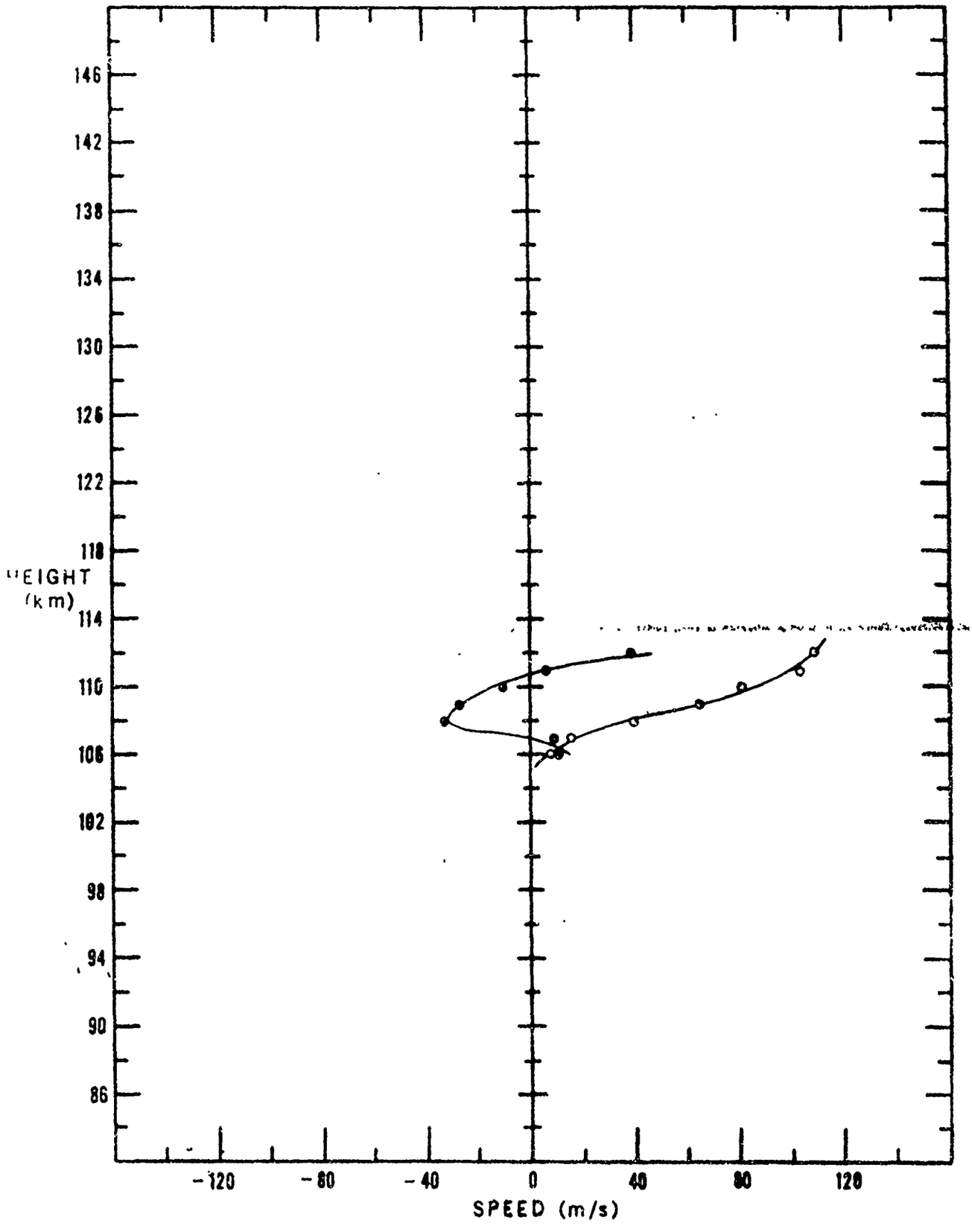
H.A.R.P. BARBADOS

WIND COMPONENTS

UP

N-S o

E-W •



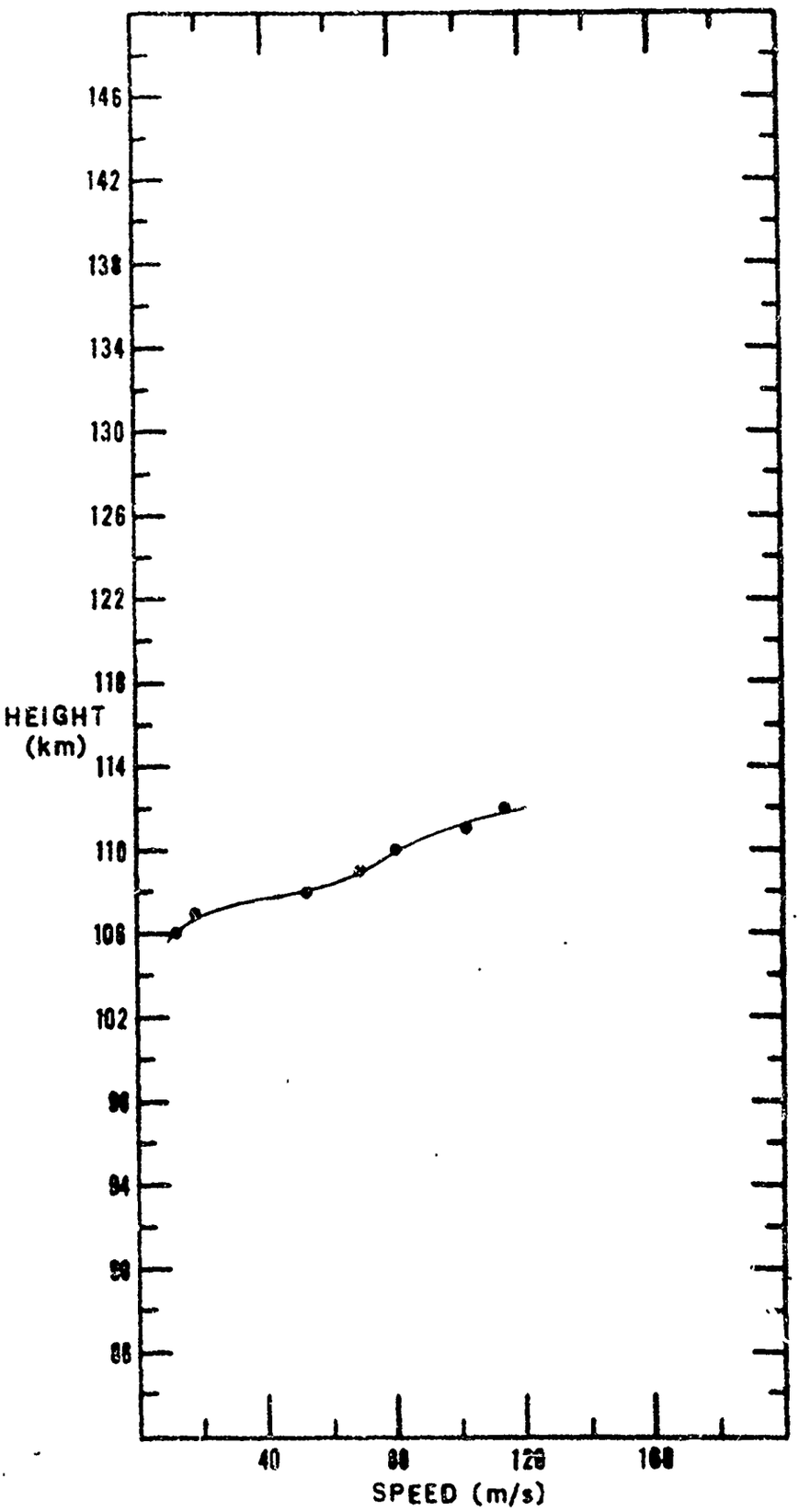
WIND SPEED

• UP

TRAIL NO. B 66 NEWRY

16 FEBRUARY 1967 05:20:00 AST

H.A.R.P. BARBADOS



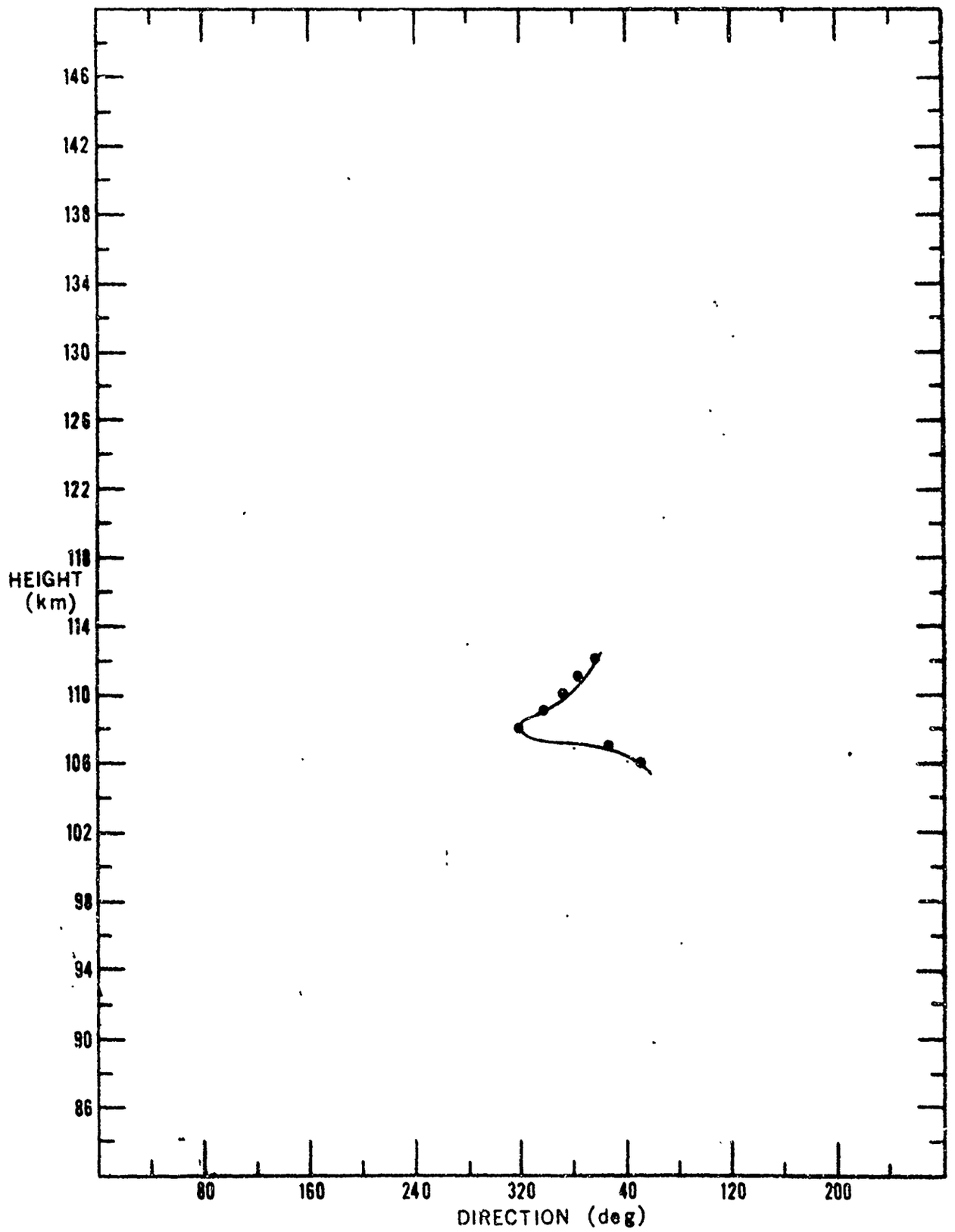
TRAIL NO. B66 NEWRY

WIND DIRECTION

• UP

16 FEBRUARY 1967 05:20:00 AST

H.A.R.P. BARBADOS



Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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(Barbados 15-16 February 1967)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

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c. d.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Ballistic Research Laboratories Aberdeen Proving Ground, Md.

13. ABSTRACT

During the night of 15-16 February 1967, eight luminous trails were produced between 88km and 123km by the release of tri-methyl aluminum from projectiles fired from a smothbore sixteen-inch gun located on the West Indian Island of Barbados (57.5°W, 13.1° N). These trails were photographed from neighboring islands and analyzed to yield wind profiles. This report contains the tabulated wind data from all eight trails together with plots versus altitude of wind components, wind speed, wind heading, and wind shear components.

DD FORM 1 NOV 68 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
HARP HIGH ALTITUDE RESEARCH PROJECT IONOSPHERIC WINDS						