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CARIBBEAN UPPER AIR MEASUREMENTS TECHNICAL REPORT I
OF CARIBBEAN RADIO DUCTING INVESTIGATIONS

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R. J. Aldrich
J. R. Herlihy
L. G. Rowlandson

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August 1969

AEROSPACE INSTRUMENTATION PROGRAM OFFICE
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

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FOREWORD

This report is prepared for the

Aerospace Instrumentation Program Office
Electronics System Division
Air Force Systems Command of the United States Air Force
L. G. Hanscom Field
Bedford, Massachusetts

Air Force Program Monitor - Lt. C. Schafer, ESD/ESSIE
Project Number 6684, Task 6684.08

Covering research over the period

1969 March 1 to 1969 October 1

Prepared under Contract No. F19628-69-C-0208 by

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Merrill Lane, University Heights
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This report was reviewed and approved by

C. Schafer, Lieutenant, USAF
Program Manager for ESD/ESSIE/6684.

ABSTRACT

A series of meteorological measurements was made in the northern part of the Caribbean Sea, during the Spring of 1969, to characterize the Trade Wind Inversion and its effect on radio wave propagation. Among the measurements made were data collected from the sensors on the airborne platform of the USAF C-131 Convair (37812), which was provided for use on this contract. This report is a compendium of some of the airborne data, namely of the magnetic tape analog measurements of air temperature, relative humidity, and radio refractivity recorded during test flights. The values of these parameters herein are relative, not absolute. Also, no corrections have been applied. No interpretations or correlations with other data obtained on the contract are included.

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SECTION I INTRODUCTION

A series of meteorological measurements was made in the Caribbean Sea during the Spring of 1969. These measurements attempt to describe the characteristics of the Trade Wind Inversion over what might generally be called the Northern half of the Sea. Specific details of the individual locations and times when and where measurements were made are presented in this report.

Since the Trade Wind Inversion generally occurs within a few thousand feet above sea level the measurements were constrained within a height of from twelve thousand feet to a few hundred feet above sea level. In most cases, descending spirals were flown at intervals in range along a given track. Recovery from the bottom of each spiral to the top of the next spiral gave records which are greatly influenced by large horizontal changes in aircraft position.

SECTION II DESCRIPTION AND CHARACTERISTICS OF THE DATA

The data presented consists of plots of the variation of air temperature, relative humidity, and radio refractivity with height above sea level. The radio refractivity, N , is given by¹

$$N = \frac{77.6}{T} \left(p + \frac{4810 e}{T} \right) \quad (1)$$

where T = the air temperature (degree K)

p = the air pressure (mb)

e = the water vapor pressure (mb)

Since the relative humidity is directly related to the water vapor pressure, the values for N could be calculated from the recorded data². For radio propagation investigations the vertical gradients of the refractivity are of primary concern, and these data can be conveniently measured directly using a microwave refractometer³.

Therefore, for propagation considerations the refractivity, N , profiles presented herein are of greatest interest. However, N is very dependent on the water vapor pressure, e , (Equation (1)) which, in turn, is related to the relative humidity. The relative humidity profiles therefore have a great similarity to the refractivity profiles. Good behavioral agreement between these profiles indicates that the refractometer data is basically correct. Lack of agreement suggests a malfunction in one or the other instruments or that precipitable water was affecting the refractometer readings. Without photographic data the latter situation cannot be verified.

Since the Trade Wind Inversion represents a demarcation of two air masses, the temperature data can provide significant information⁴. The Inversion defines the boundary between cool maritime air over the sea and warmer, dry air overlying it. The temperature records can be used to show the temperature gradient and thickness of this Inversion although in terms of the absolute temperature change (Kelvin) it has little direct effect on the calculation of N (Equation (1)).

By presenting the temperature, relative humidity, and refractivity data on the same height scale one may therefore determine the meteorological conditions causing the relative variations. For example, a temperature increase over a small region would not be indicative of the Inversion unless accompanied by a rapid decrease of relative humidity and refractivity through this same height interval. In fact, an increase in humidity with a temperature

increase suggests the presence of a cloud. If excessive liquid is collected in the refractometer cavity, the resonant frequency of the cavity could increase, indicating that the air is drying out. In summary, the sets of data presented herein can potentially be used to define the meteorological behavior of the air mass in space.

SECTION III ACCURACY OF THE DATA

The profiles recorded herein were obtained from magnetic tape analog records. They have the advantage that as much fine structure as possible can be observed but with the disadvantage that the absolute values can be in error. Unlike the case with the digital, processed data, the effect of aircraft motion and temperature coefficient effects has not been removed. However, by comparing these profiles with corrected data the scales indicating the magnitudes of each parameter were adjusted in an attempt to constrain these errors as much as possible. The real significance of these profiles is not their absolute accuracy but that they present interesting and important fine structure not available from the digitally-recorded data.

A comparison of these data with calculations obtained from digital records shows that the N profiles presented herein can be as much as 15 per cent in accumulated error over one spiral. This means that if the bottom of the spiral, for example, is tied to a correct N value the values around three kilometers in height can be off by 15 per cent on the average. This effect results from the fact that the microwave refractometer cavity changes its physical size due to the change in temperature. This effect is largely removed when the digital data is used to calculate N. The effect of air speed and air density in the temperature data presented herein introduces an overall error of about two degrees from the surface to three kilometers in height. See Appendix I, page 8, for a listing of measurement accuracy in the absence of aircraft motion effects.

The relative humidity is greatly effected by air temperature; therefore, no single scale can be defined which applies at all altitudes. The seventy per cent scale shown on the profiles is associated with a thirty N unit change in refractivity at an air pressure of nine hundred millibars in a standard atmosphere. This pressure was chosen since the inversion generally occurs around one kilometer in height.

During Mission I, the humidity recordings were not obtained due to an instrument failure. This information is available from the digital records and will be presented in a later report. Also, in Mission 9, Spiral A, the sensitivity of the tape recordings of N and relative humidity are reduced. This is attributed to an oscillator tube failure in the Ampex recorder.

REFERENCES

1. Smith, E. K., and S. Weintraub (August 1953), "The Constants in the Equation for Atmospheric Refractive Index at Radio Frequencies," Proc. IRE, 41, pp. 1035 - 1037.
2. List, R. J., (1966), Smithsonian Meteorological Tables, Smithsonian Institution, Washington, D. C.
3. Crain, C. M., (May 1950), "Apparatus for Recording Fluctuations in the Refractive Index of the Atmosphere at 3.2 Centimeter Wavelengths," Rev. Sci. Instr., 21, No. 5, pp. 456 - 457.
4. Cahoon, B. A., and L. P. Riggs, (September 1964), "Climatology of Elevated Super-Refractive Layers Arising From Atmospheric Subsidence," National Bureau of Standards, Proc. 1964, World Conference on Radio Meteorology.

SECTION IV ORGANIZATION OF THE COMPENDIUM

On 11 separate dates during March, 14 data collection missions were flown over the geographical area illustrated in Figure 1, the Master Flight Record Map. The notations of flight paths and spiral locations on this map correspond to the Flight Log, which is included as Table 1.

Following Table 1 are the x-y plots of all analog magnetic tape measurements of air temperature, relative humidity, and refractivity. These are arranged by mission, with data from each mission preceded by maps which are enlarged sections of the Master Flight Record Map. The missions, in turn, are grouped by calendar date, and data taken on each date are preceded by a print of the U. S. Weather Bureau Northern Hemisphere Surface Chart and 850 mb constant pressure chart (1200 Z) for that date.

Included are data recorded during test spirals as well as data records for some of the ascents between downward spirals.

TABLE I
FLIGHT LOG

Mission No.	Spiral No.	Path	Location	Up or Down	Spiral Start Time
1 (6 March)	A	I	a. Key West NAS	↑ 10K 500	1131 Z
	B	I	b. 24-06 N 81-51 W	↓ 10K 500	1214 Z
	C	I	c. 24-06 N 81-08 W	↓ 15K 500	1315 Z
2 (6 March)	A	I	c. 24-06 N 81-08 W	↓ 10K 500	2019 Z
	B	I	a. Key West NAS	↓ 10K 500	2107 Z
	C	I	b. 24-06 N 81-51 W	↓ 10K 500	2156 Z
	D	I	c. 24-06 N 81-08 W	↓ 10K 500	2235 Z
	E	I	a. Key West NAS	↑ 10K 1K	2313 Z
3 (9 March)	A	II	a. Key West NAS	↑ 10K 500	1555 Z
	B	II	b. 25-15 N 83-15 W	↓ 10K 500	1635 Z
	C	II	c. 26-00 N 85-00 W	↓ 10K 500	1743 Z
	D	II	d. 27-07 N 86-20 W	↓ 10K 500	1834 Z
	E	II	e. 29-10 N 89-07 W	↓ 10K 500	2016 Z
4 (10 March)	A	III	a. 29-00 N 87-00 W	↓ 10K 500	2132 Z
	B	III	b. 25-00 N 88-13 W	↓ 10K 500	2217 Z
	C	III	c. 23-00 N 89-00 W	↓ 10K 500	2313 Z

TABLE 1 (Cont'd.)
FLIGHT LOG

Mission No.	Spiral No.	Path	Location	Up or Down	Spiral Start Time
5 (11 March)	A	IV	a. 20-00 N 86-25 W	↓ 11K 500	1848 Z
	B	IV	b. 19-00 N 85-35 W	↓ 11K 500	1935 Z
	C	IV	c. 18-30 N 84-00 W	↓ 11K 500	2030 Z
	D	IV	d. 19-15 N 81-15 W	↓ 11K 500	2150 Z
6 (14 March)	A	V	a. 18-36 N 62-00 W	↑ 10K 500	1629 Z
	B	V	b. 17-30 N 67-00 W	↓ 10K 500	1706 Z
	C	V	c. 16-17 N 67-17 W	↓ 10K 500	1810 Z
	D	V	d. 15-37 N 67-23 W	↓ 10K 500	1848 Z
	E	V	e. 17-03 N 66-14 W	↓ 10K 500	1945 Z
	F	V	f. 18-23 N 65-37 W	↓ 10K 500	2033 Z
7 (17 March)	A	VI	a. 18-32 N 67-07 W	↑ 10K 500	1702 Z
	B	VI	b. 19-10 N 68-01 W	↓ 10K 500	1744 Z
	C	VI	c. 19-53 N 69-00 W	↓ 10K 500	1828 Z
	D	VI	d. 20-36 N 70-00 W	↓ 10K 500	1915 Z
	E	VI	e. 20-34 N 71-10 W	↓ 10K 500	1955 Z
	F	VI	f. Grand Turk	↓ 10K 500	2033 Z

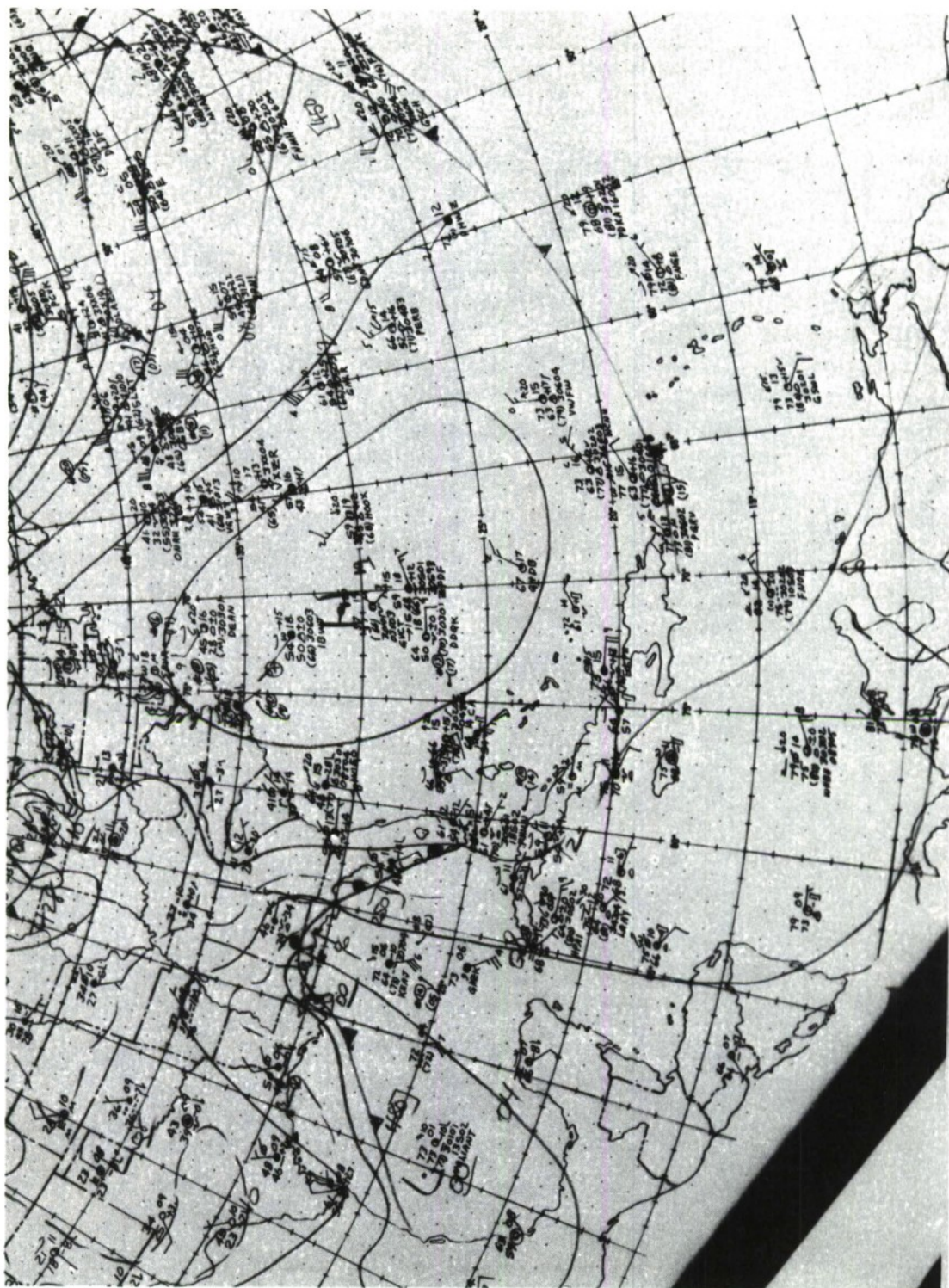
TABLE 1 (Cont'd.)
FLIGHT LOG

Mission No.	Spiral No.	Path	Location	Up or Down	Spiral Start Time
8 (18 March)	A	VII	a. Grand Turk	↑ 10.5K 500	1447 Z
	B	VII	b. 22-35 N 73-07 W	↓ 10.5K 500	1547 Z
	C	VII	c. 23-08 N 74-00 W	↓ 10.5K 500	1630 Z
	D	VII	d. 24-00 N 75-35 W	↓ 10.5K 500	1723 Z
9 (21 March)	A	I	a. Key West NAS	↑ 10K 500	1135 Z
	B	I	b. 24-06 N 81-51 W	↓ 10K 500	1200 Z
	C	I	c. 24-06 N 81-08 W	↓ 10K 500	1235 Z
10 (21 March)	A	I	b. 24-06 N 81-51 W	↓ 10K 500	1608 Z
	B	I	c. 24-06 N 81-08 W	↓ 10K 500	1645 Z
	C	I	a. Key West NAS	↓ 10K 500	1720 Z
11 (21 March)	A	I	b. 24-06 N 81-51 W	↓ 10K 500	2159 Z
	B	I	c. 24-06 N 81-08 W	↓ 10K 500	2233 Z
	C	I	a. Key West NAS	↑ 10K 500	2318 Z
12 (23 March)	A	VIII	a. Key West NAS	↑ 10K 500	0712 Z
	B	VIII	b. 24-35 N 87-32 W	↓ 10K 500	0748 Z
	C	VIII	c. 24-35 N 83-32 W	↓ 10K 500	0828 Z
	D	VIII	d. 24-35 N 84-26 W	↓ 10K 500	0909 Z
	E	VIII	e. 24-35 N 83-03 W	↓ 10K 500	0952 Z

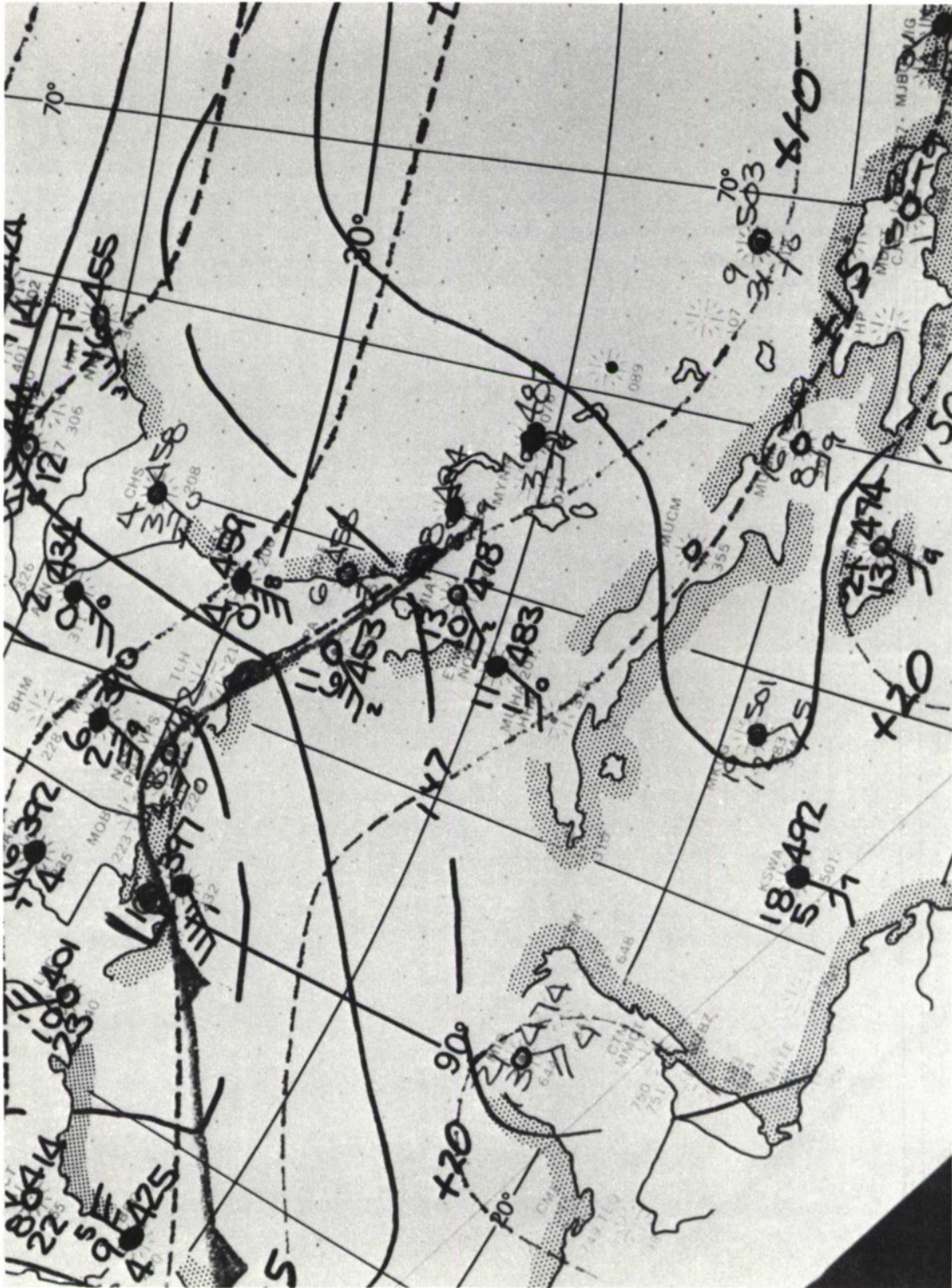
TABLE 1 (Cont'd.)
FLIGHT LOG

Mission No.	Spiral No.	Path	Location	Up or Down	Spiral Start Time
12 (23 March)	F	VIII	f. 24-43 N 81-04 W	↓ 10K 500	1043 Z
	G	VIII	a. Key West NAS	↓ 10K 500	1119 Z
13 (24 March)	A	VIII	a. Key West NAS	↑ 10K 500	1132 Z
	B	VIII	b. 24-35 N 82-37 W	↓ 10K 500	1212 Z
	C	VIII	c. 24-35 N 83-32 W	↓ 10K 500	1257 Z
	D	VIII	d. 24-35 N 84-26 W	↓ 10K 500	1348 Z
	E	VIII	e. 24-35 N 83-03 W	↓ 10K 500	1430 Z
	F	VIII	a. Key West NAS	↓ 10K 500	1511 Z
14 (25 March)	A	VIII	a. Key West NAS	↑ 10K 500	1154 Z
	B	VIII	b. 24-35 N 82-37 W	↓ 10K 500	1238 Z
	C	VIII	c. 24-35 N 83-32 W	↓ 10K 500	1370 Z
	D	VIII	d. 24-35 N 84-26 W	↓ 10K 500	1403 Z
	E	VIII	e. 24-35 N 83-03 W	↓ 10K 500	1444 Z
	F	VIII	a. Key West NAS	↓ 10K 500	1527 Z

A 6939



SURFACE CHART
6 March 1969



850 mb CHART
6 March 1969

MISSION NO. 1

Date: 6 March 1969

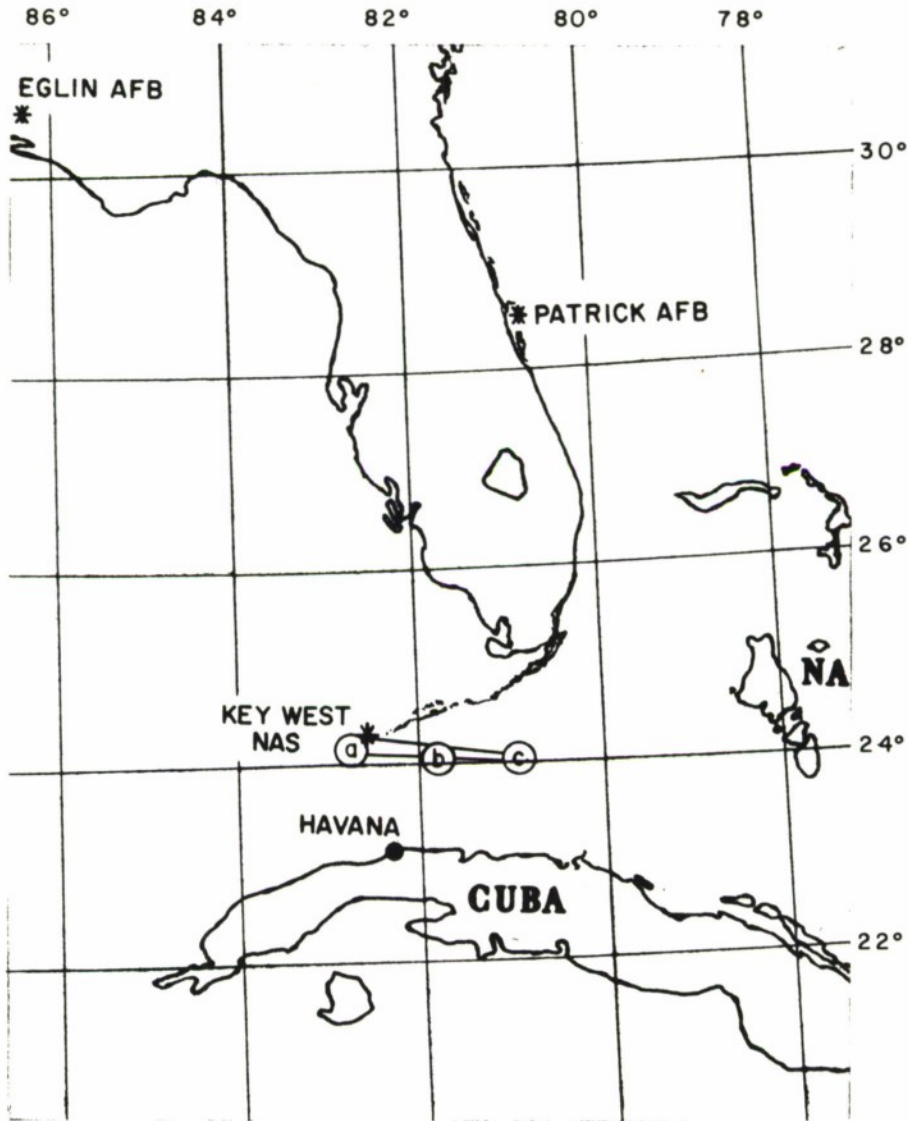
The aircraft was flown from Key West Naval Air Station in a generally eastward direction on the flight path designated I on the Master Flight Record Map. The extent of the reach eastward was approximately 110 statute miles.

Data were obtained during three spirals flown from altitudes of 500 to 10,000 feet (approximately 0.15 to 3.0 km). The spirals were located as shown on the Master Flight Map at

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. Key West NAS	1131	0631
B	b. 25-06 N, 81-51 W	1214	0714
C	c. 24-06 N, 81-08 W	1315	0815

Plots of data recorded during these spirals follow. No measurements were recorded on the ascents between spirals.

B 6831



SCALE 1:5,702,400 OR 90 MILES TO 1 INCH

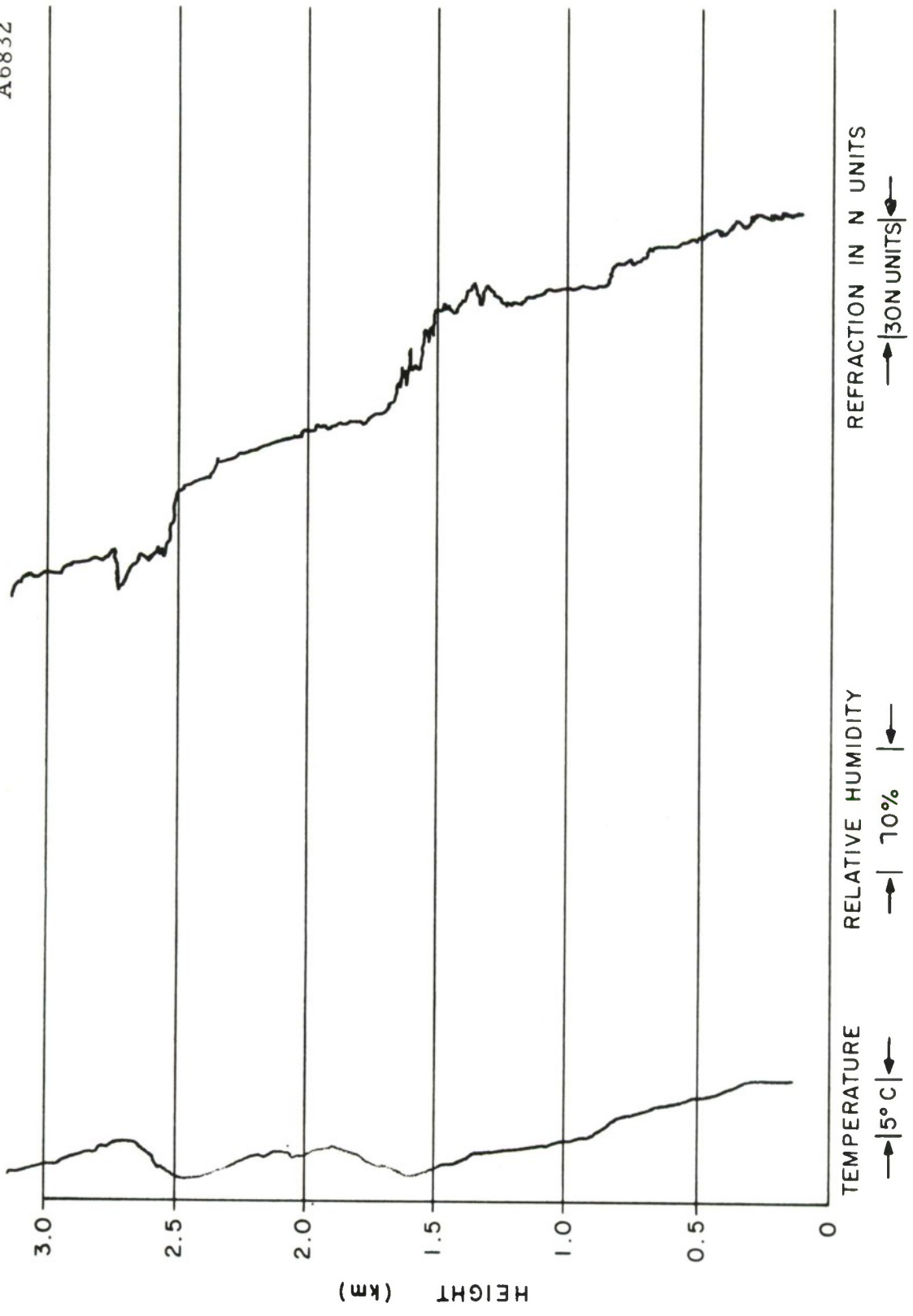


FLIGHT PATH I

MISSIONS 1 AND 2 - 6 MARCH 1969

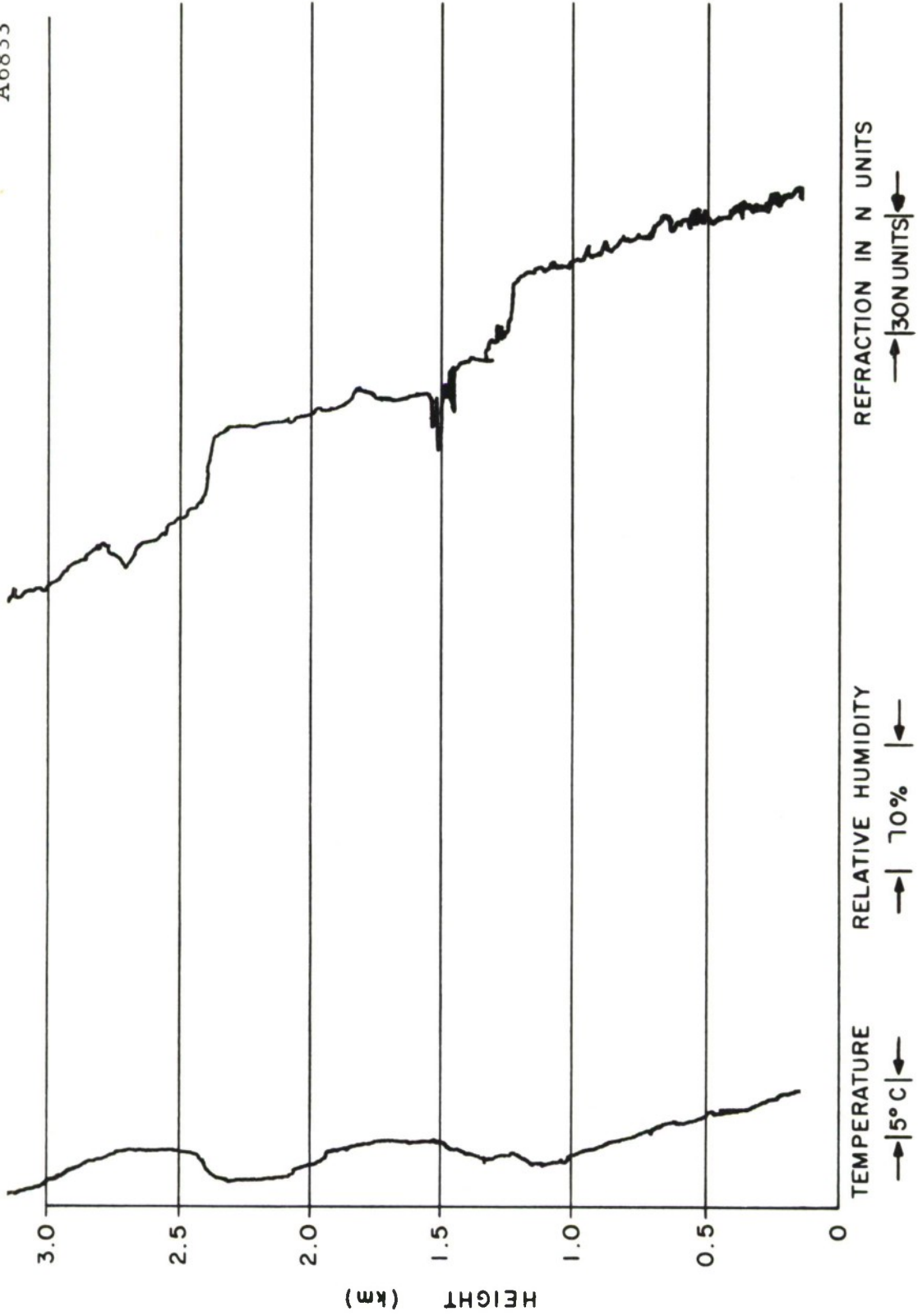
MISSIONS 9, 10, AND 11 - 21 MARCH 1969

A6832



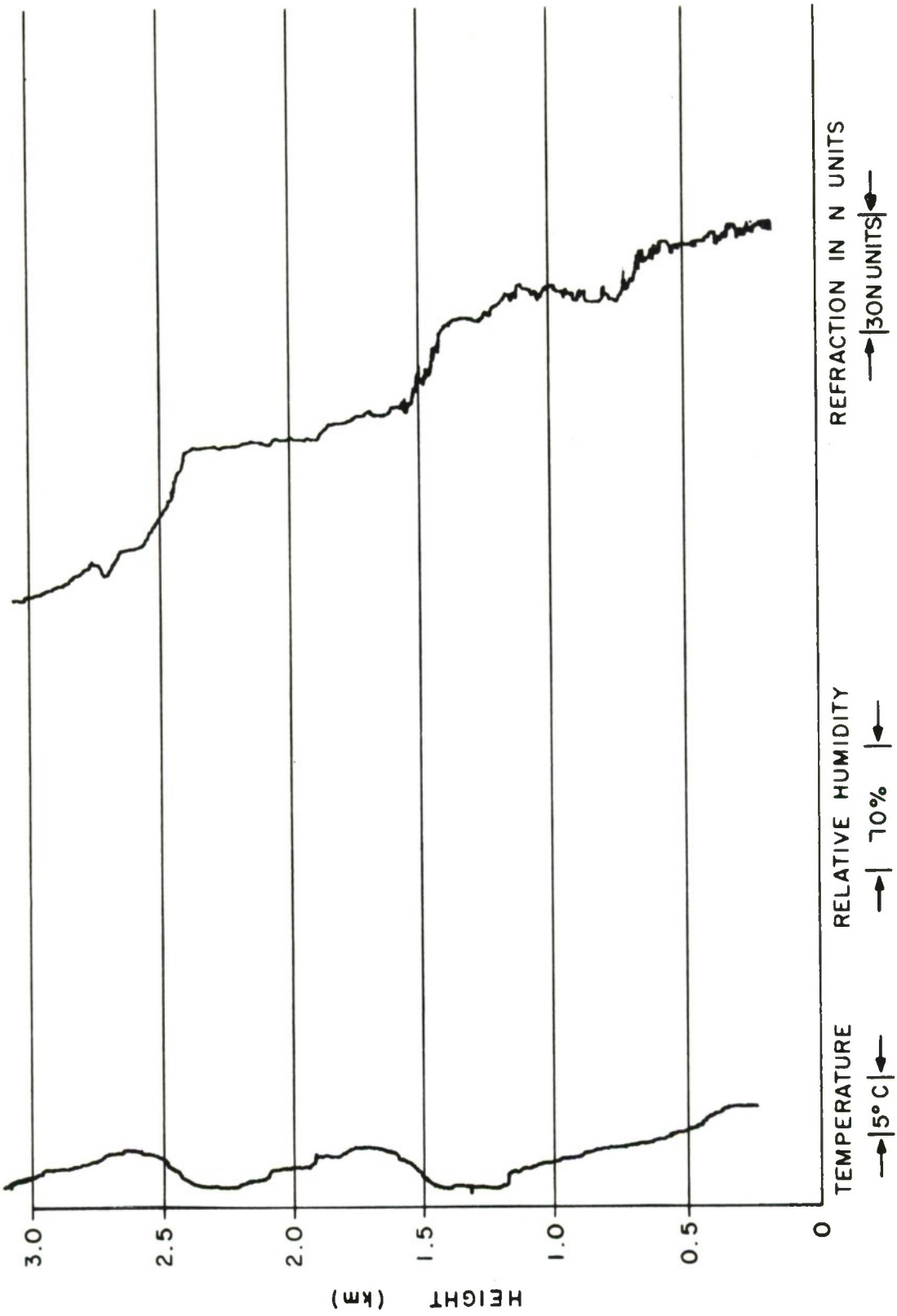
MISSION 1 - SPIRAL A

A6833



MISSION 1 - SPIRAL B

A6834



MISSION 1 - SPIRAL C

MISSION NO. 2

Date: 6 March 1969

On the same flight path (Path I) and as a continuation of the same aircraft flight of Mission 1, spirals were repeated at the three locations of Mission 1. The flight was terminated at Key West NAS. A total of five spirals at altitudes from 0.15 to 3.0 km were flown at

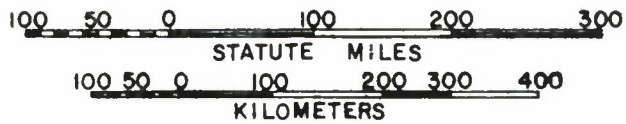
<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	c. 24-06 N, 81-08 W	2019	1519
B	a. Key West NAS	2107	1607
C	b. 24-06 N, 81-51 W	2156	1657
D	c. 24-06 N, 81-08 W	2235	1735
E	a. Key West NAS	2313	1813

Plots of data recorded during these spirals follow. No measurements were recorded on the ascents between spirals.

B 6831



SCALE 1:5,702,400 OR 90 MILES TO 1 INCH

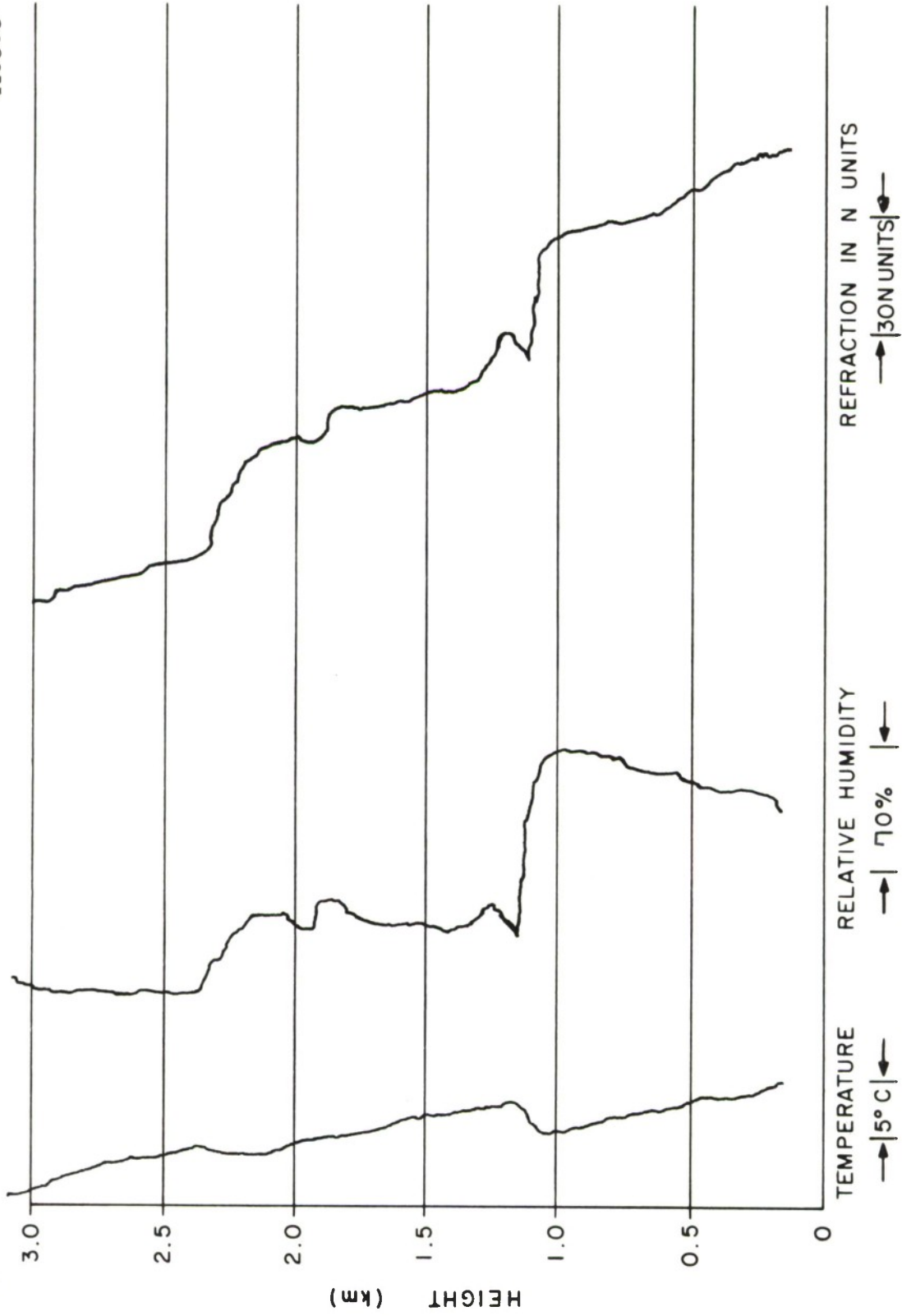


FLIGHT PATH I

MISSIONS 1 AND 2 - 6 MARCH 1969

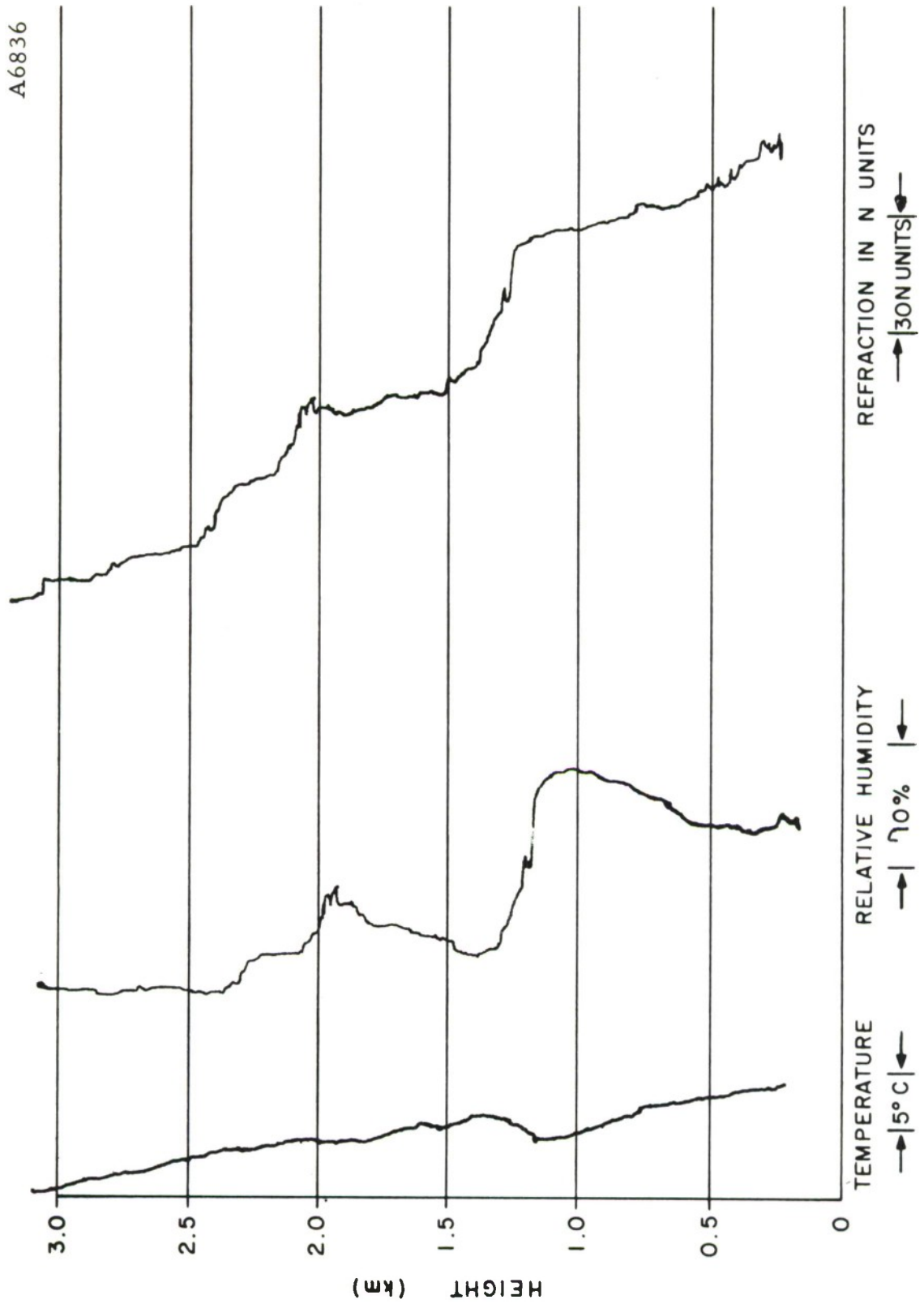
MISSIONS 9, 10, AND 11 - 21 MARCH 1969

A6835



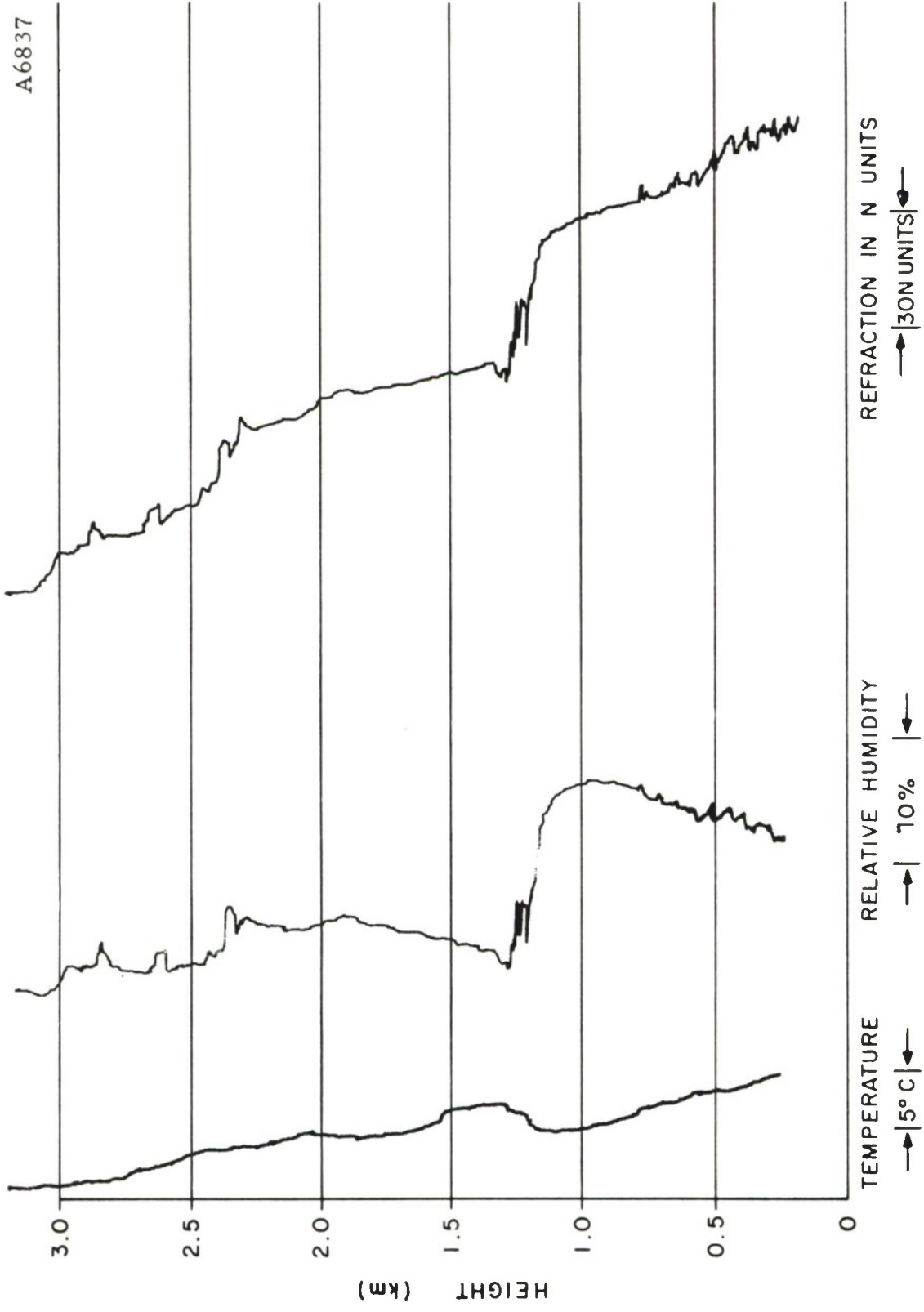
MISSION 2 - SPIRAL A

A6836



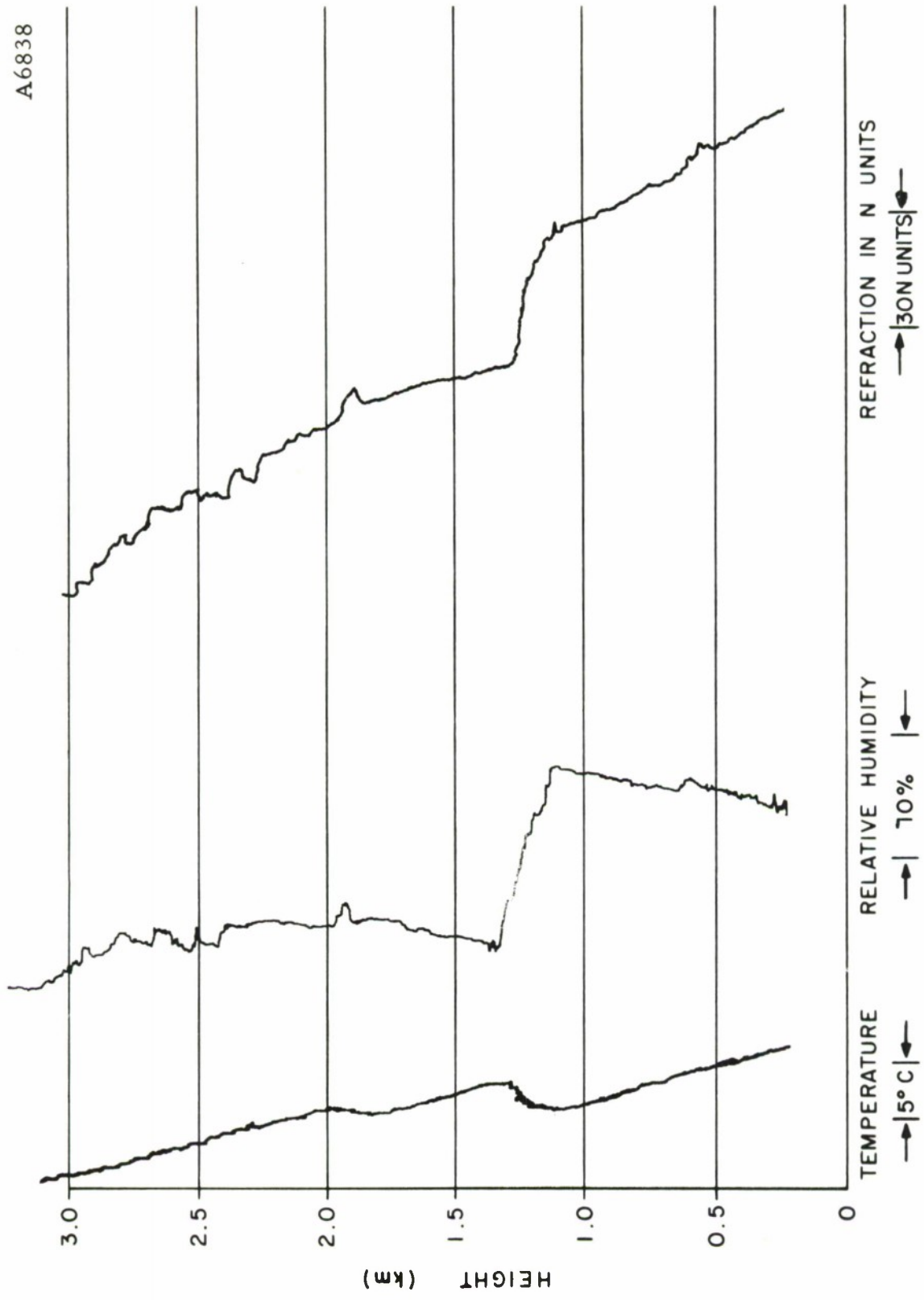
MISSION 2 - SPIRAL B

A6837

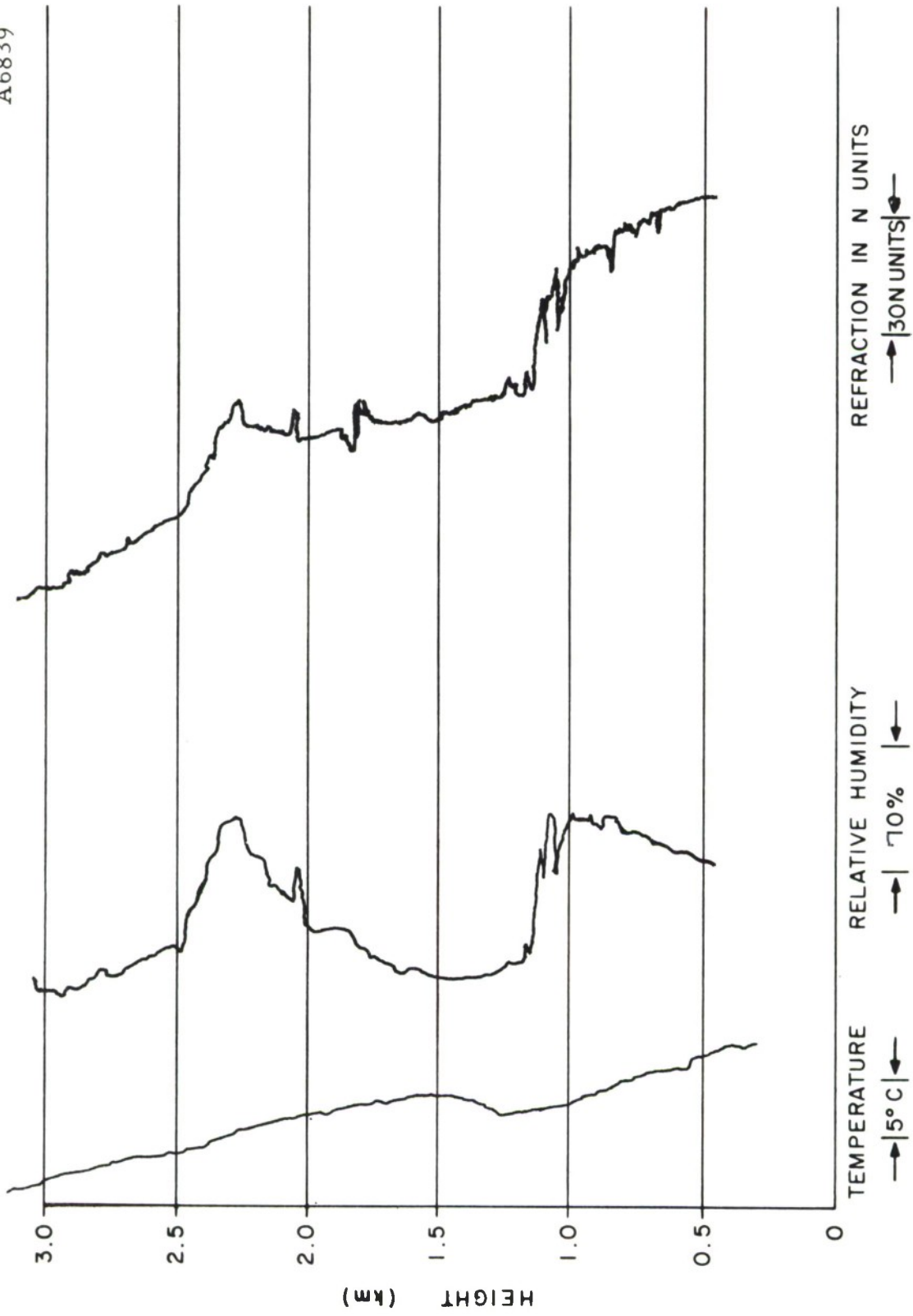


MISSION 2 - SPIRAL C

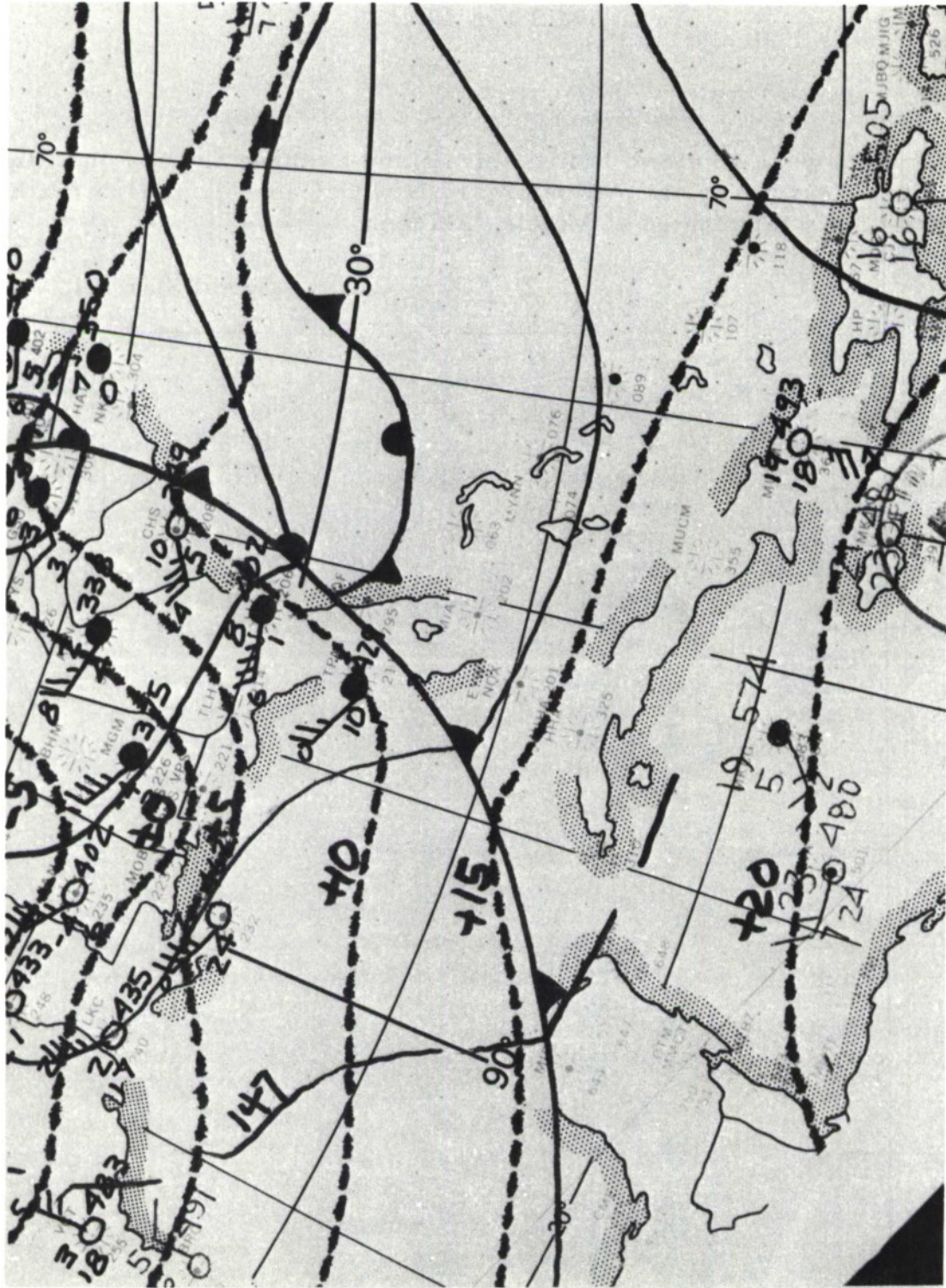
A6838



A6839



MISSION 2 - SPIRAL E



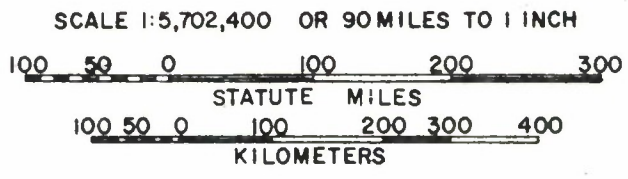
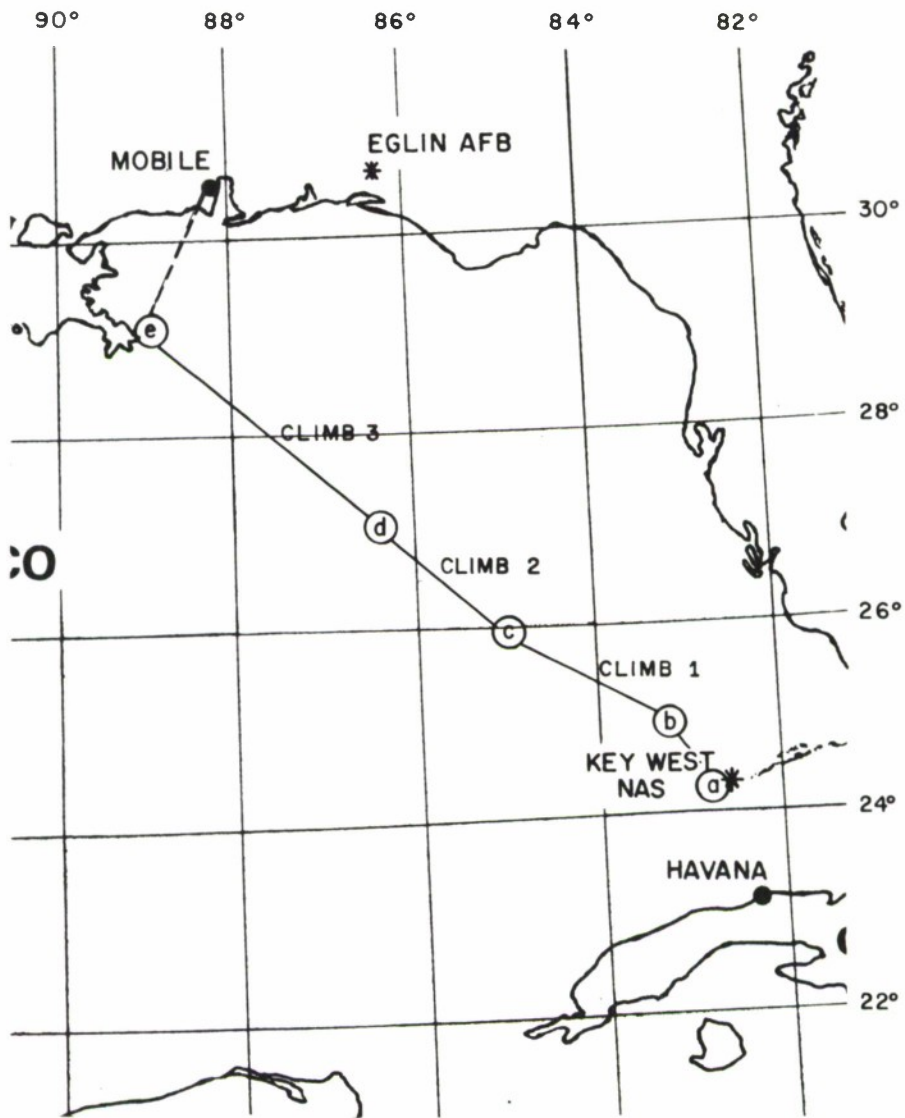
850 mb CHART
9 March 1969

MISSION NO. 3

Date: 9 March 1969

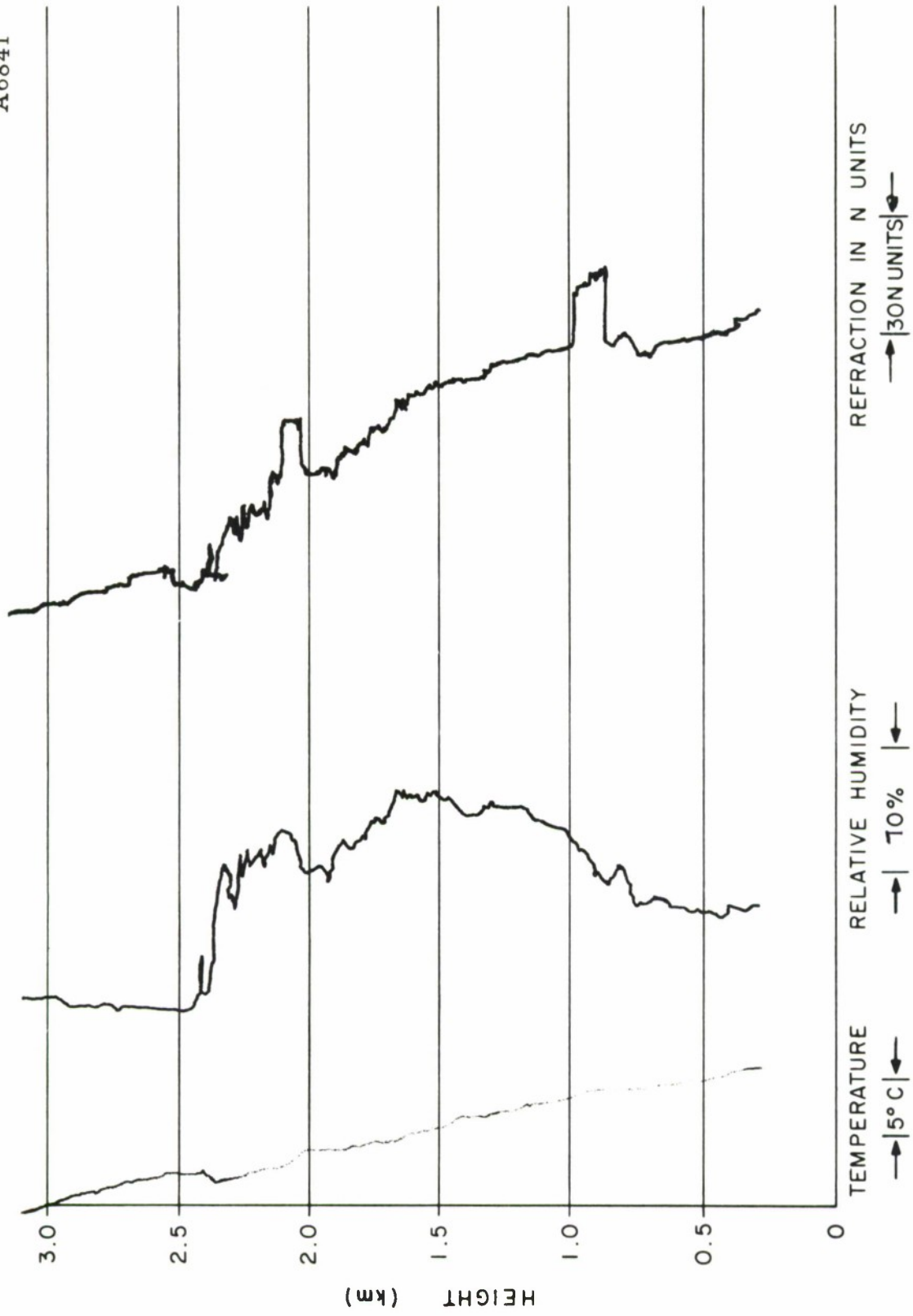
Data were obtained on five spirals and on three ascents on a flight from Key West Naval Air Station toward New Orleans, Louisiana (Path II). The flight was terminated at Mobile, Alabama.

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. Key West NAS	1555	1055
B	b. 25-15 N, 83-15 W	1635	1135
Climb 1	b-c	1656	1156
C	c. 26-00N, 85-00 W	1743	1243
Climb 2	c-d	1755	1255
D	d. 27-07 N, 86-20 W	1834	1334
Climb 3	d-e	1856	1356
E	e. 29-10 N, 89-07 W	2016	1516



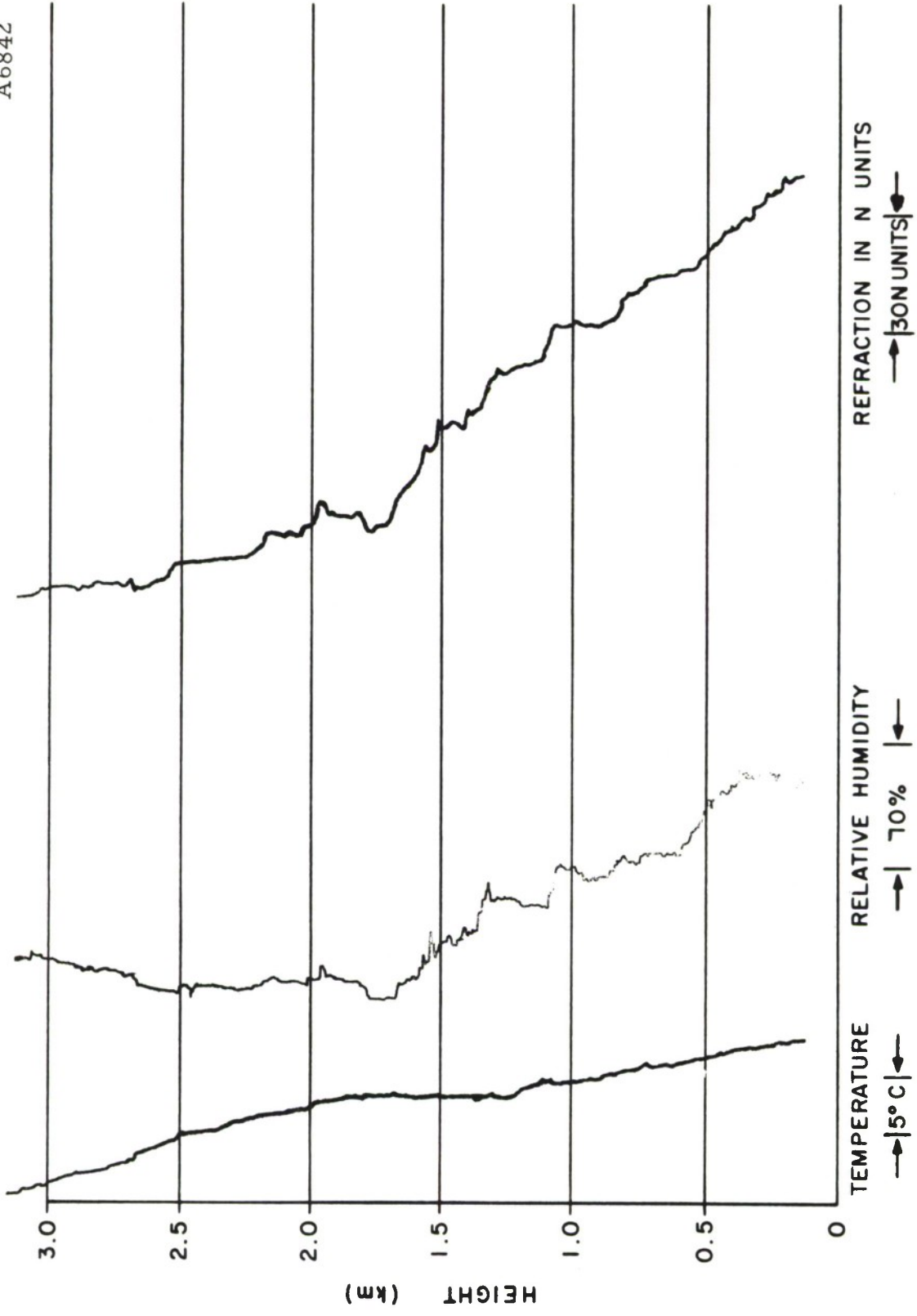
FLIGHT PATH II
MISSION 3 — 9 MARCH 1969

A6841



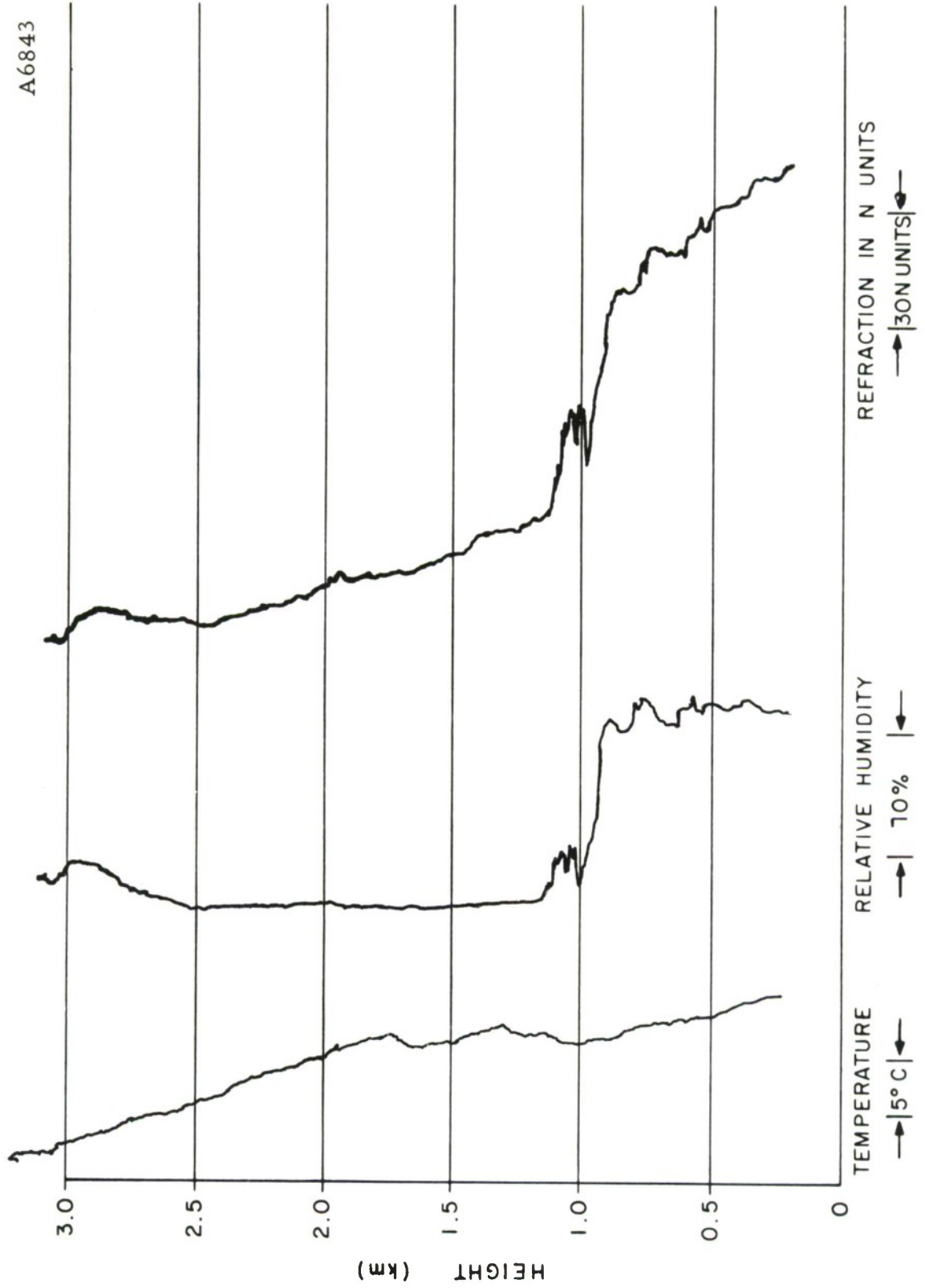
MISSION 3 - SPIRAL A

A6842

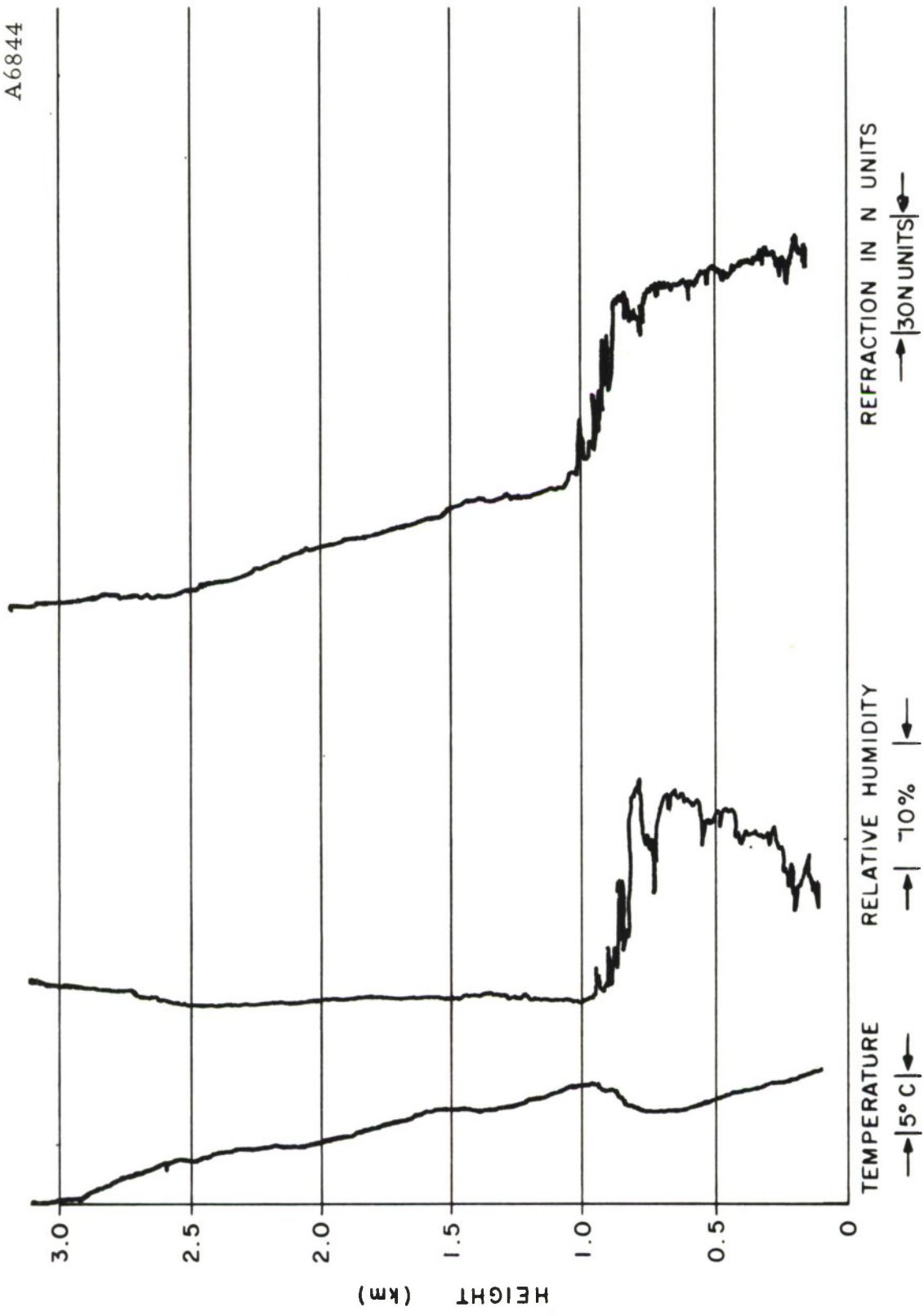


MISSION 3 - SPIRAL B

A6843

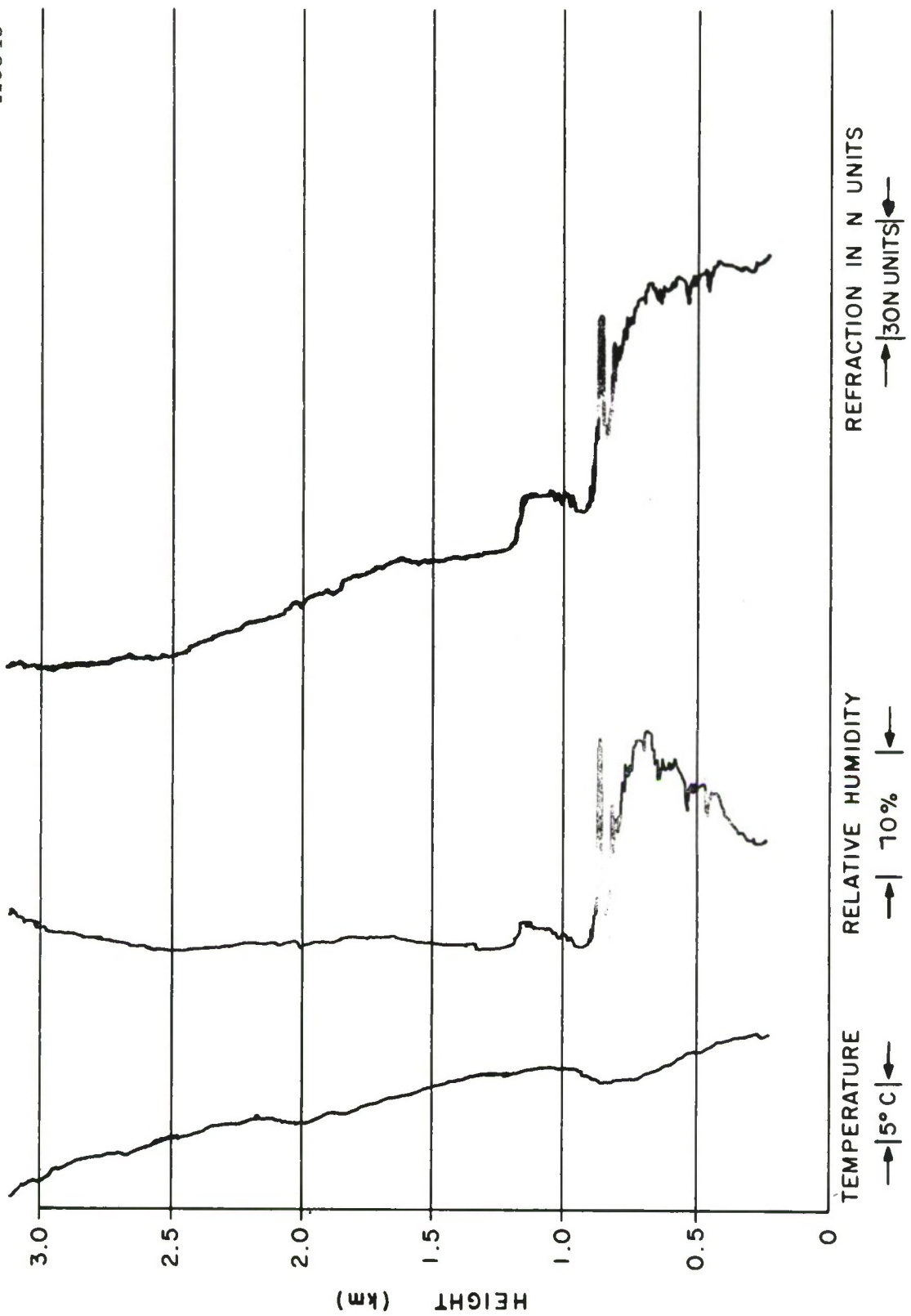


A6844



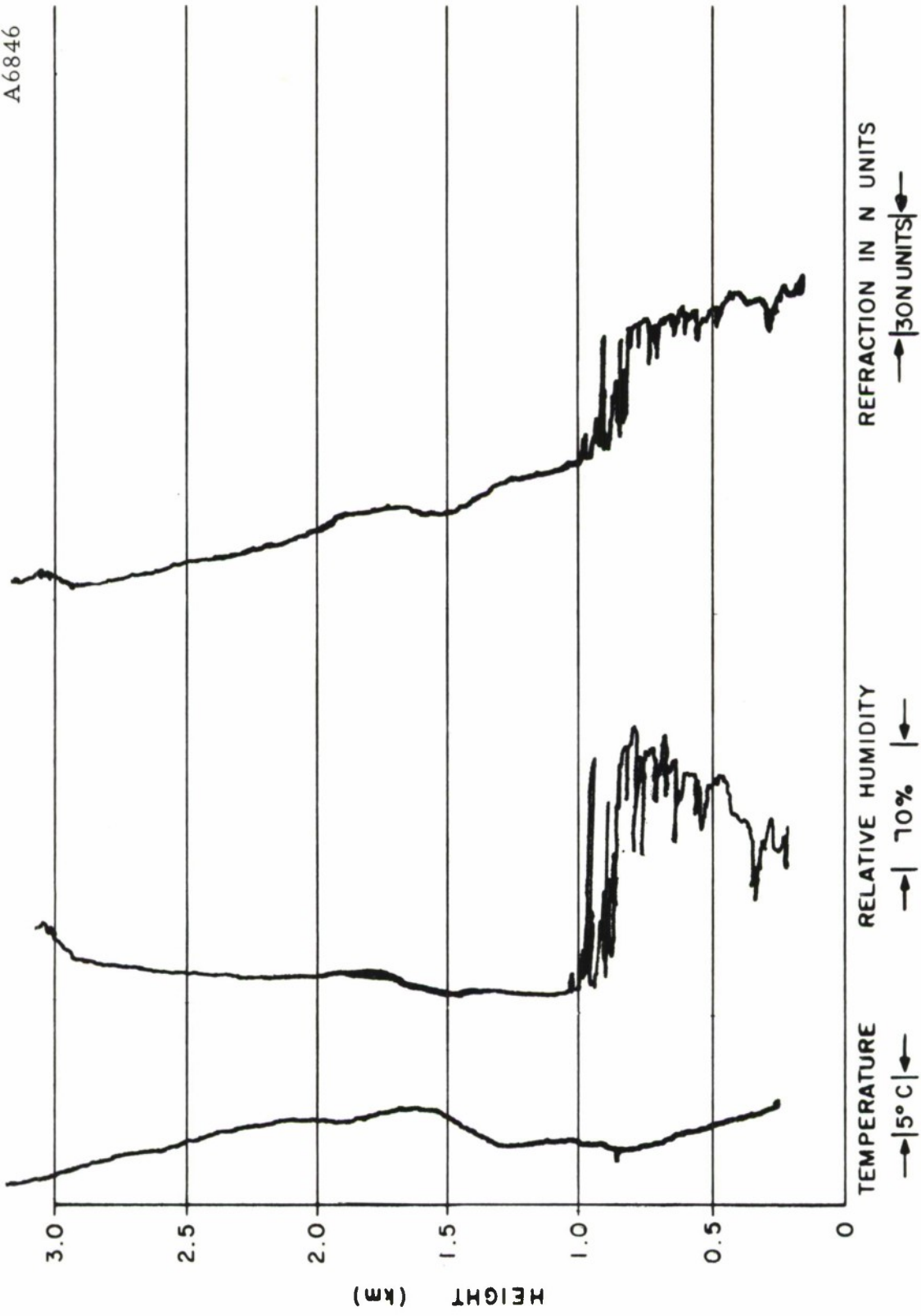
MISSION 3 - SPIRAL C

A6845



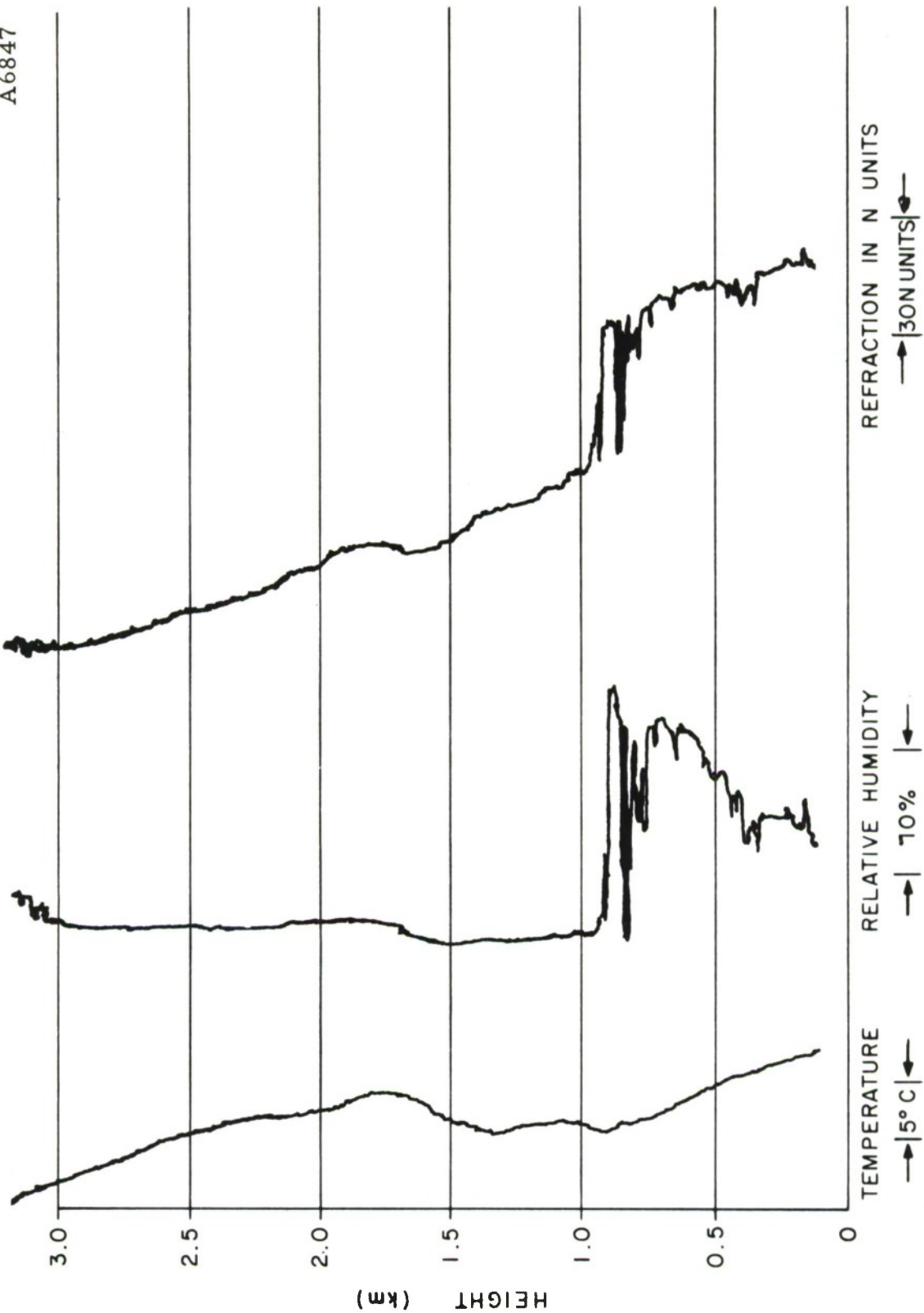
MISSION 3 - CLIMB 2

A6846



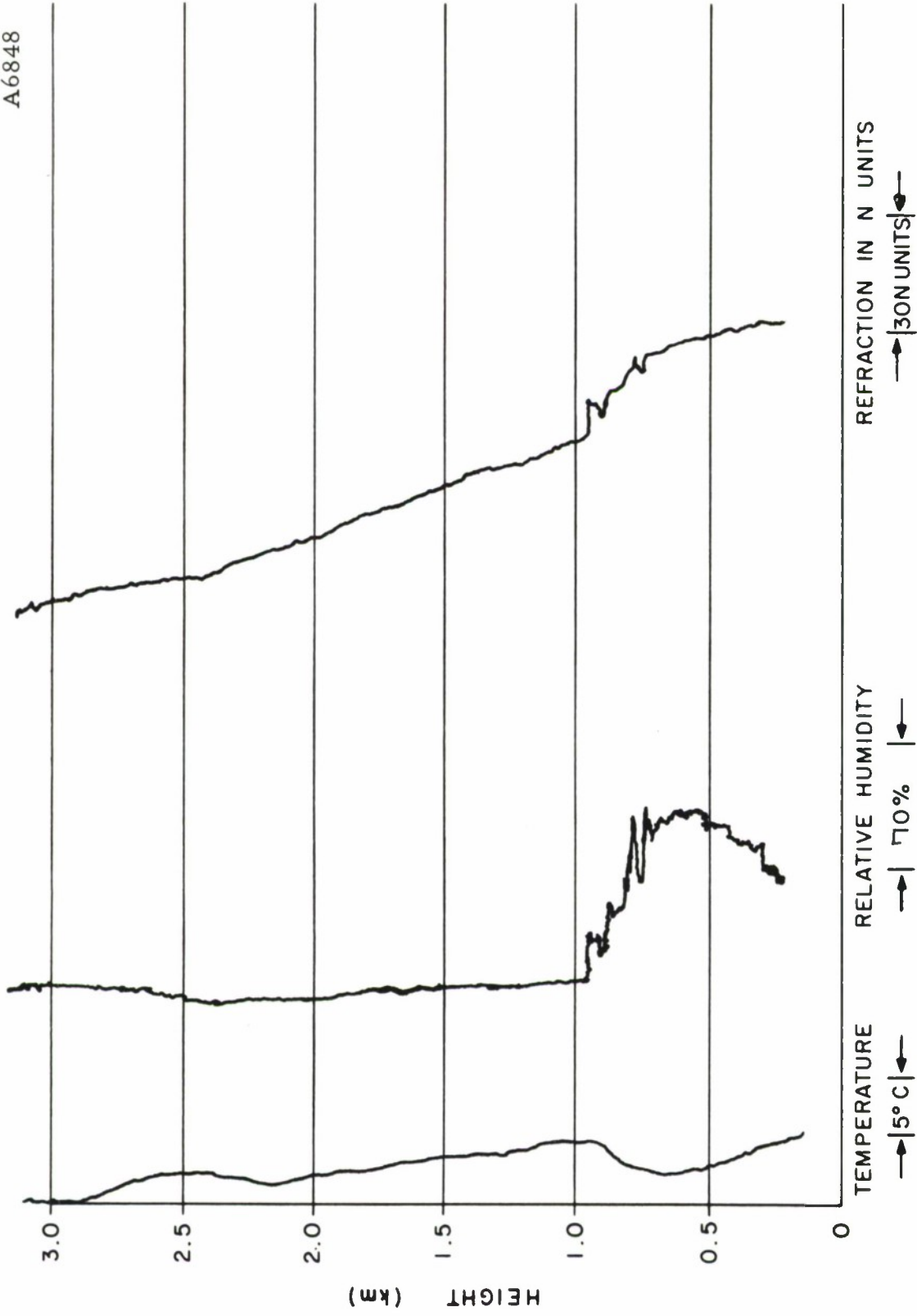
MISSION 3 - SPIRAL D

A6847



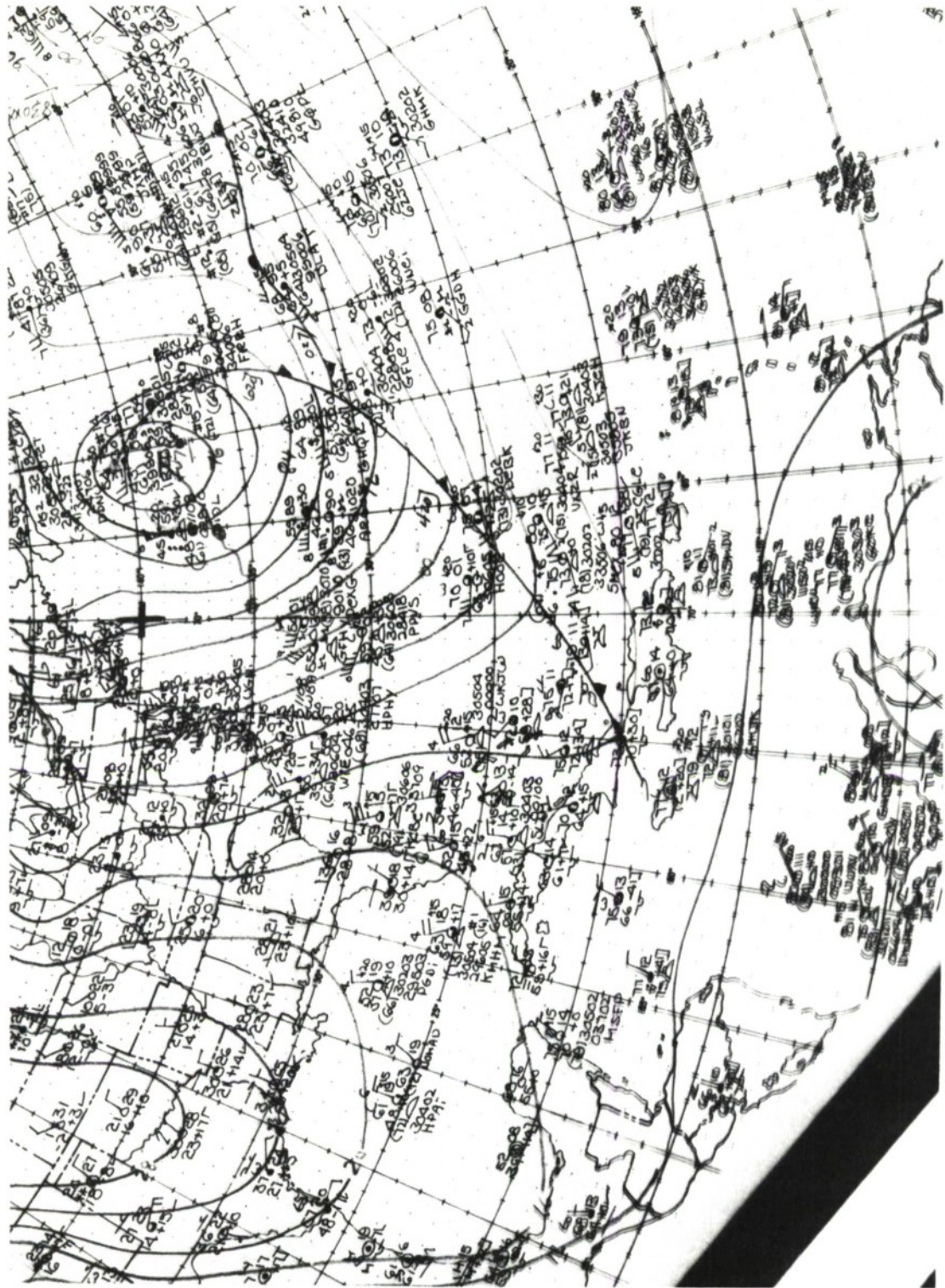
MISSION 3 - CLIMB 3

A6848



MISSION 3 - SPIRAL E

A6941



SURFACE CHART
10 March 1969

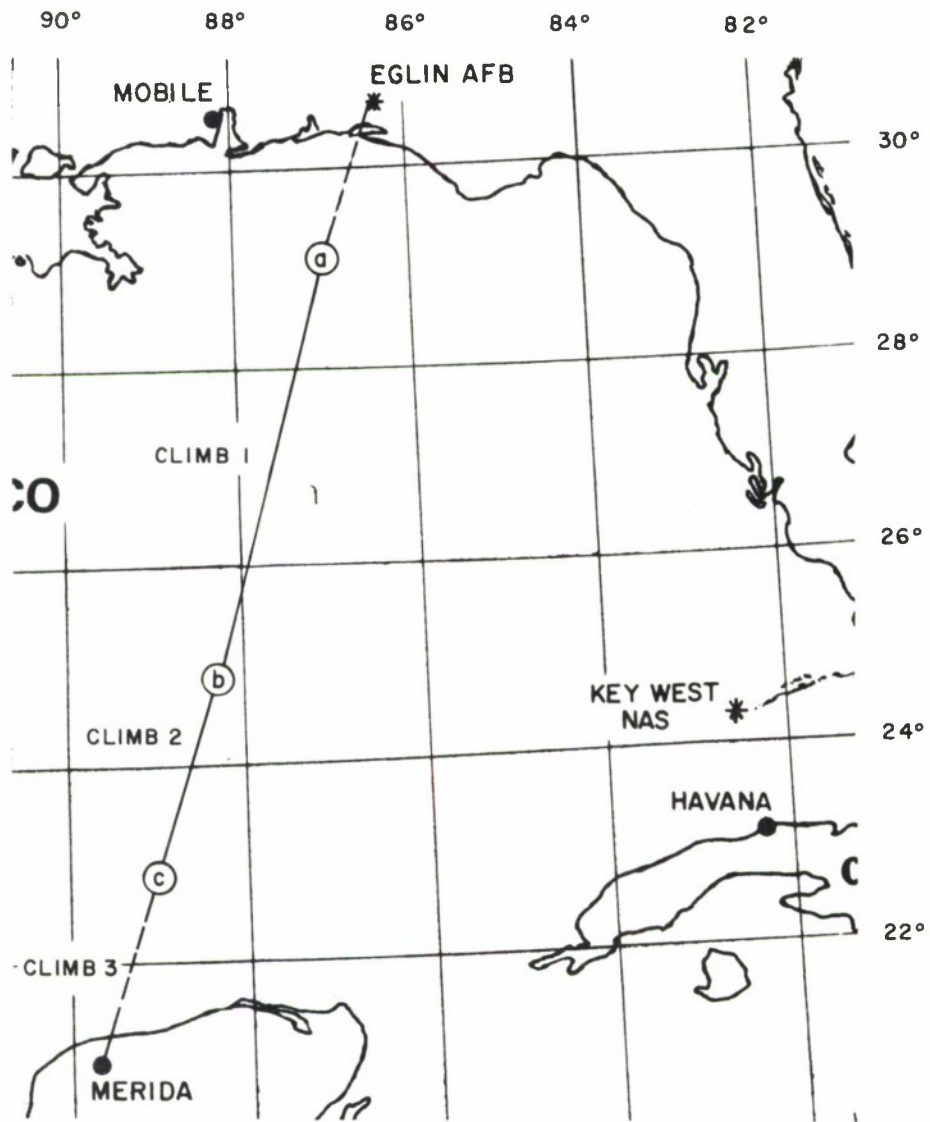
MISSION NO. 4

Date: 10 March 1969

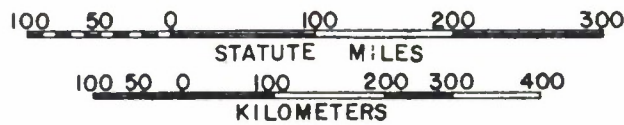
Data were obtained along Flight Path III, from Eglin AFB to Merida, Mexico. Measurements were recorded during three spirals and two ascents, the limitation on number of spirals arising from a combination of two factors: (1) delayed start of mission, (2) need to land at Merida before nightfall.

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. 29-00 N, 87-00 W	2032	1432
Climb 1	a-b	2050	1450
B	b. 25-00 N, 88-13 W	2217	1617
Climb 2	b-c	2235	1635
C	c. 23-00 N, 89-00 W	2315	1715

86849

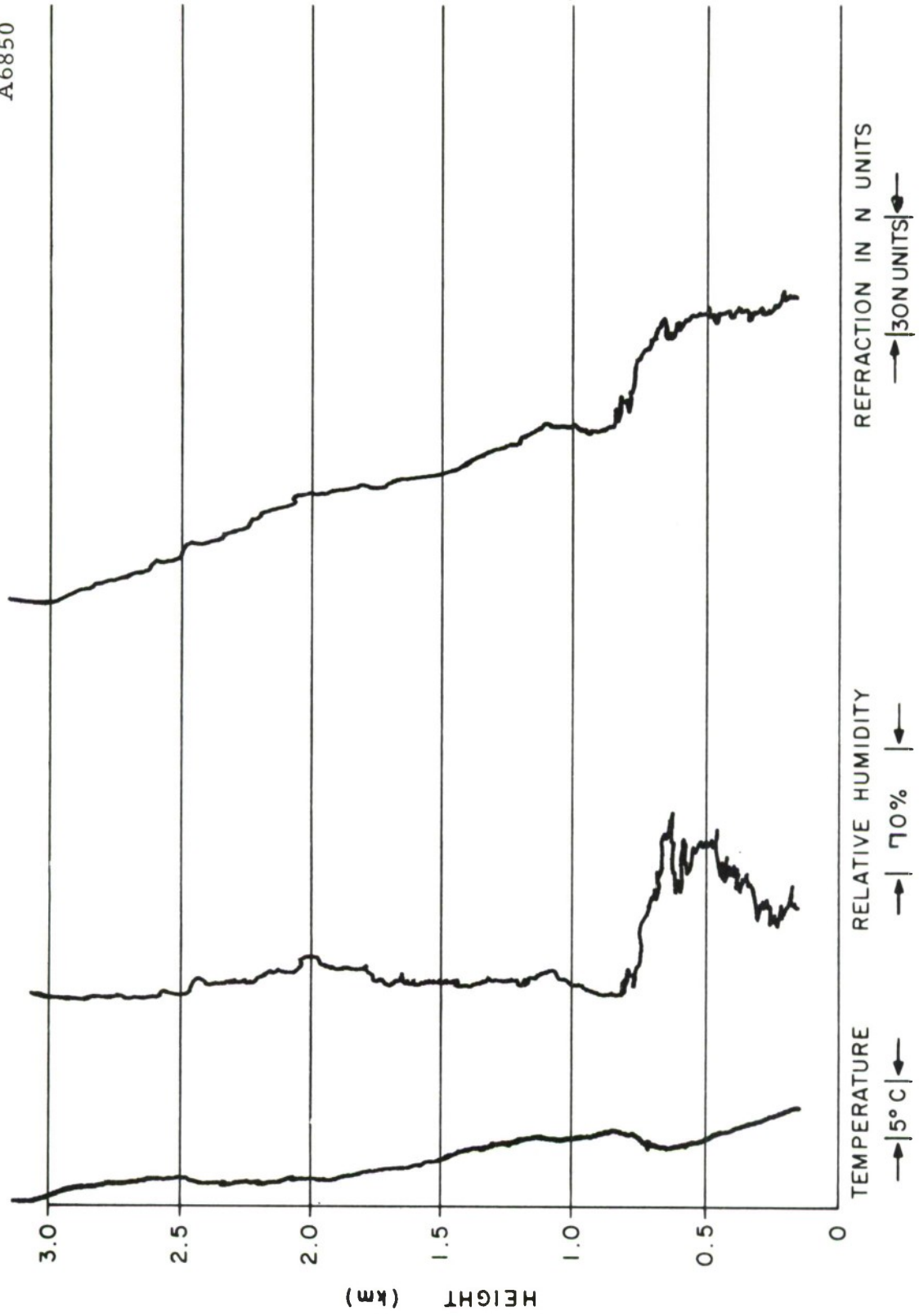


SCALE 1:5,702,400 OR 90 MILES TO 1 INCH



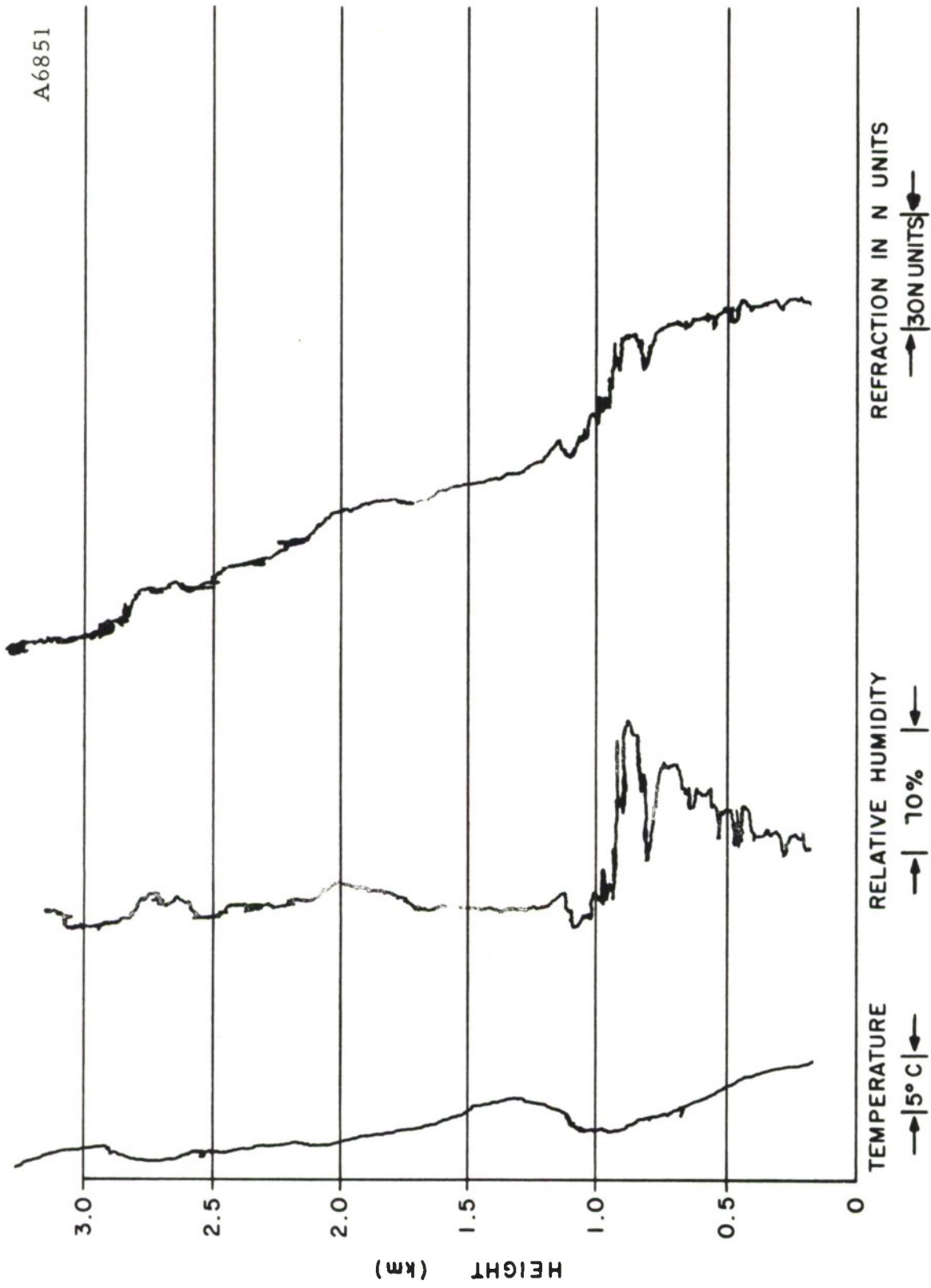
FLIGHT PATH III
MISSION 4 — 10 MARCH 1969

A6850



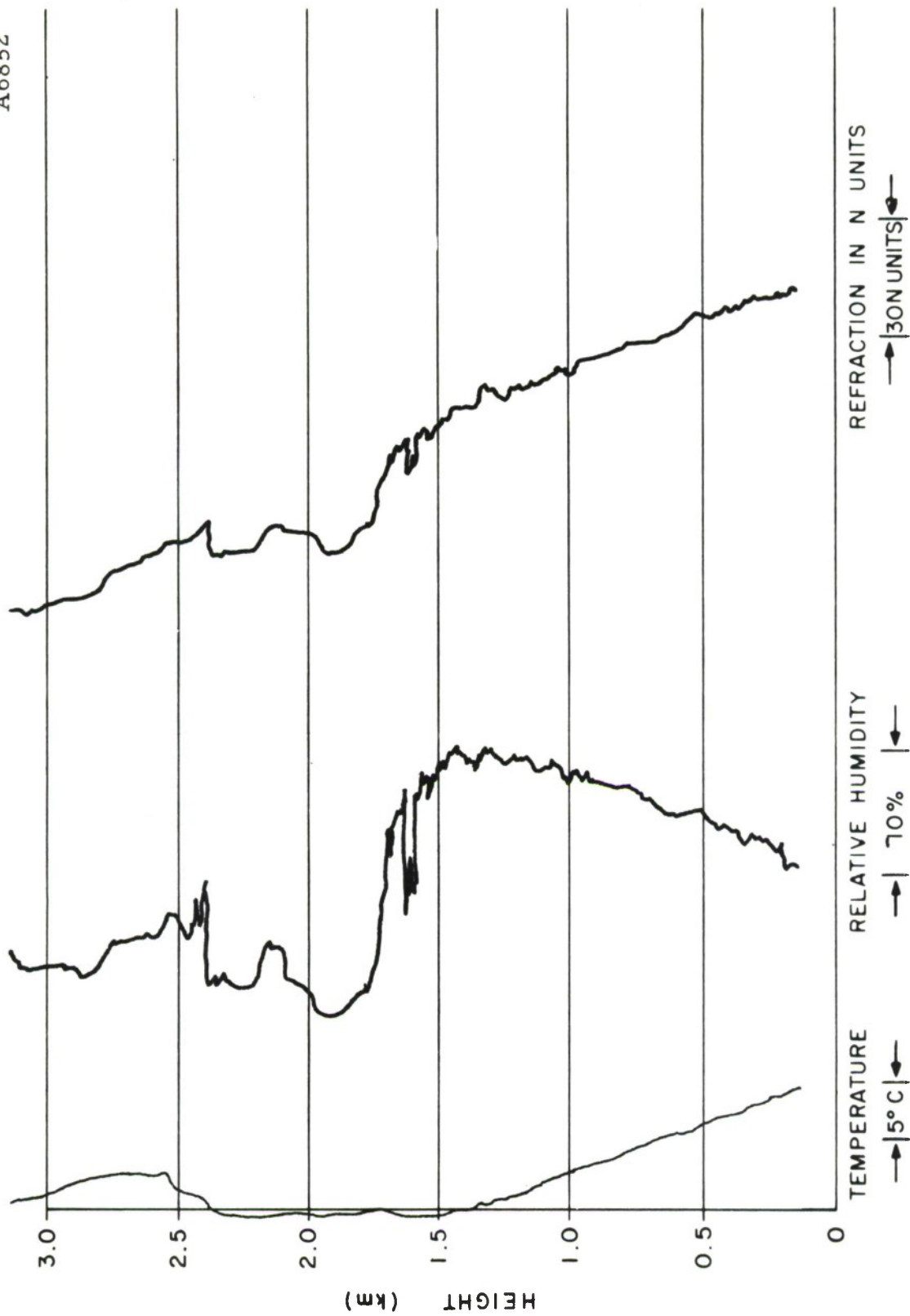
MISSION 4 - SPIRAL A

A6851



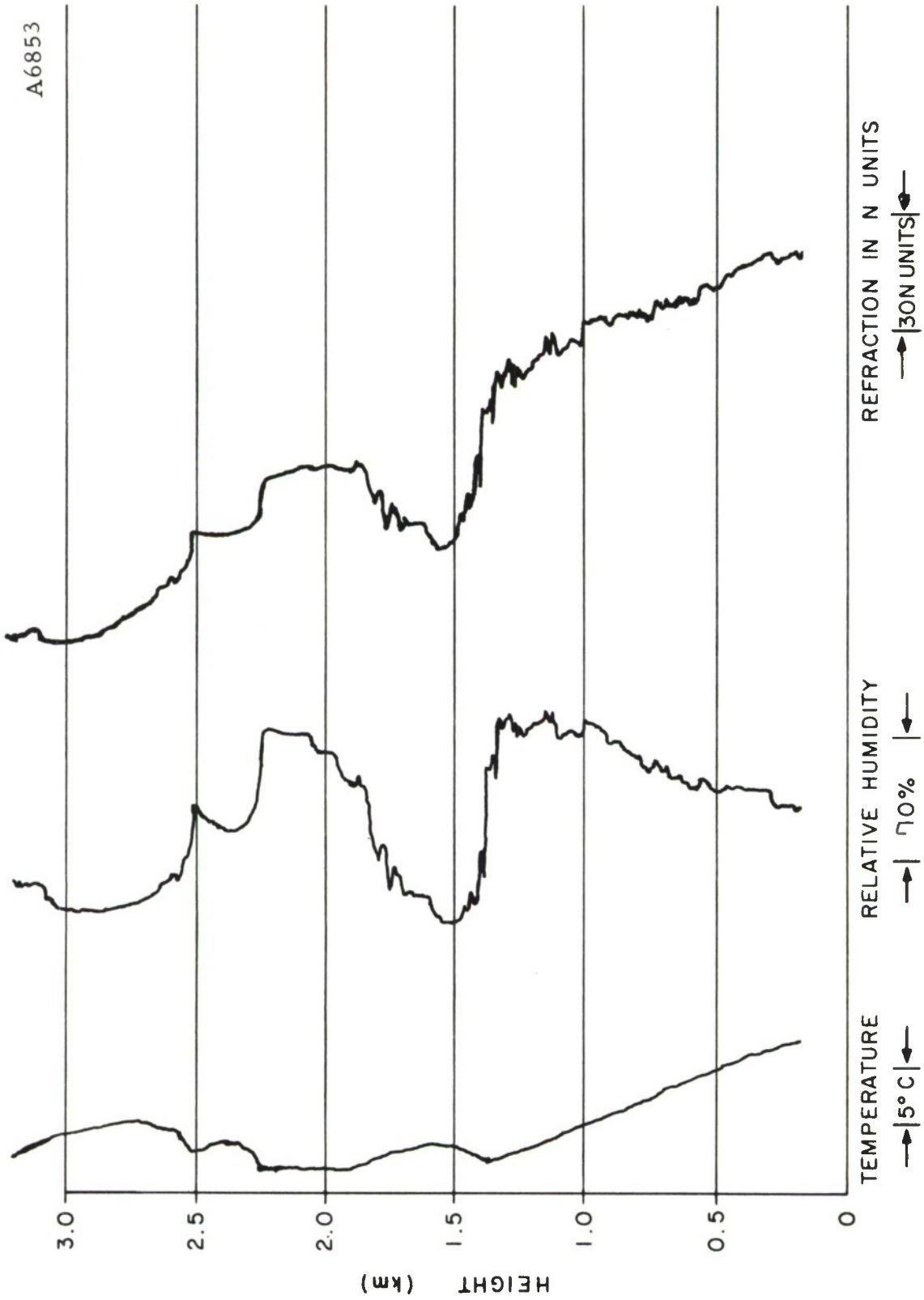
MISSION 4 - CLIMB 1

A6852



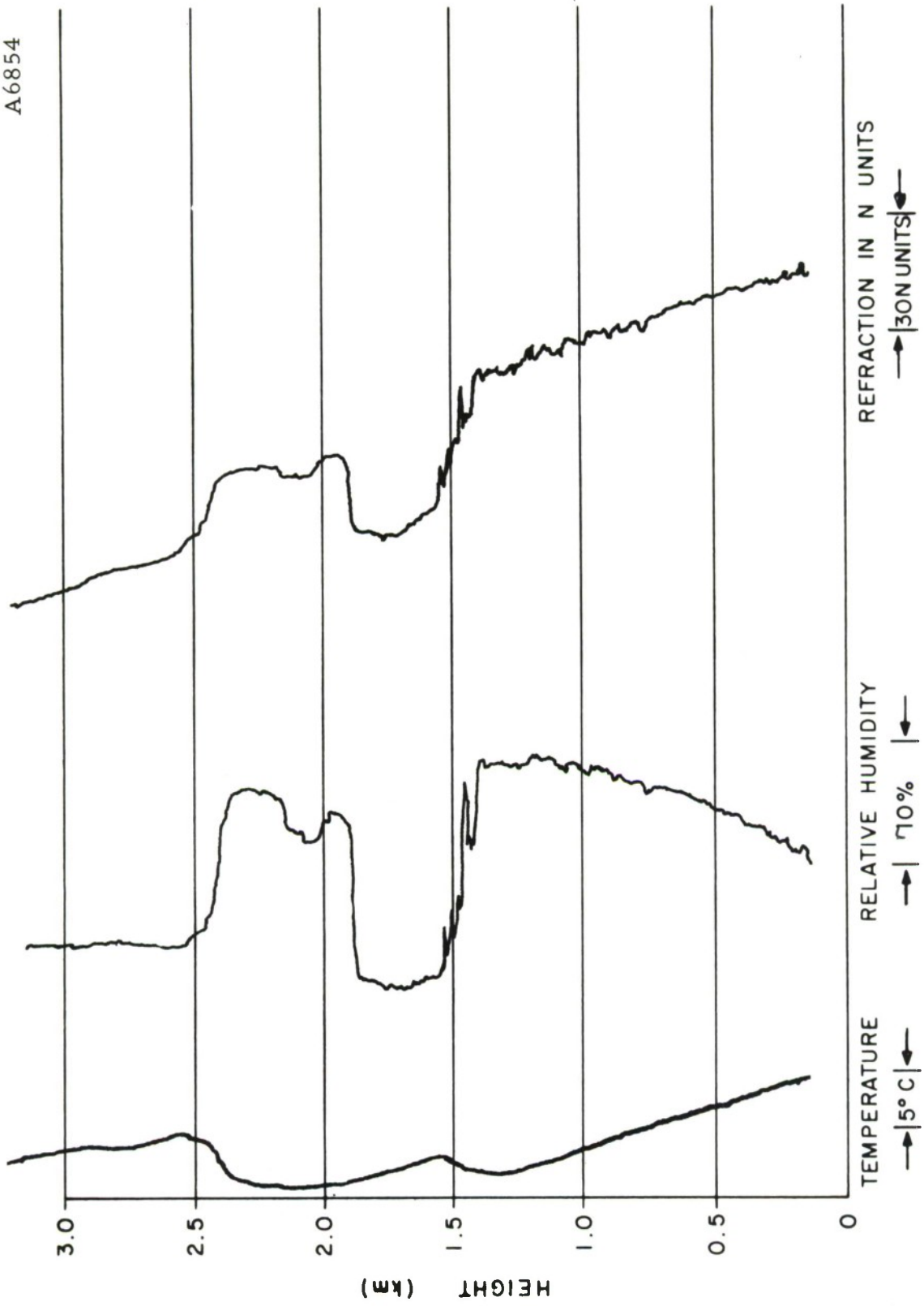
MISSION 4 - SPIRAL B

A6853

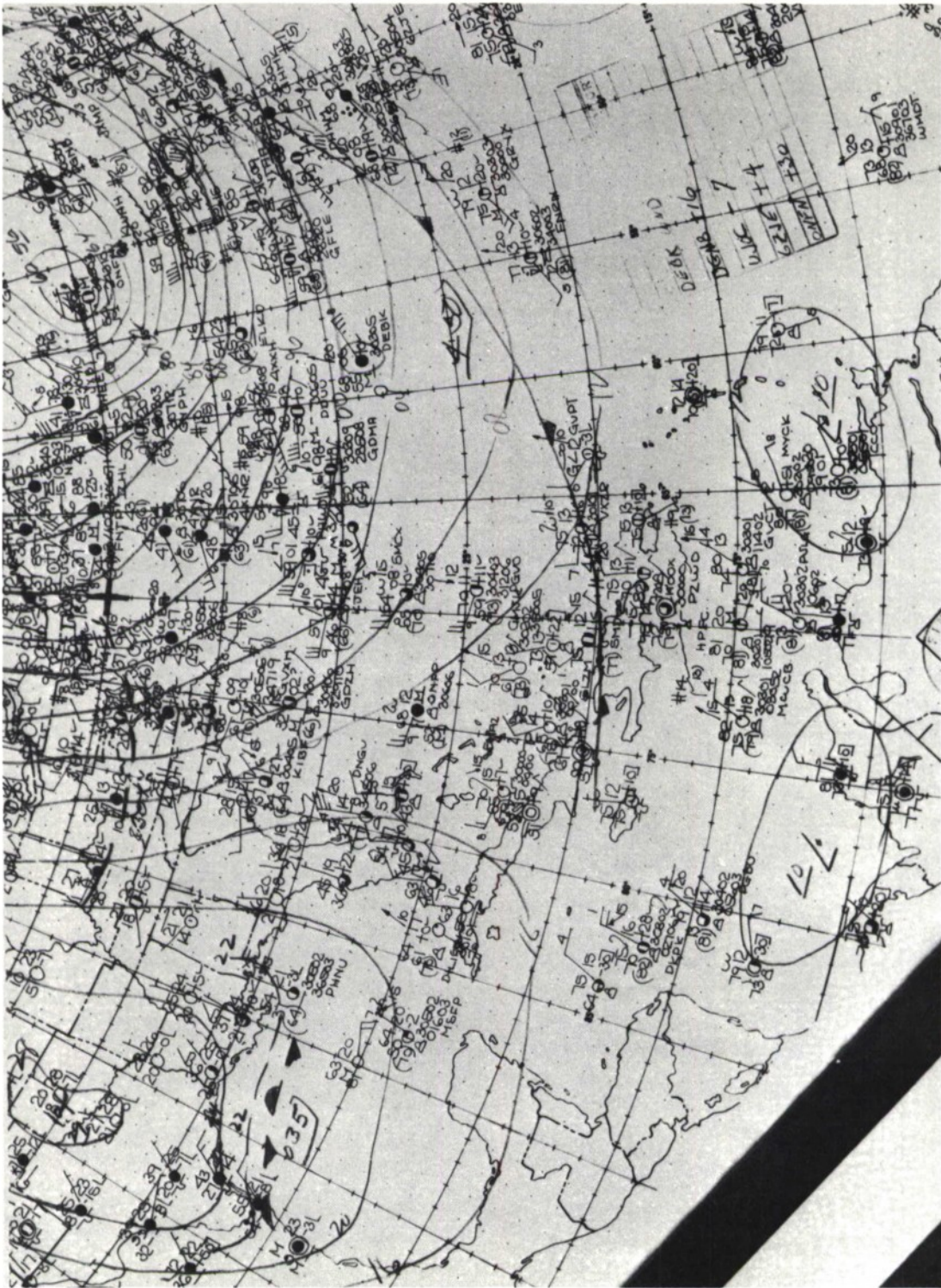


MISSION 4 - CLIMB 2

A6854



MISSION 4 - SPIRAL C



SURFACE CHART
11 March 1969

MISSION NO. 5

Date: 11 March 1969

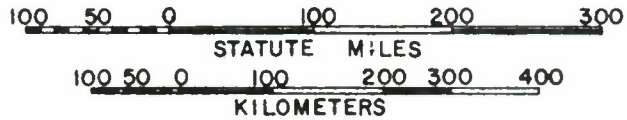
Data were obtained on four spirals and two ascents along Flight Path IV, from Merida, Mexico, to Georgetown, Cayman Islands.

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. 20-00 N, 86-25 W	1848	1248
Climb 1	a-b	1908	1308
B	b. 19-00 N, 85-35 W	1935	1335
Climb 2	b-c	1958	1358
C	c. 18-30 N, 84-00 W	2030	1430
D	d. 19-15 N, 81-15 W	2150	1550

80665



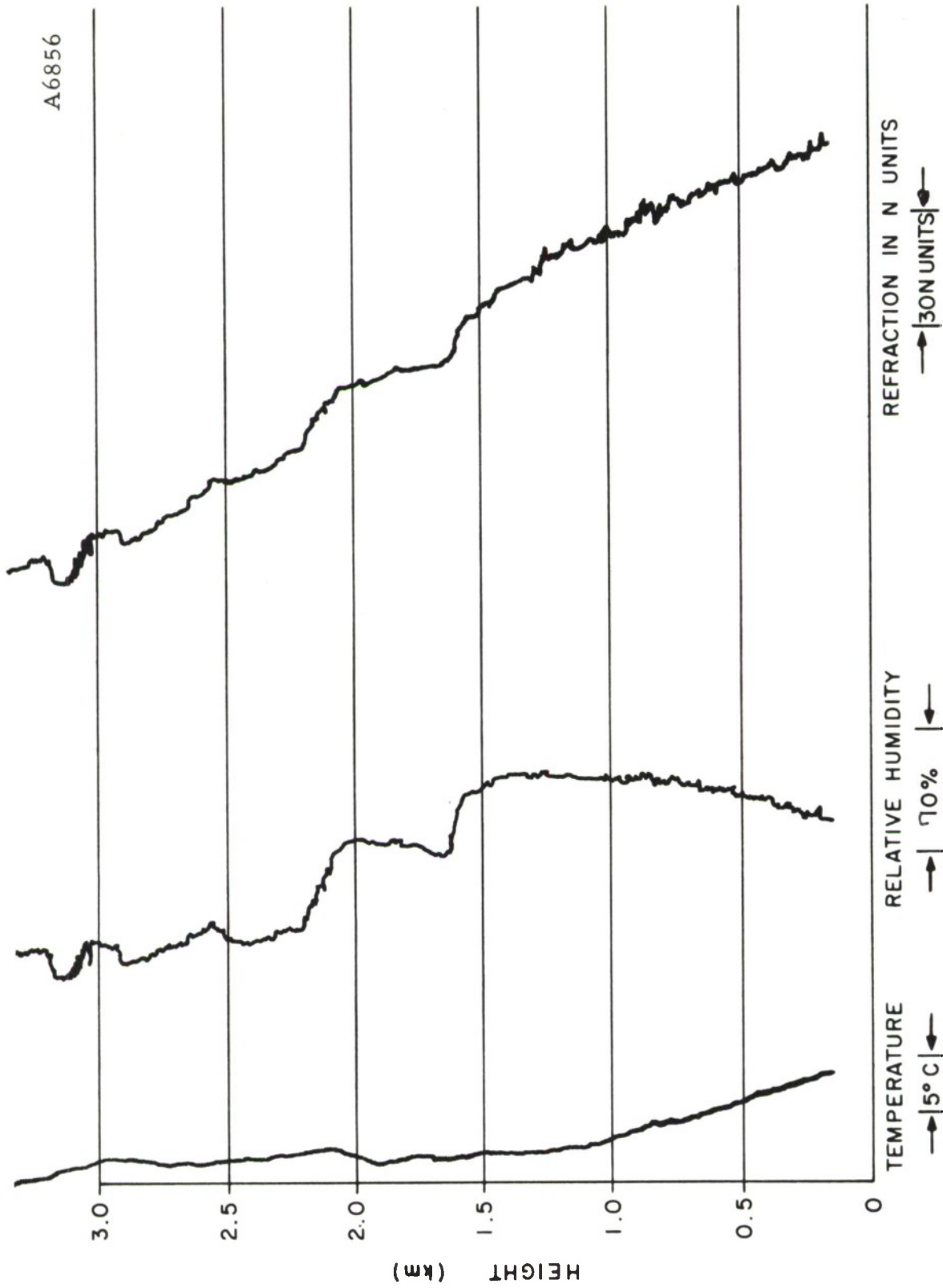
SCALE 1:5,702,400 OR 90 MILES TO 1 INCH



FLIGHT PATH IV

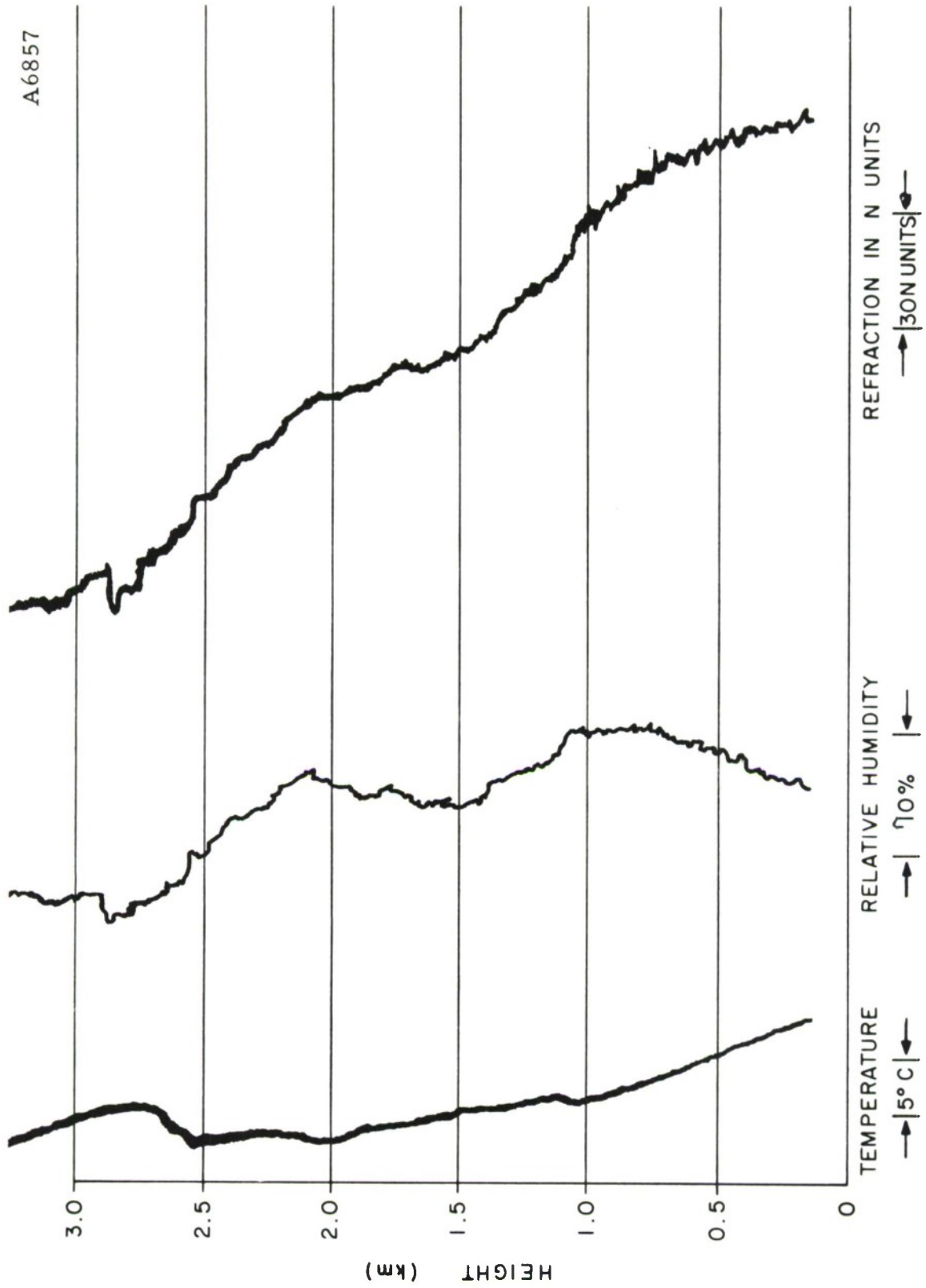
MISSION 5 — 11 MARCH 1969

A6856



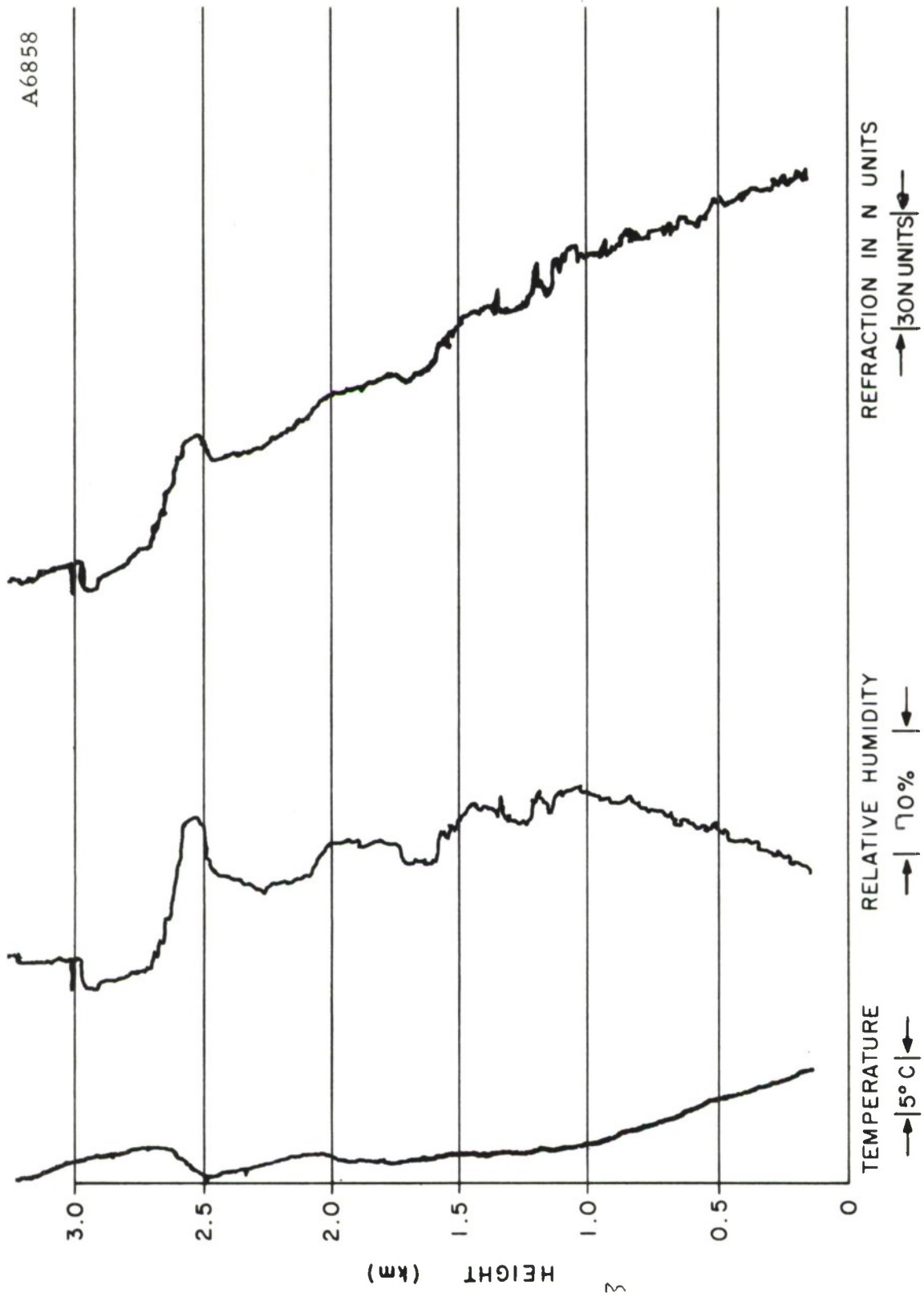
MISSION 5 - SPIRAL A

A6857



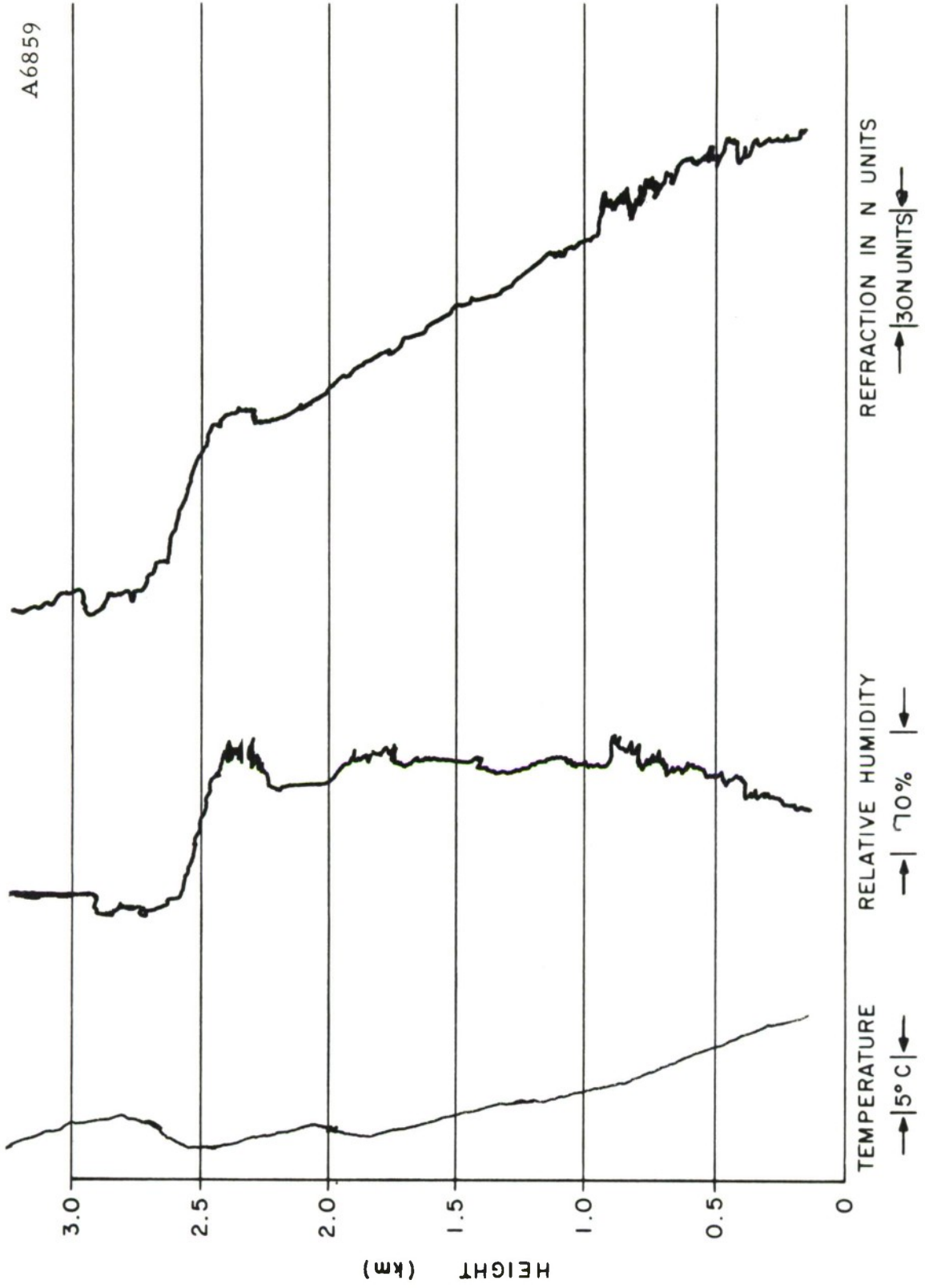
MISSION 5 - CLIMB 1

A6858

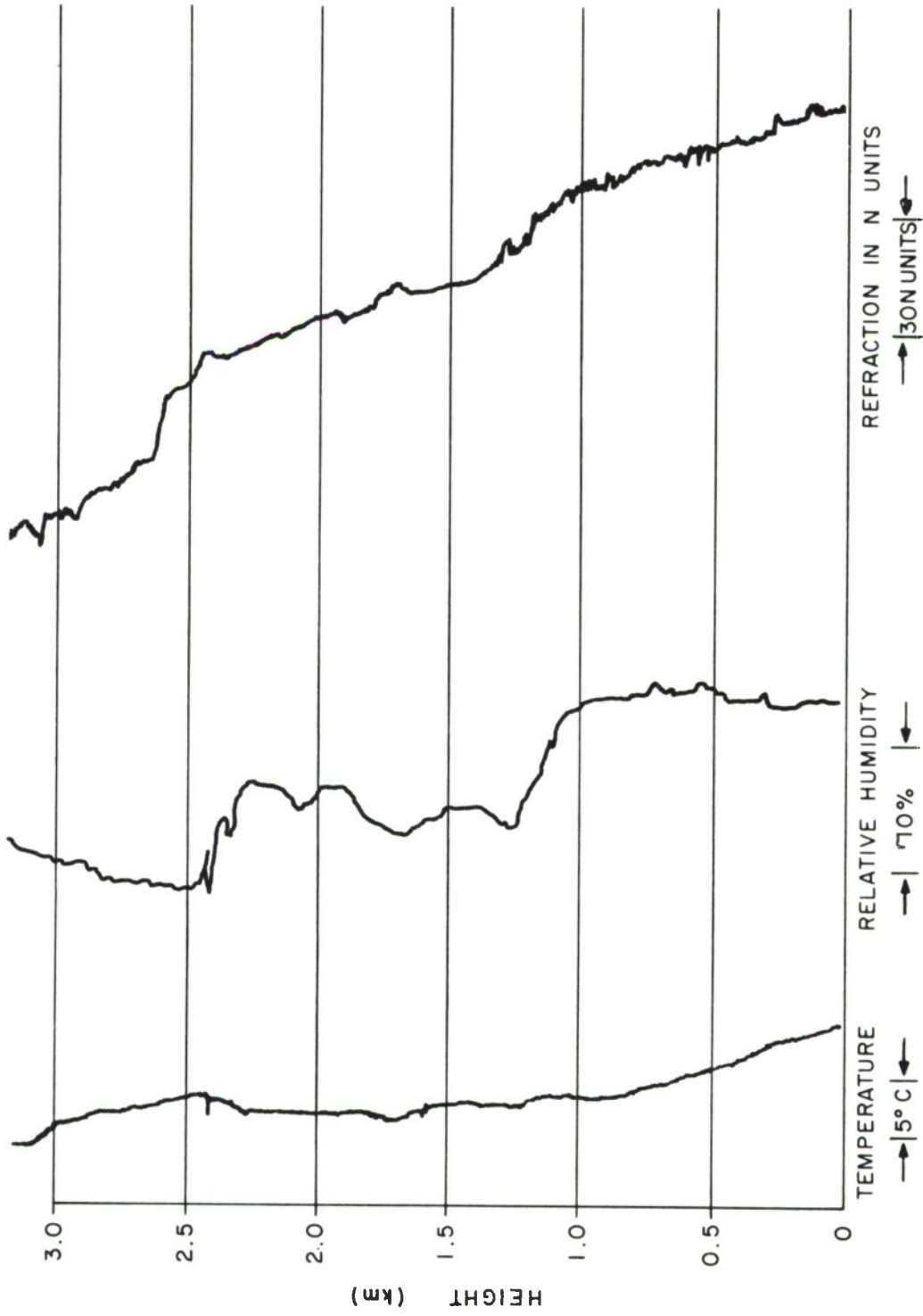


MISSION 5 - SPIRAL B

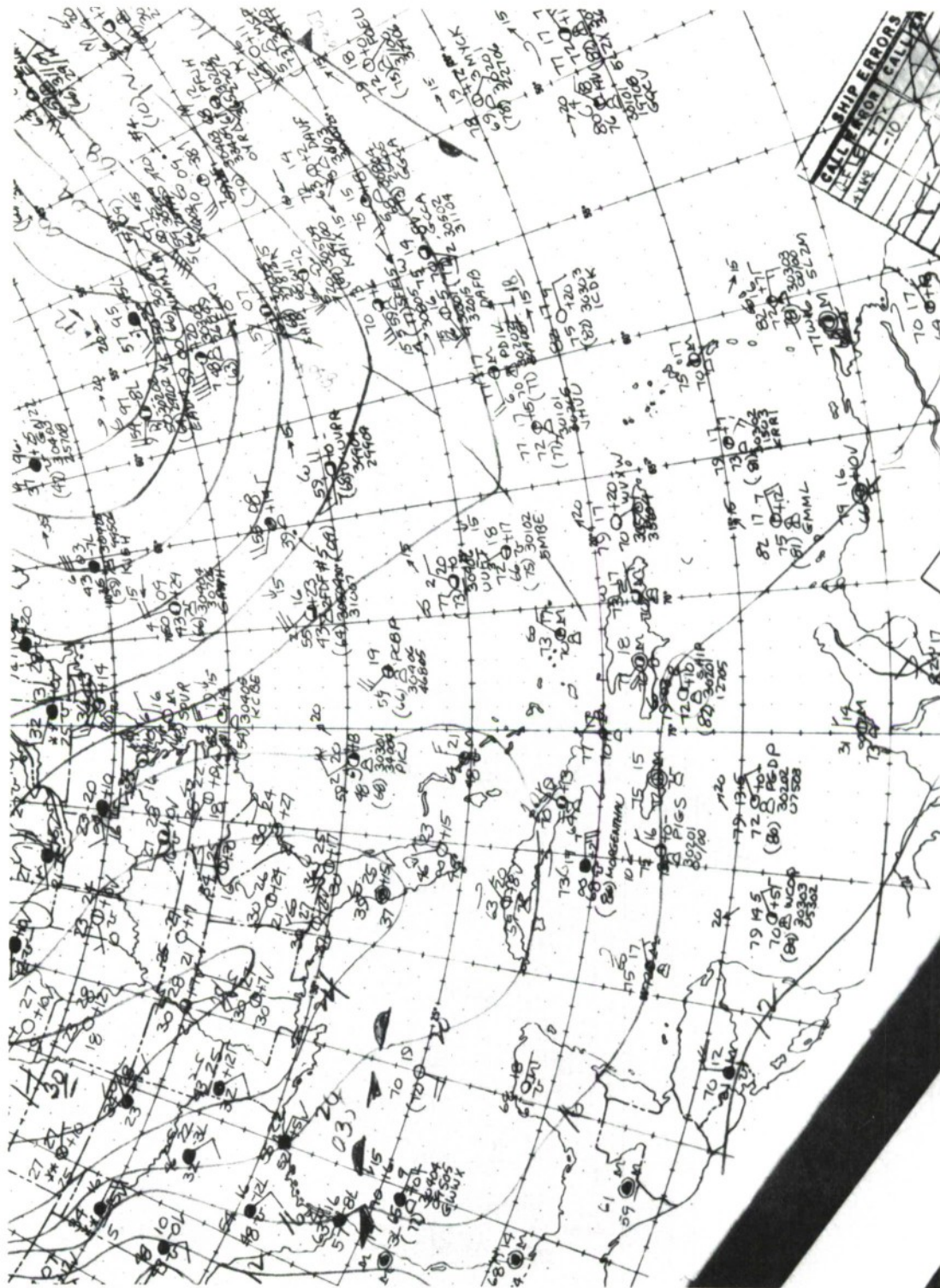
A6859



MISSION 5 - CLIMB 2



MISSION 5 - SPIRAL C



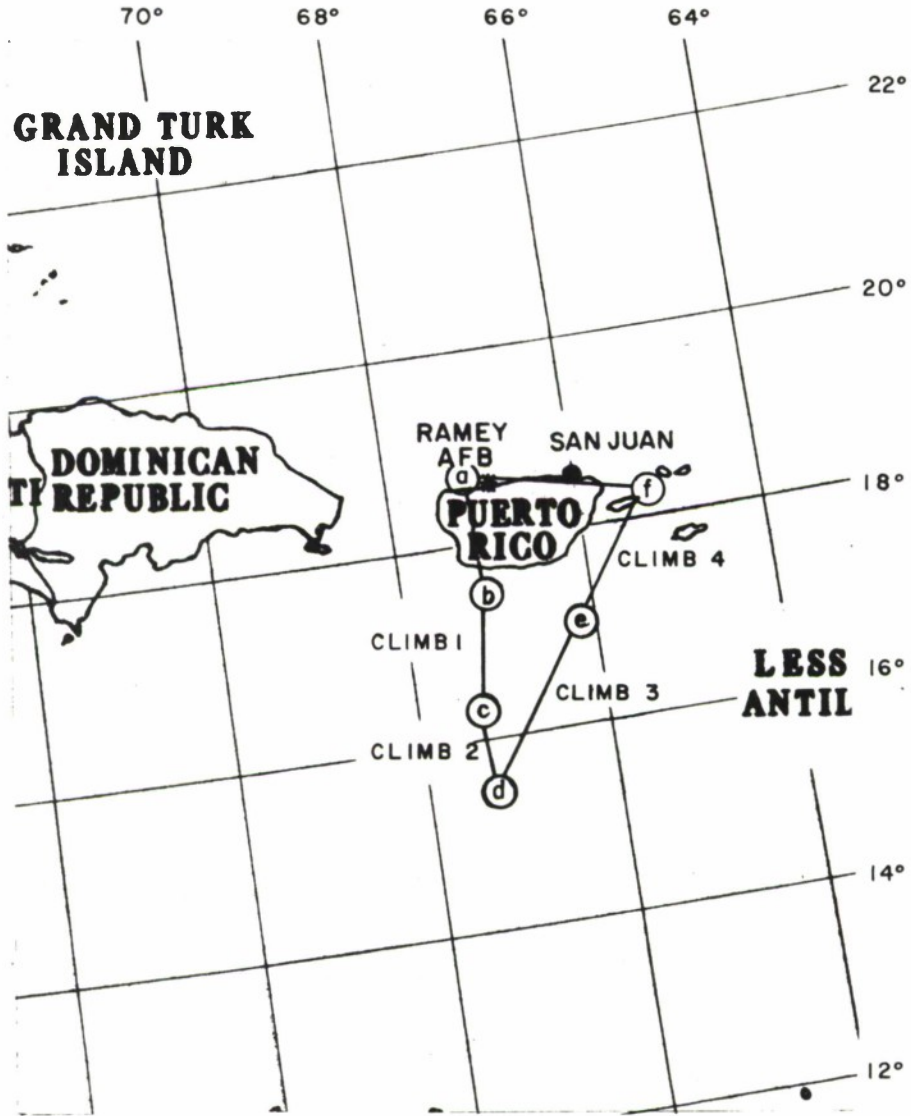
SURFACE CHART
14 March 1969

MISSION NO. 6

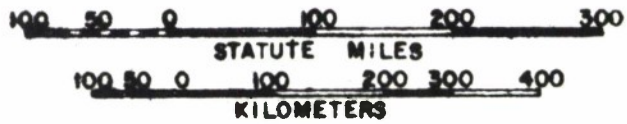
Date: 14 March 1969

Data were obtained on six spirals and four ascents along Flight Path V, southward and eastward from Ramey AFB, Puerto Rico.

<u>Spiral</u>	<u>Location</u>	<u>Spiral-Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. 18-36 N, 62-00 W	1629	1229
B	b. 17-30 N, 67-00 W	1706	1306
Climb 1	b-c	1726	1326
C	c. 16-17 N, 67-17 W	1810	1410
Climb 2	c-d	1828	1428
D	d. 15-37 N, 67-23 W	1848	1448
Climb 3	d-e	1905	1505
E	e. 17-03 N, 66-14 W	1945	1545
Climb 4	e-f	2003	1603
F	f. 18-34 N, 65-37 W	2033	1633

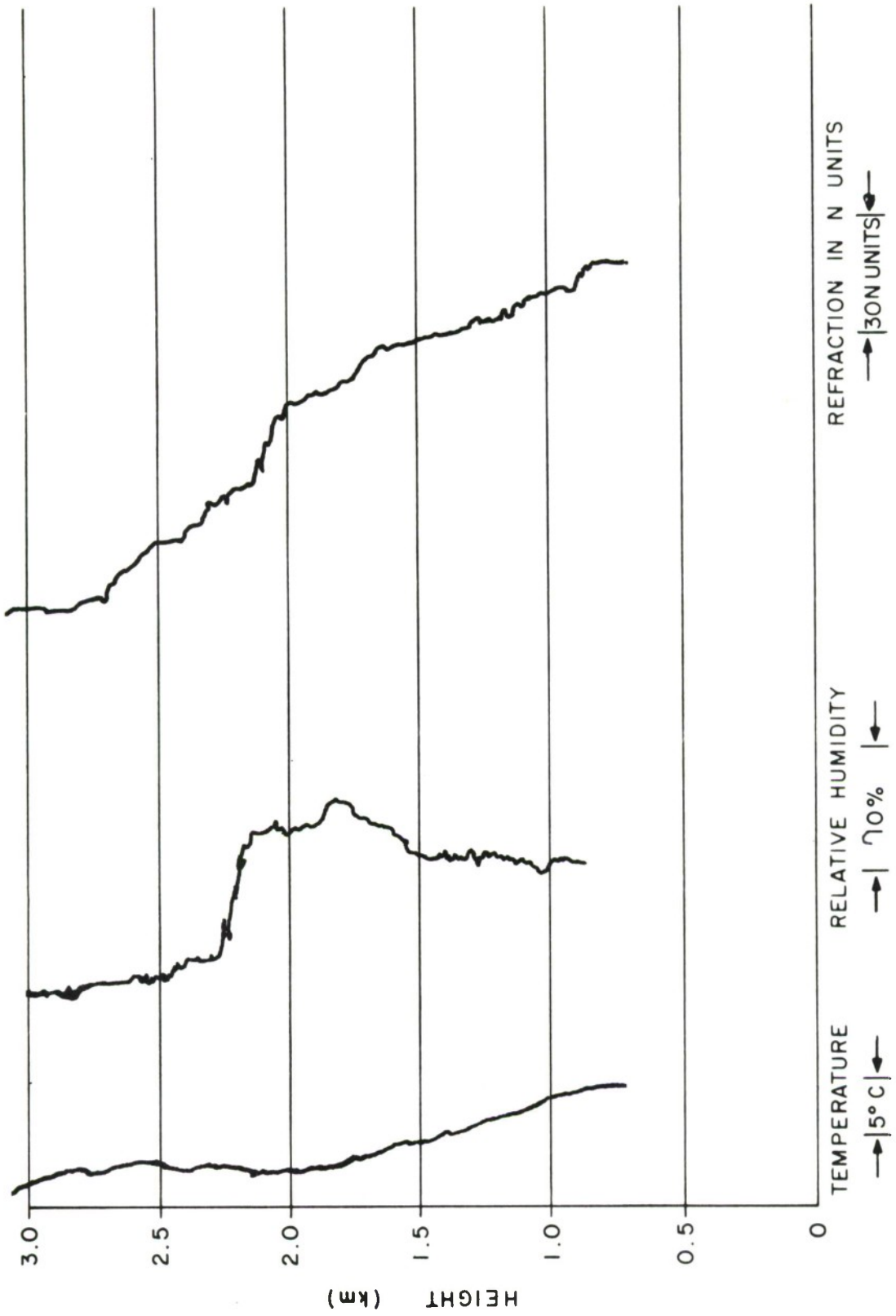


SCALE 1:5,702,400 OR 90 MILES TO 1 INCH



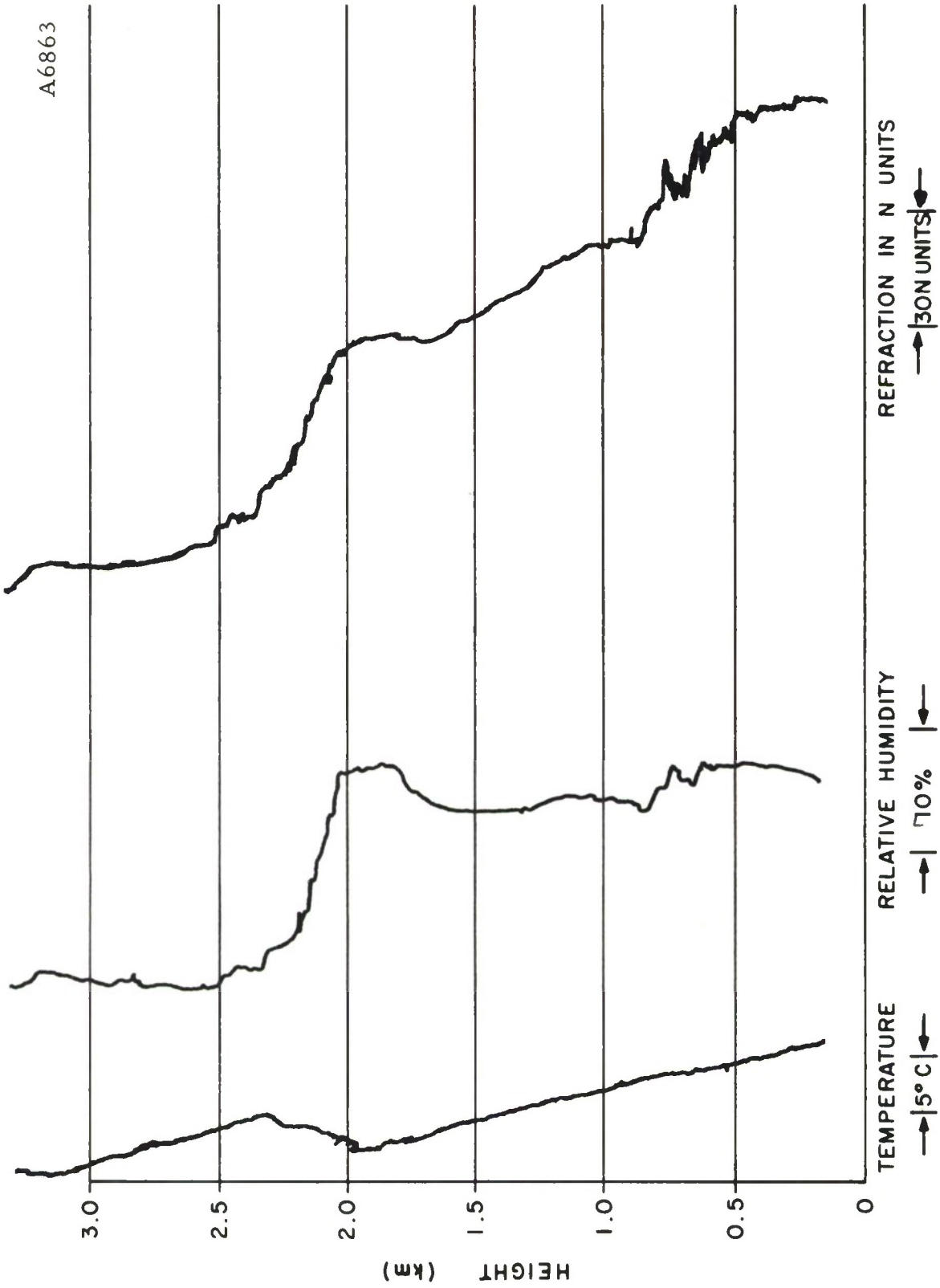
FLIGHT PATH V
 MISSION 6 — 14 MARCH 1969

A6862



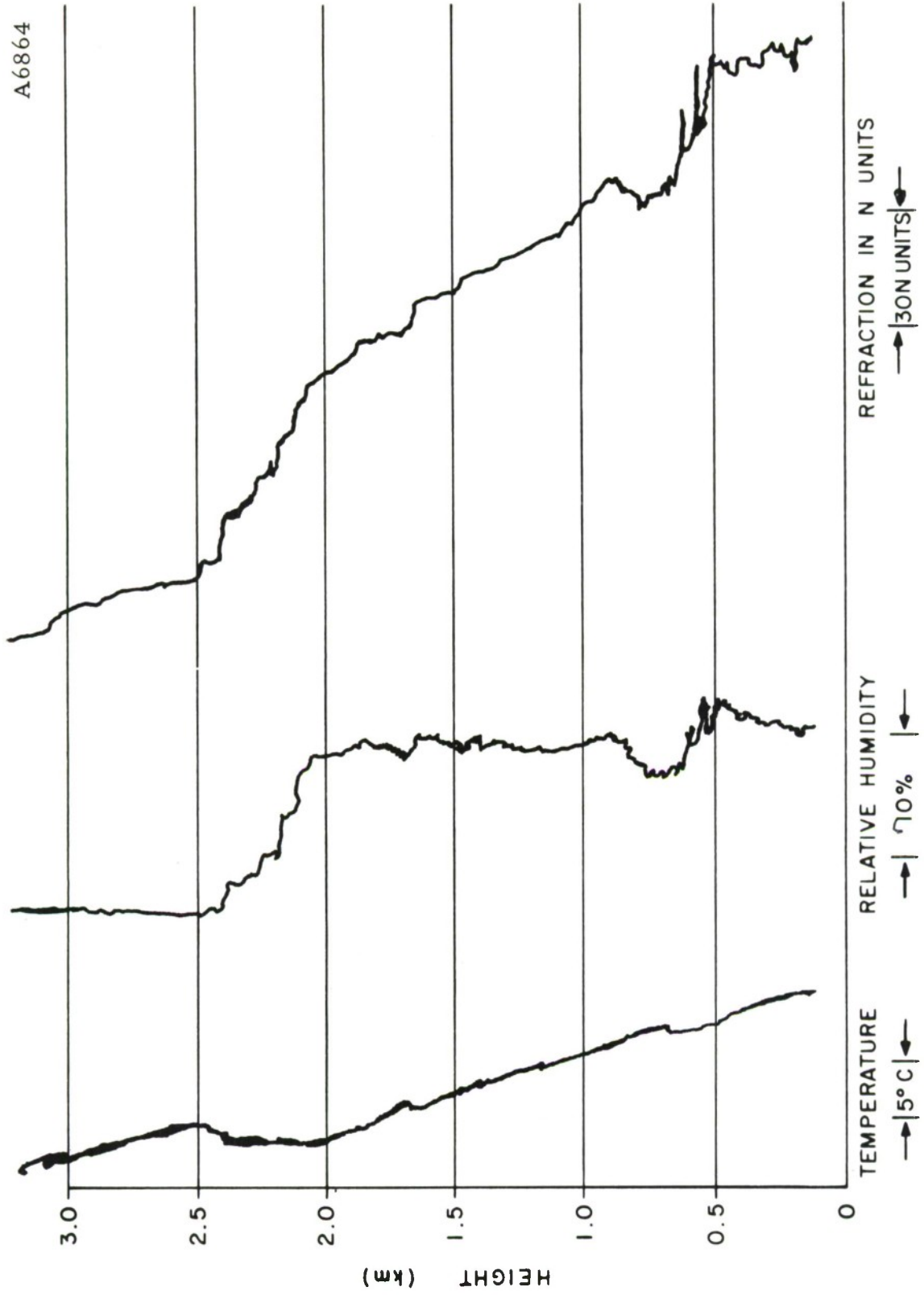
MISSION 6 - SPIRAL A

A6863



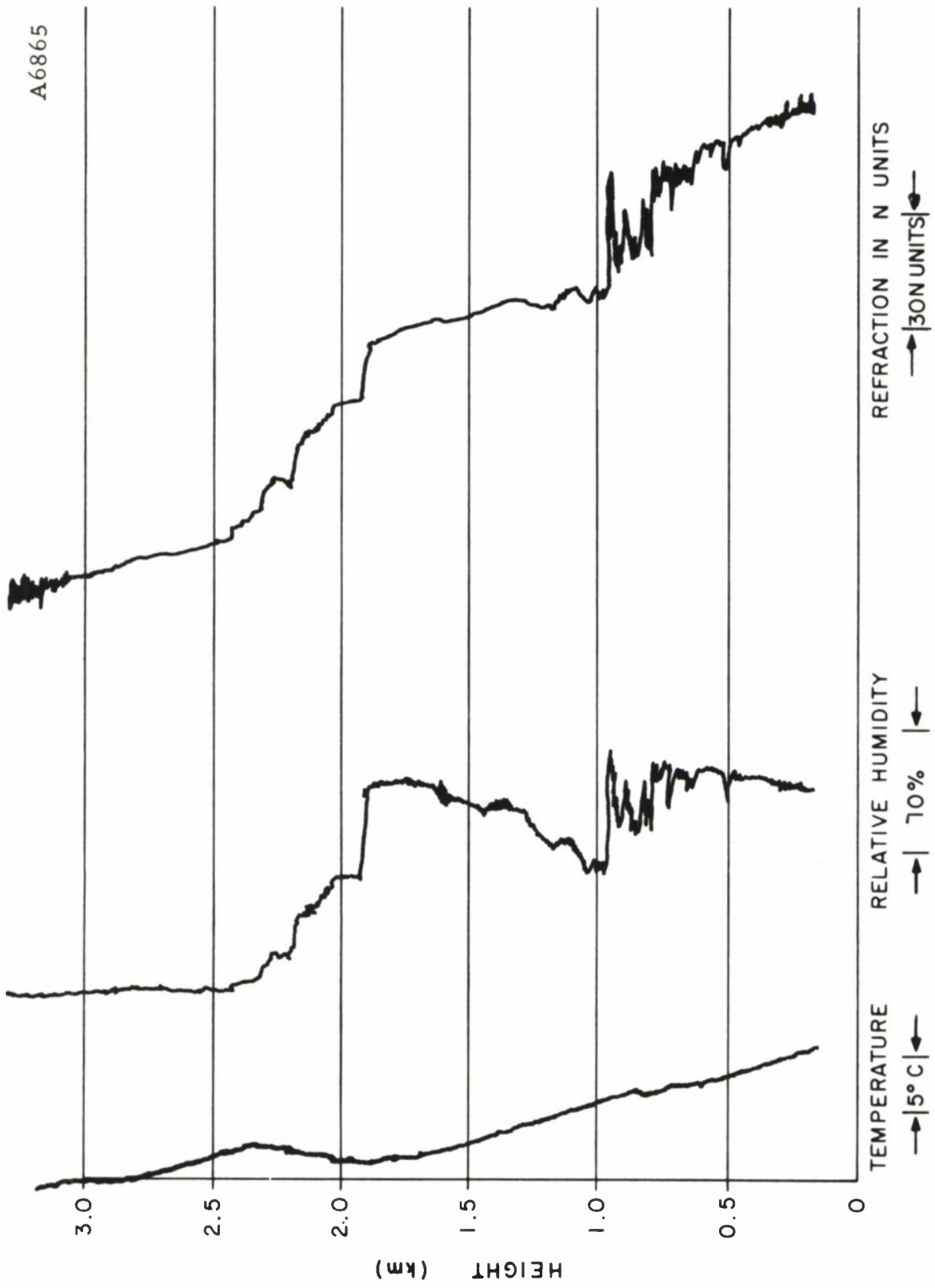
MISSION 6 - SPIRAL B

A6864



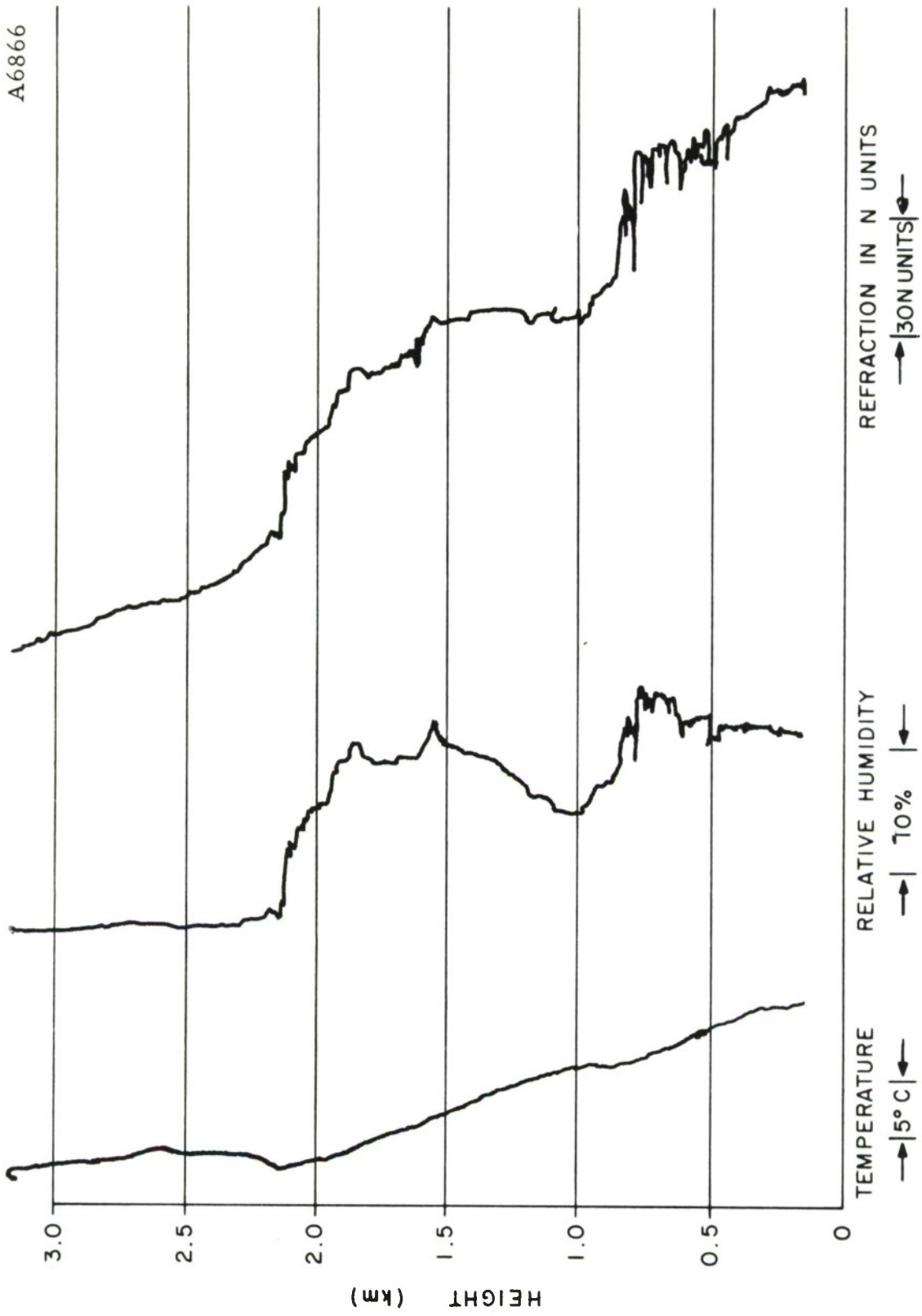
MISSION 6 - CLIMB 1

A6865



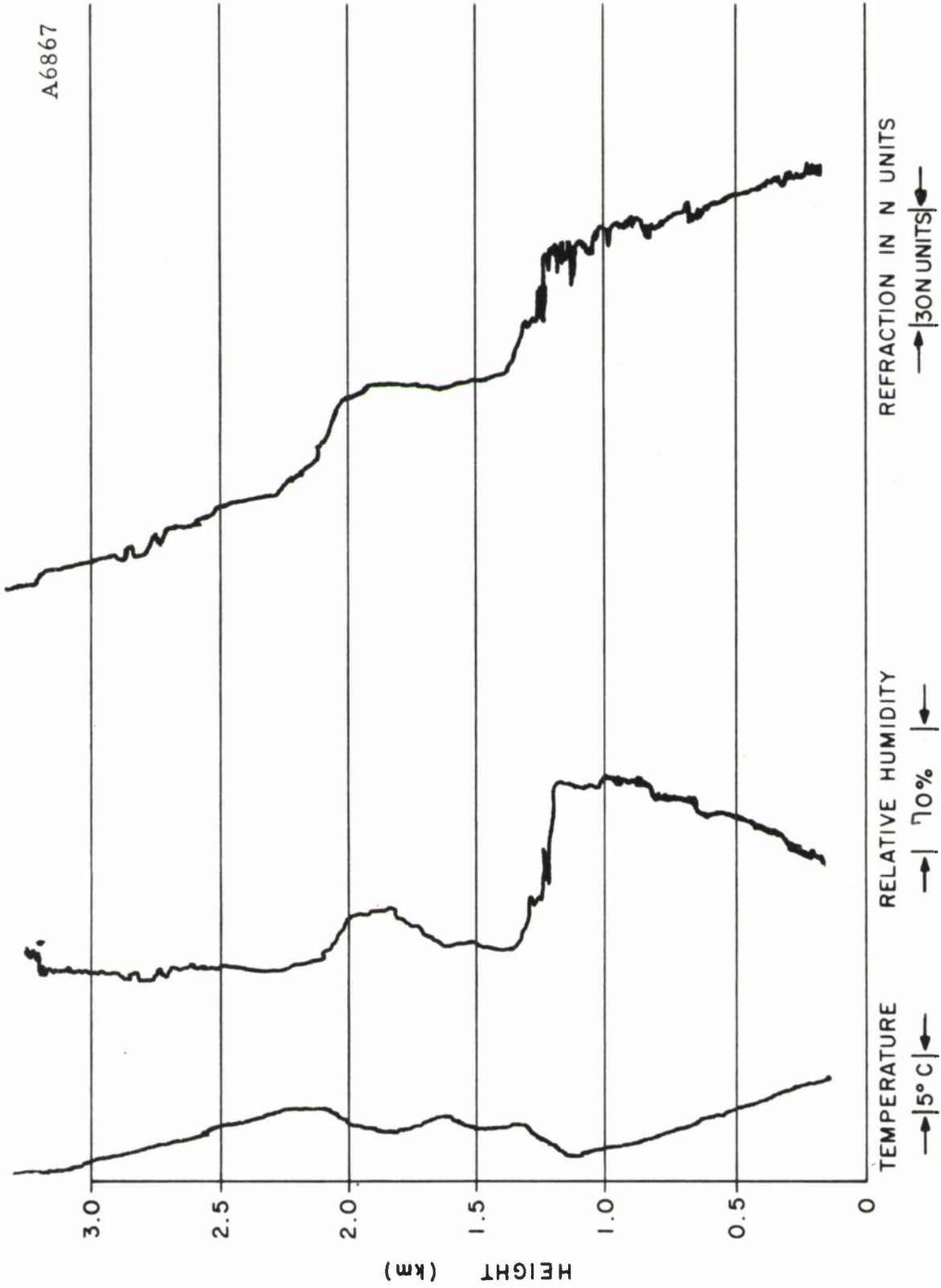
MISSION 6 - SPIRAL C

A6866



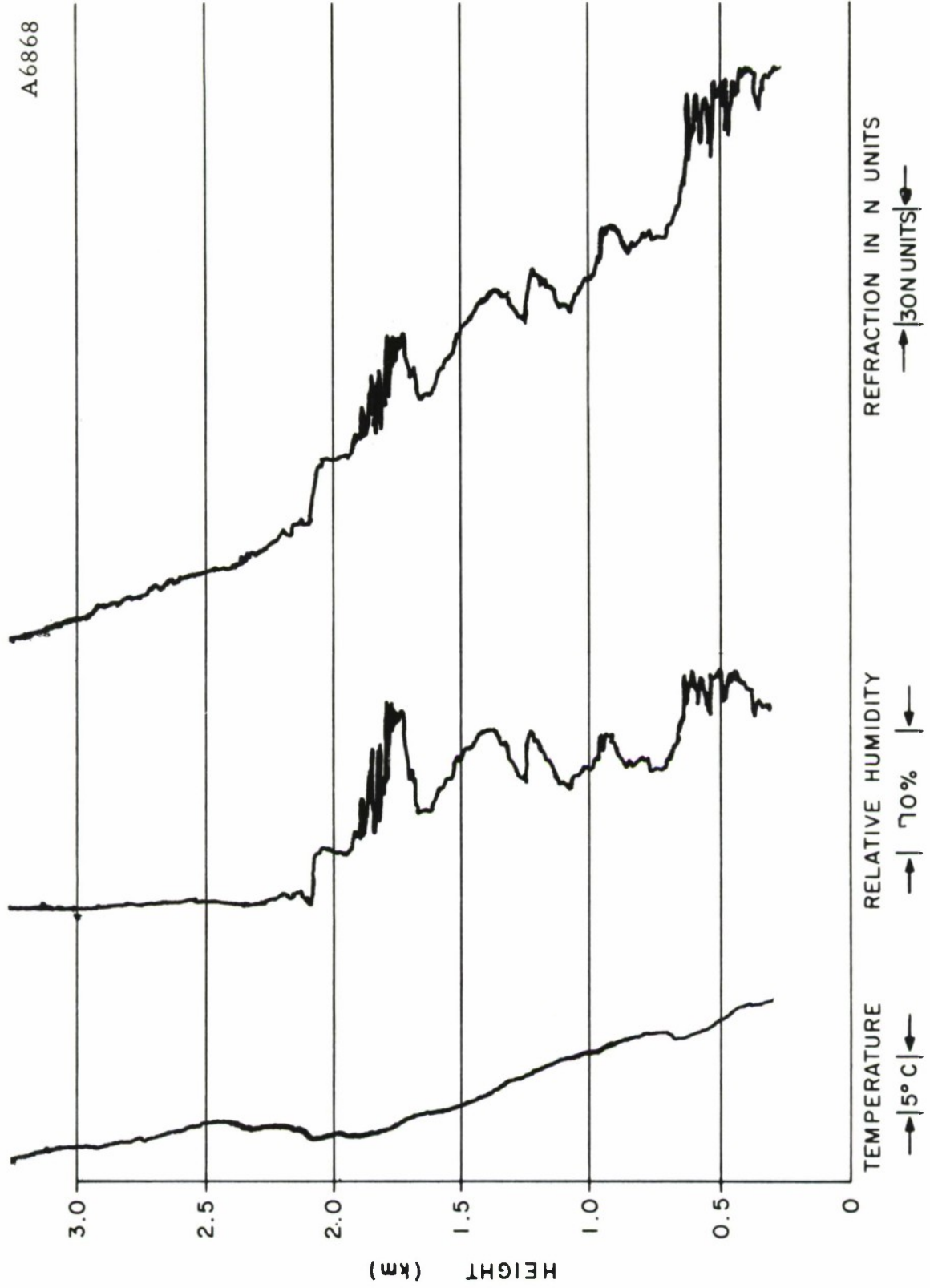
MISSION 6 - CLIMB 2

A6867

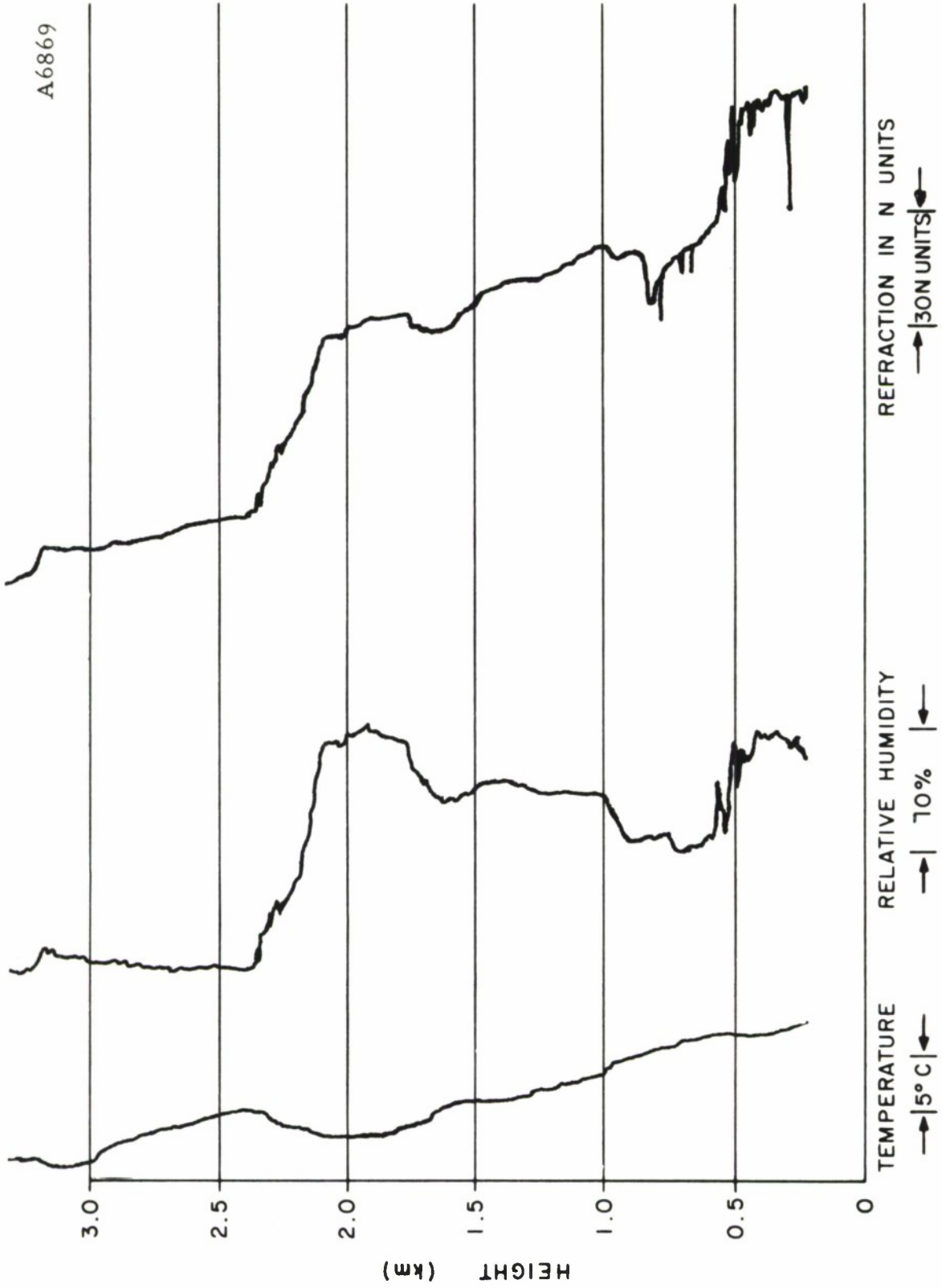


MISSION 5 - SPIRAL D

A6868

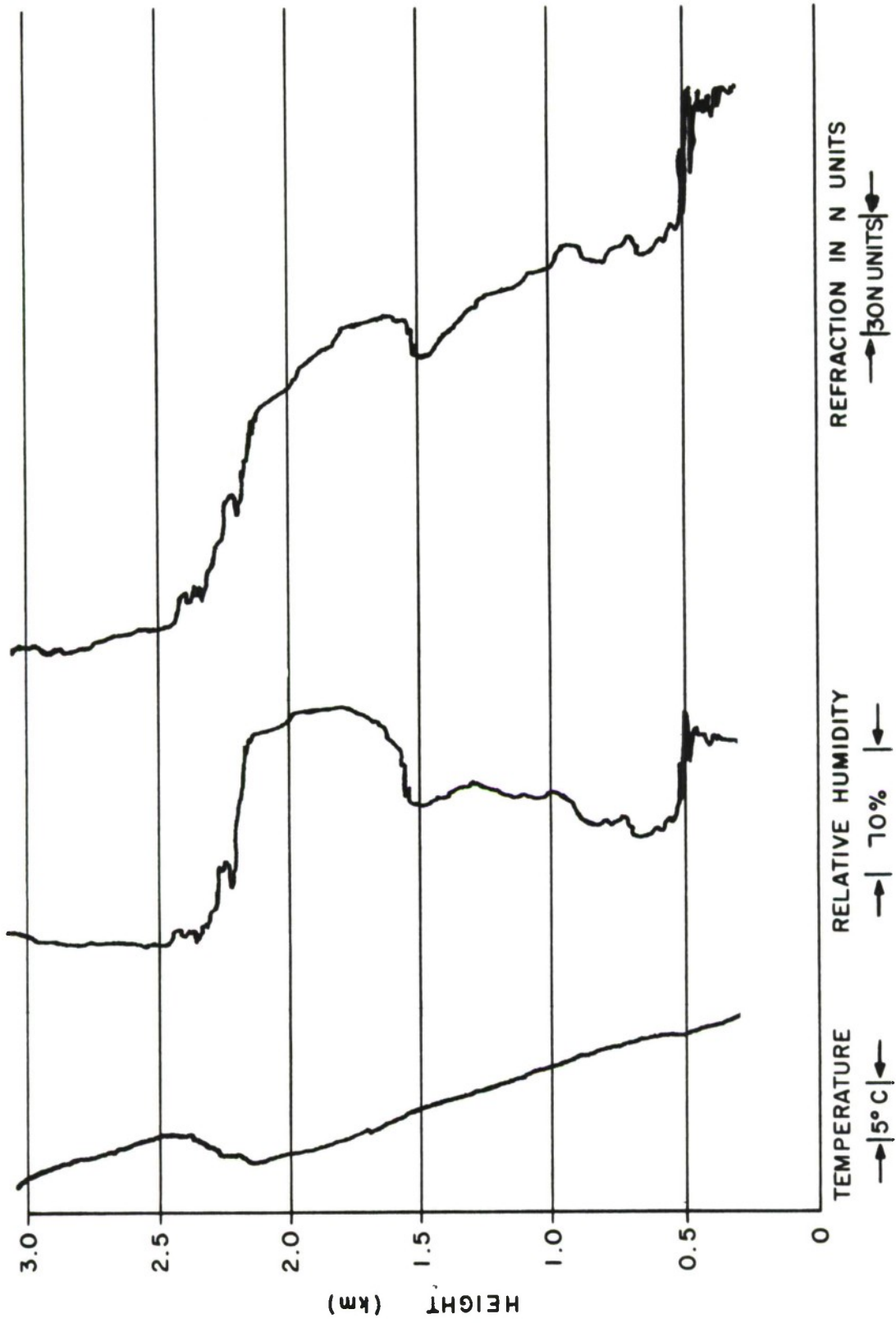


A6869

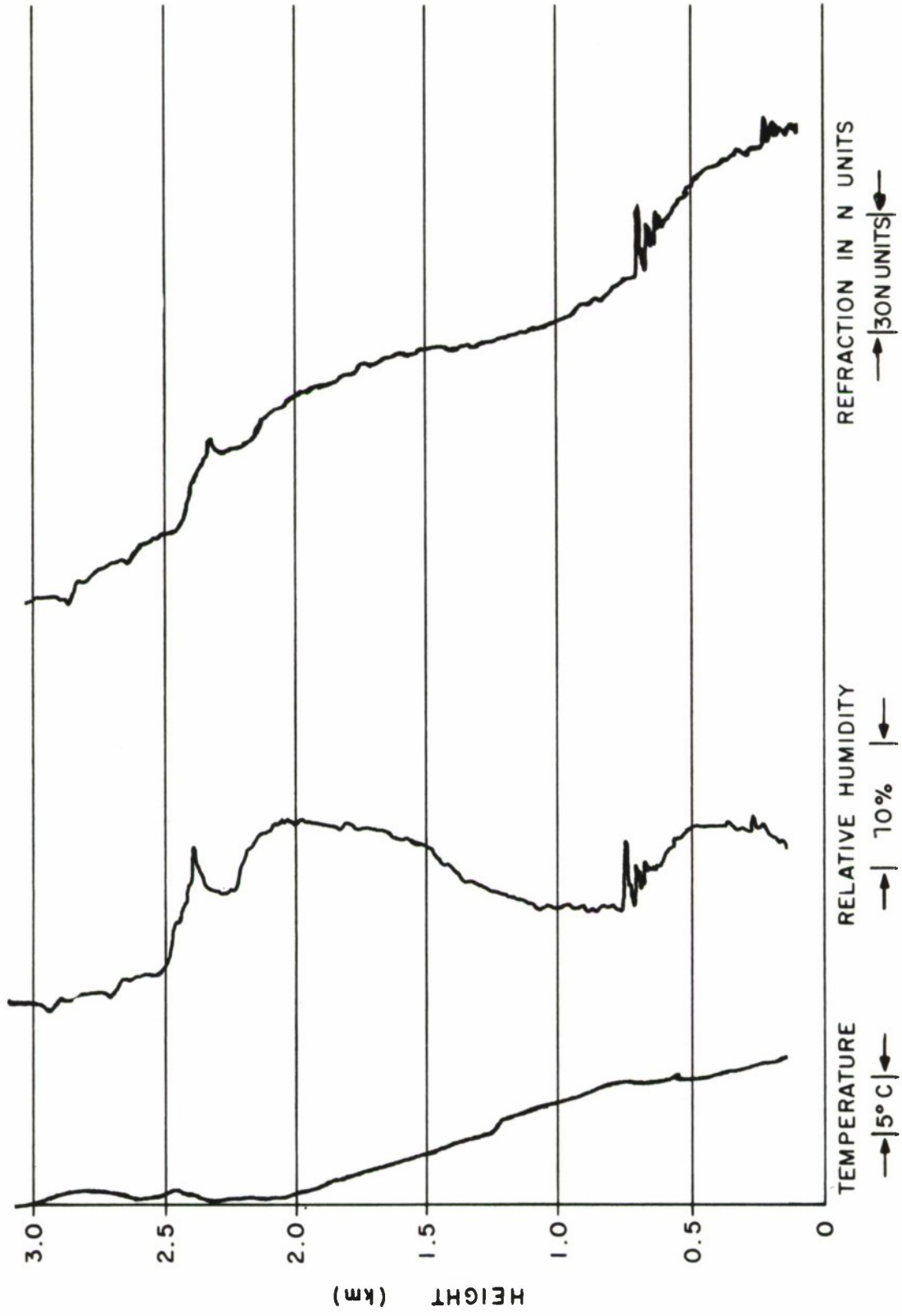


MISSION 6 - SPIRAL E

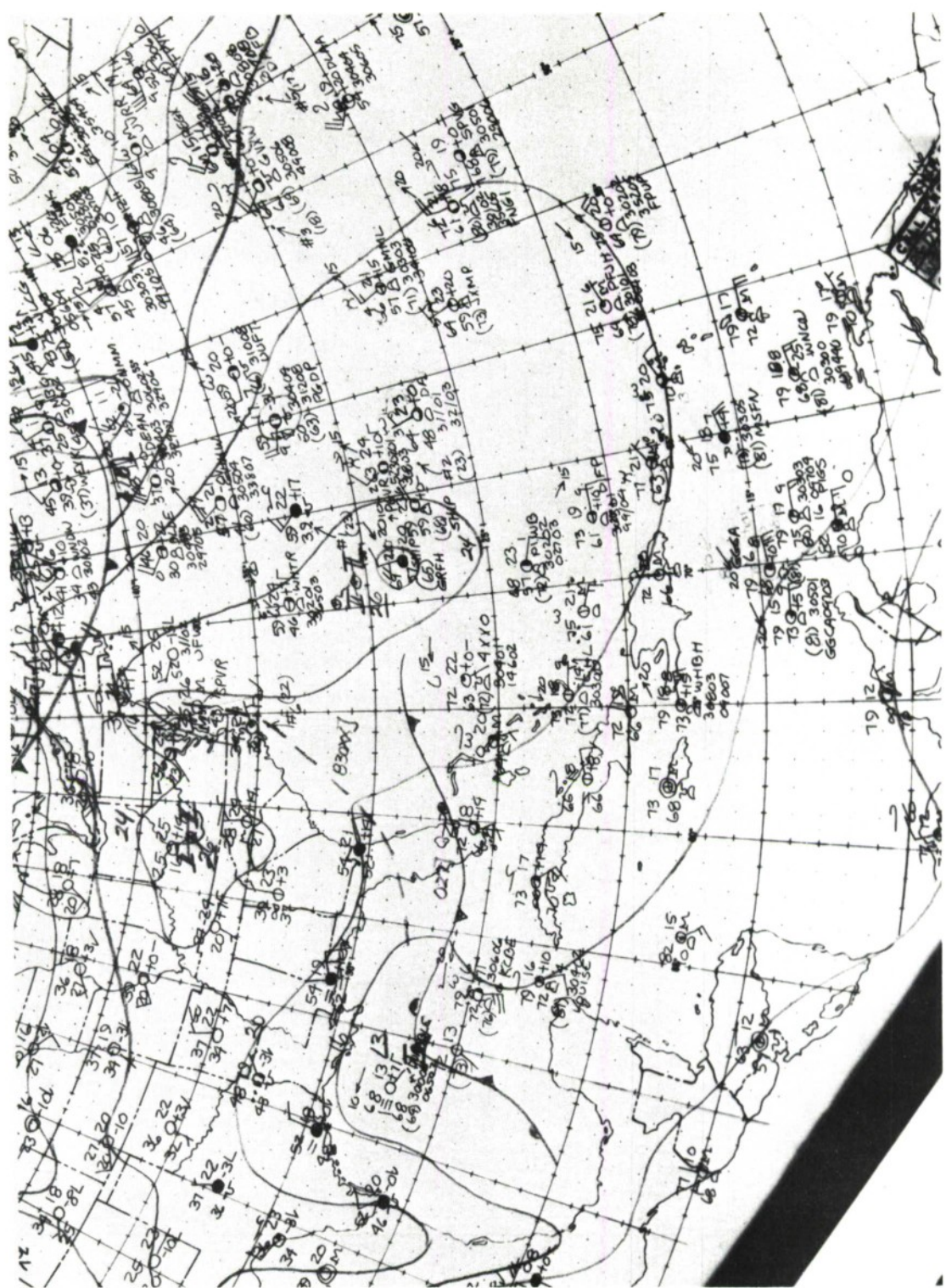
A6870



A6871



MISSION 6 - SPIRAL F



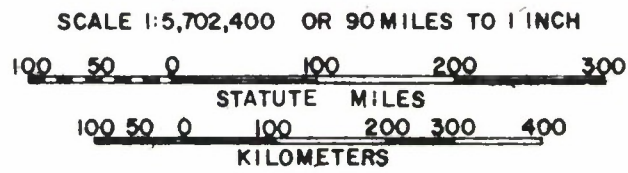
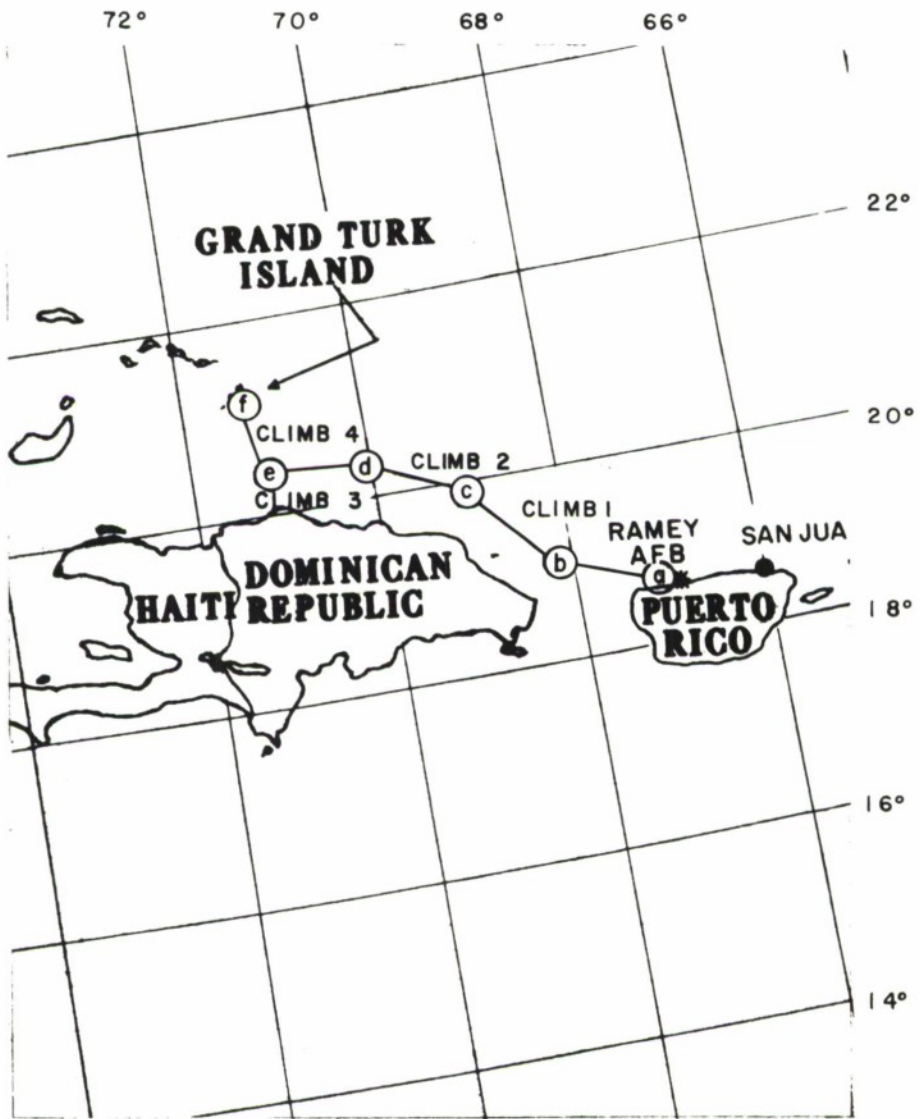
SURFACE CHART
17 March 1969

MISSION NO. 7

Date: 17 March 1969

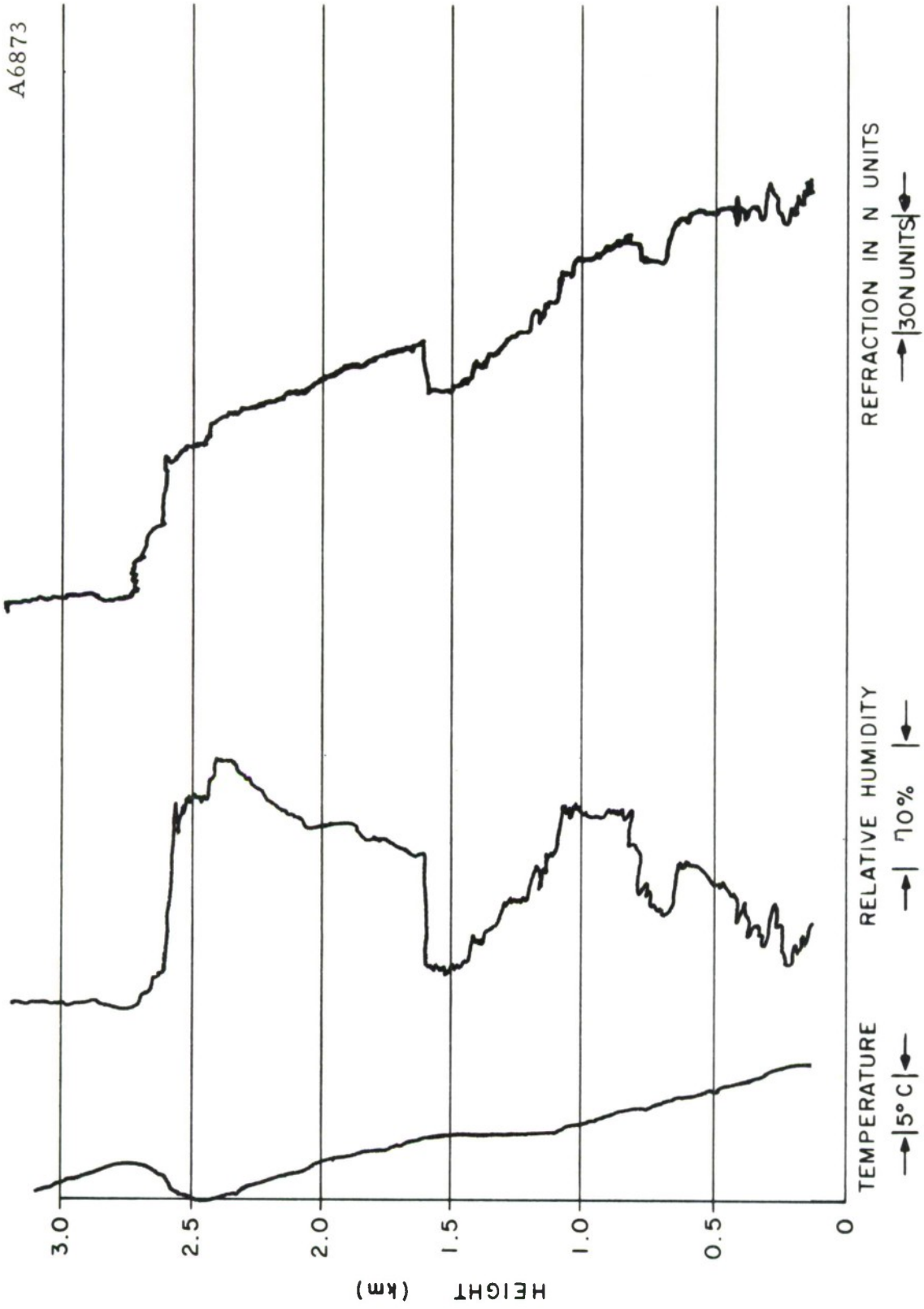
Data were obtained on six spirals and four ascents along Flight Path VI, from Ramey AFB, Puerto Rico, to Grand Turk Island.

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. 18-32 N, 67-07 W	1702	1302
B	b. 19-10 N, 68-01 W	1744	1344
Climb 1	b-c	1800	1400
C	c. 19-53 N, 69-00 W	1828	1428
Climb 2	c-d	1848	1448
D	d. 20-36 N, 70-00 W	1915	1515
Climb 3	d-e	1932	1532
E	e. 20-34 N, 71-10 W	1955	1555
Climb 4	e-f	2013	1613
F	f. Grand Turk	2033	1633



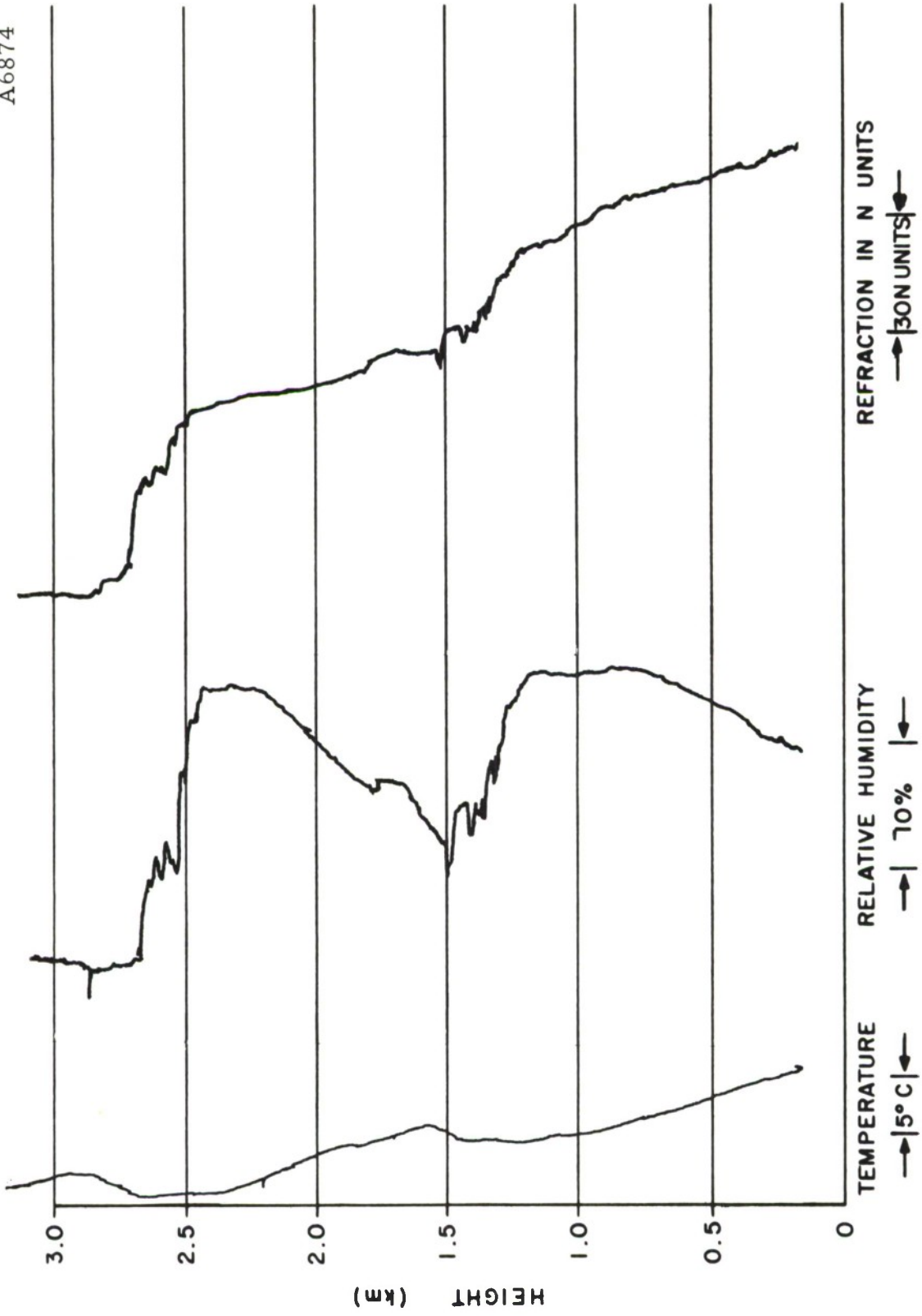
FLIGHT PATH VI
MISSION 7 — 17 MARCH 1969

A6873



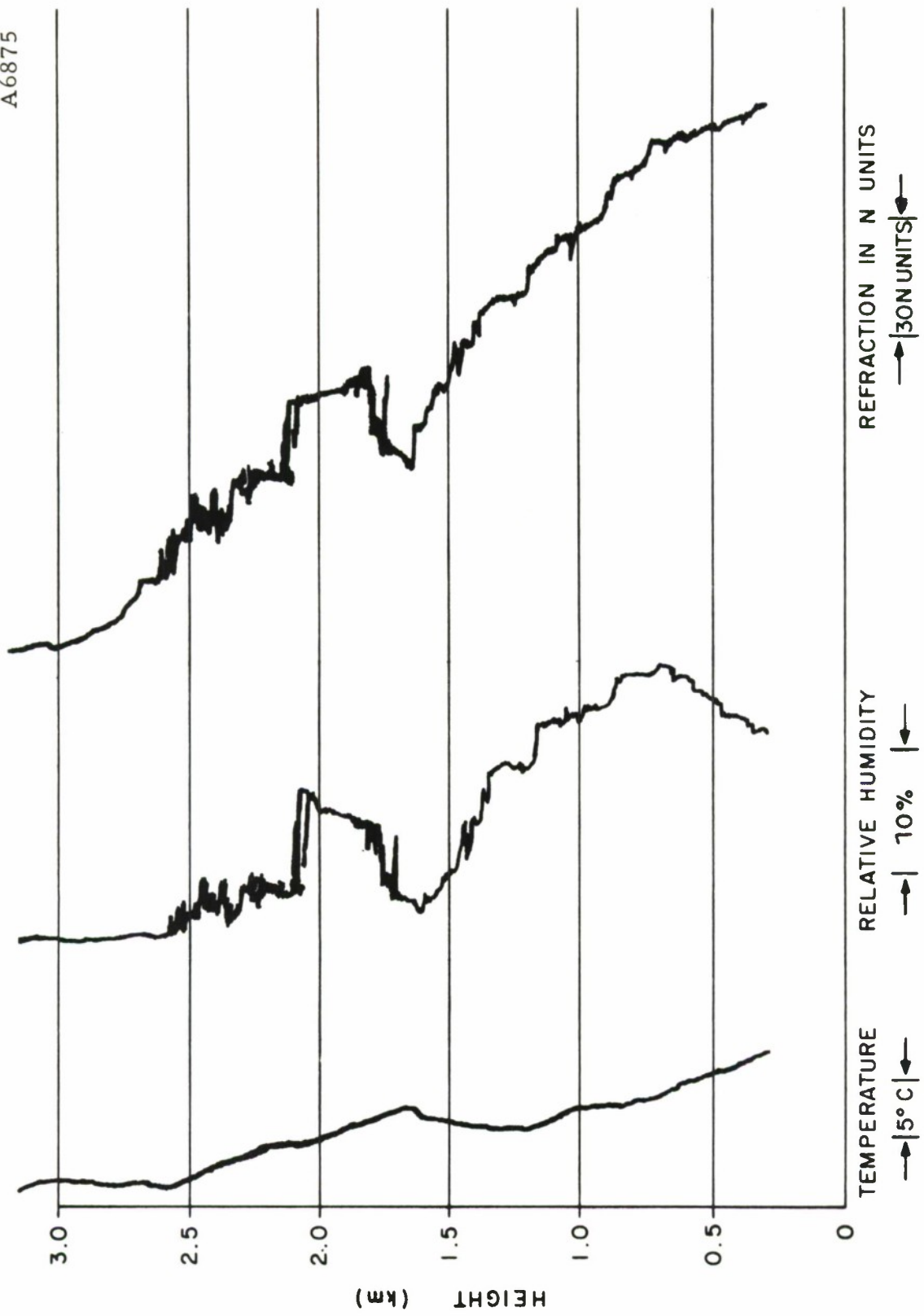
MISSION 7 - SPIRAL A

A6874



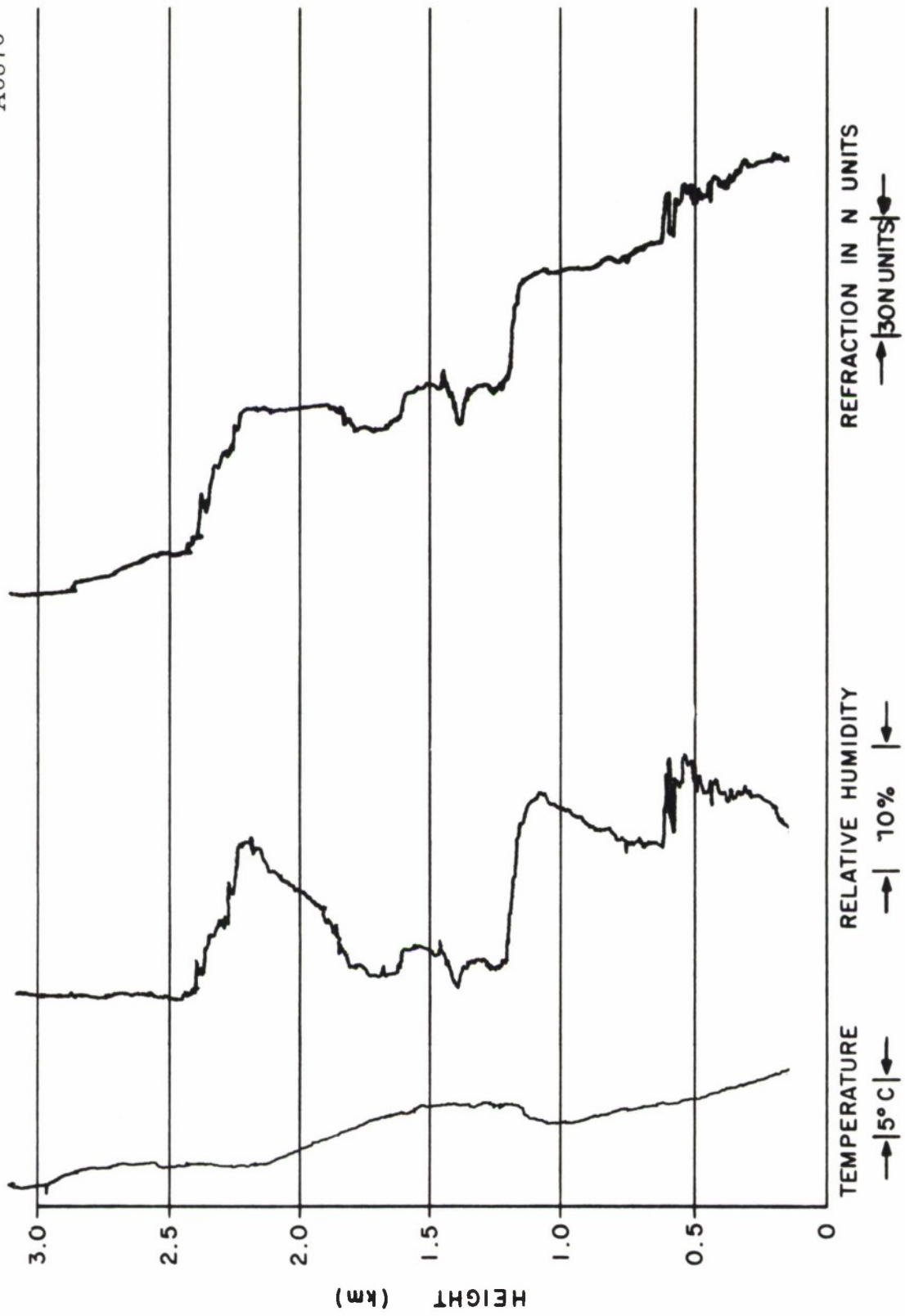
MISSION 7 - SPIRAL B

A6875



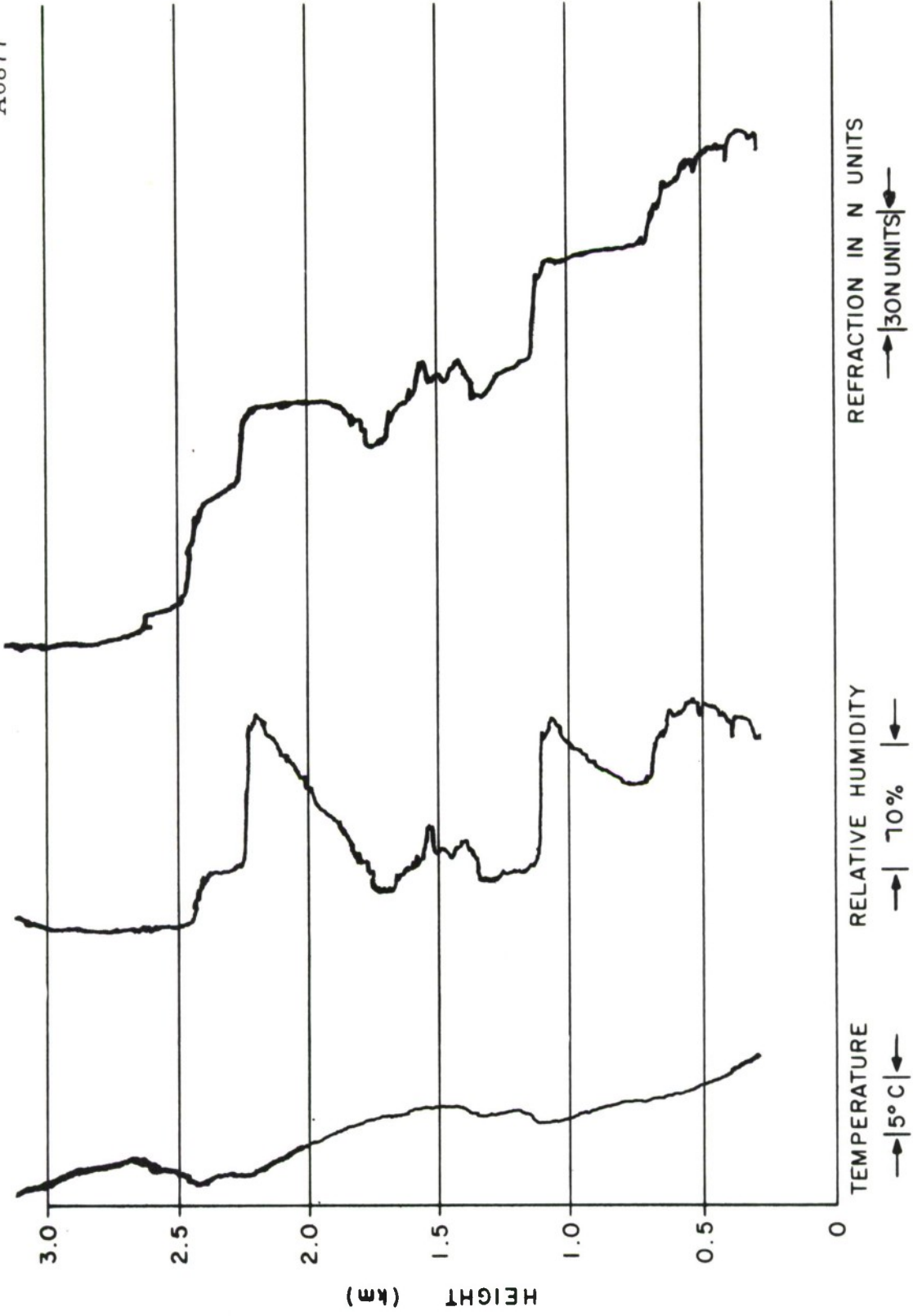
MISSION 7 - CLIMB 1

A6876

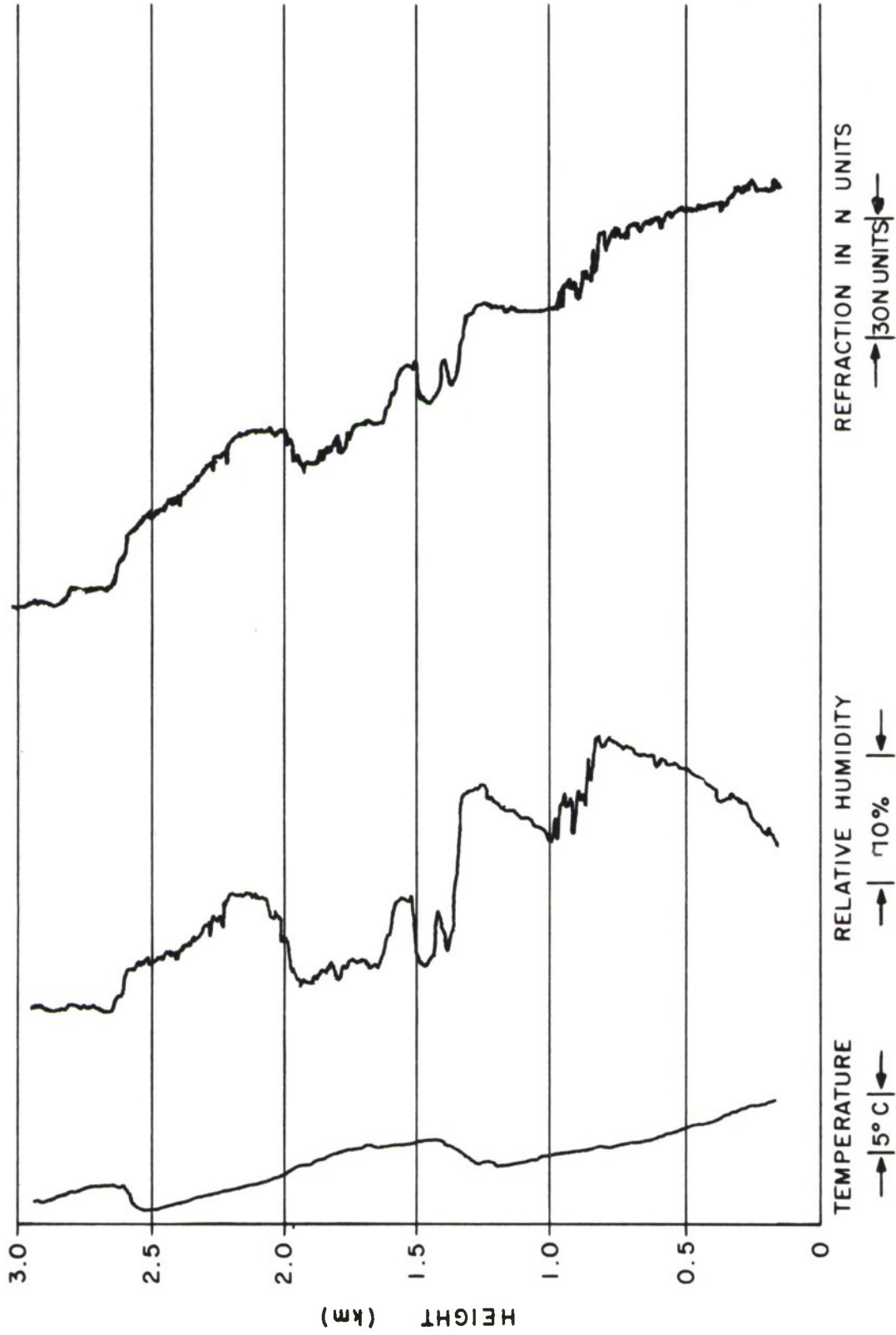


MISSION 7 - SPIRAL C

A6877

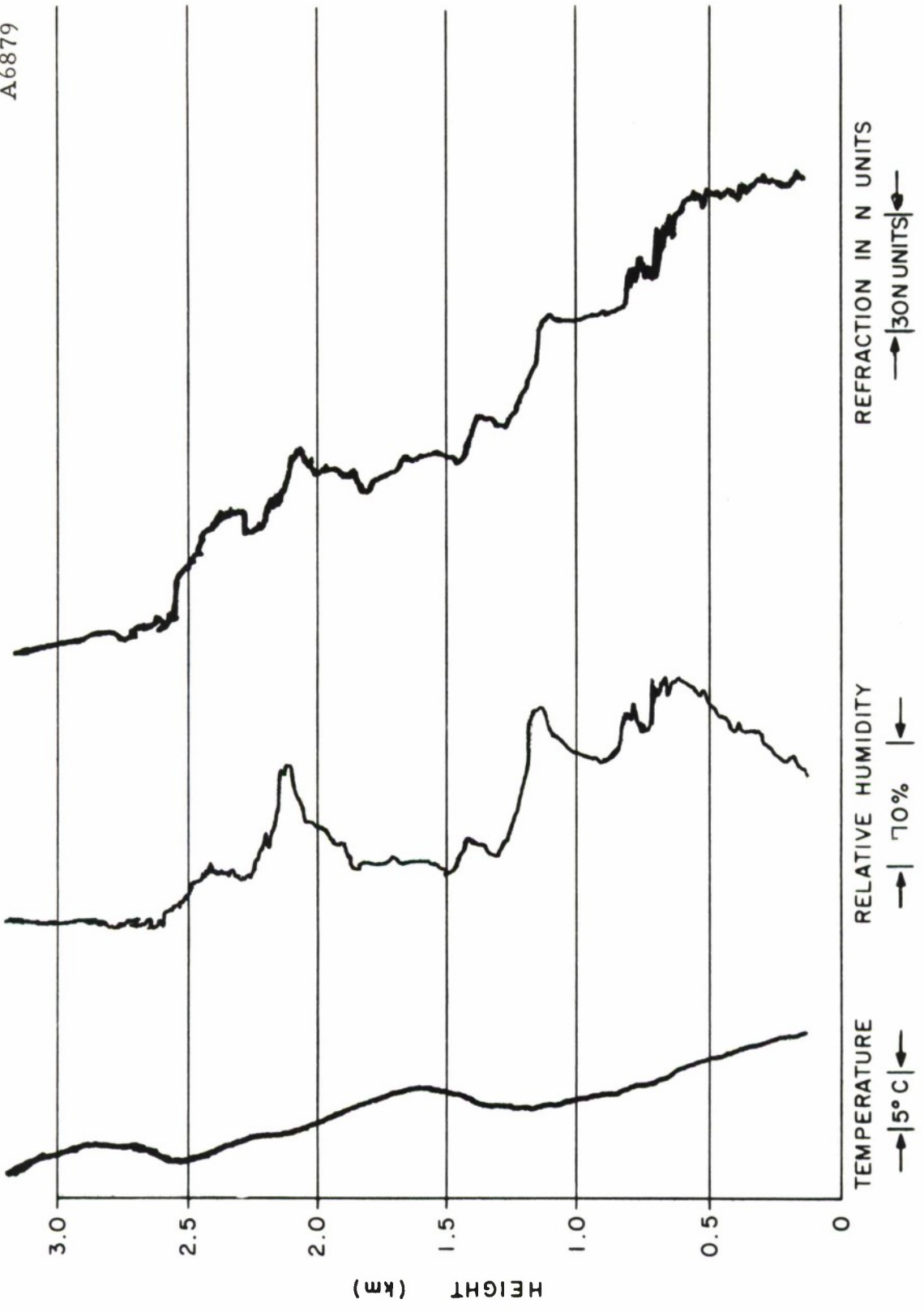


MISSION 7 - CLIMB 2

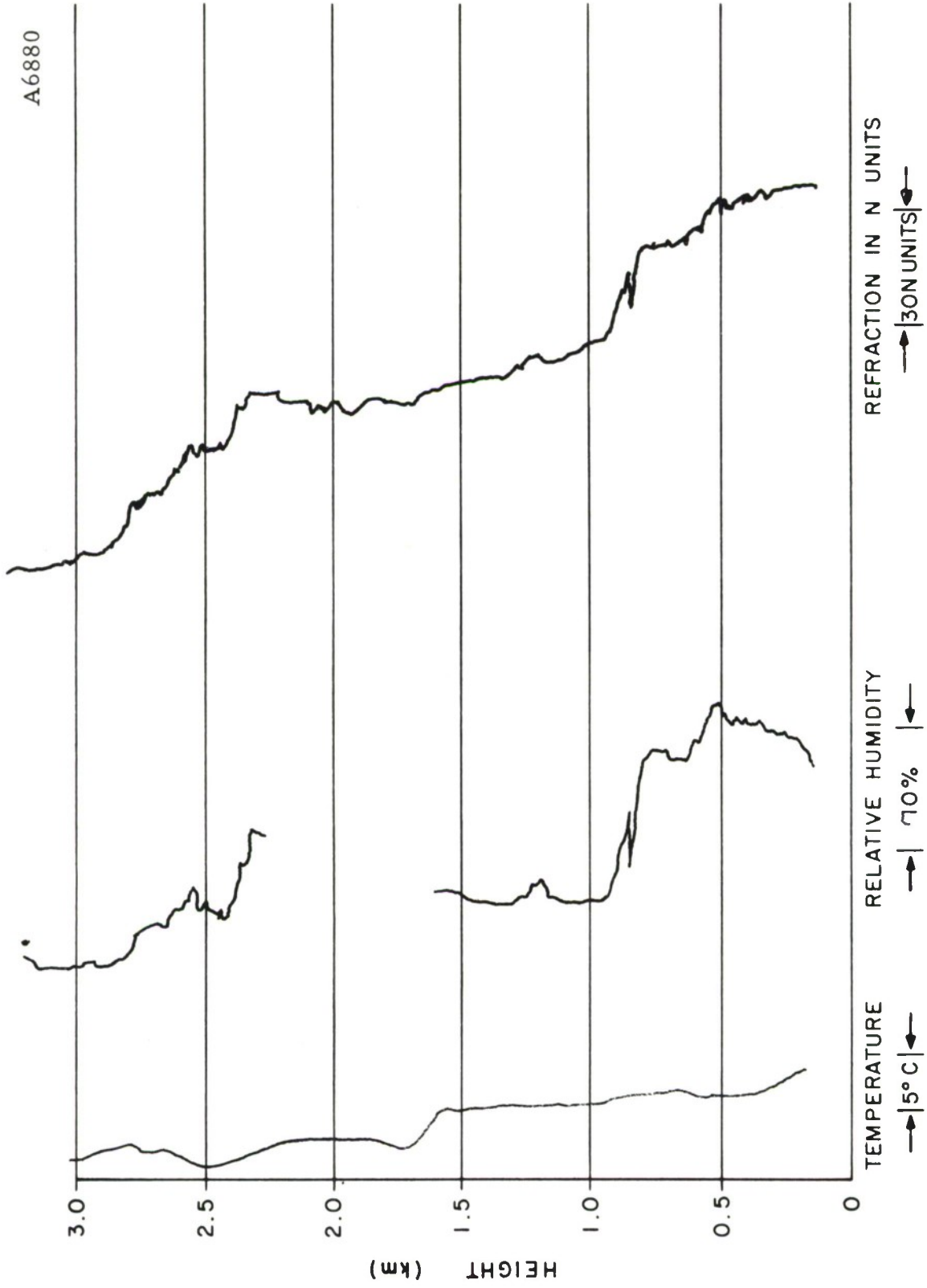


MISSION 7 - SPIRAL D

A6879

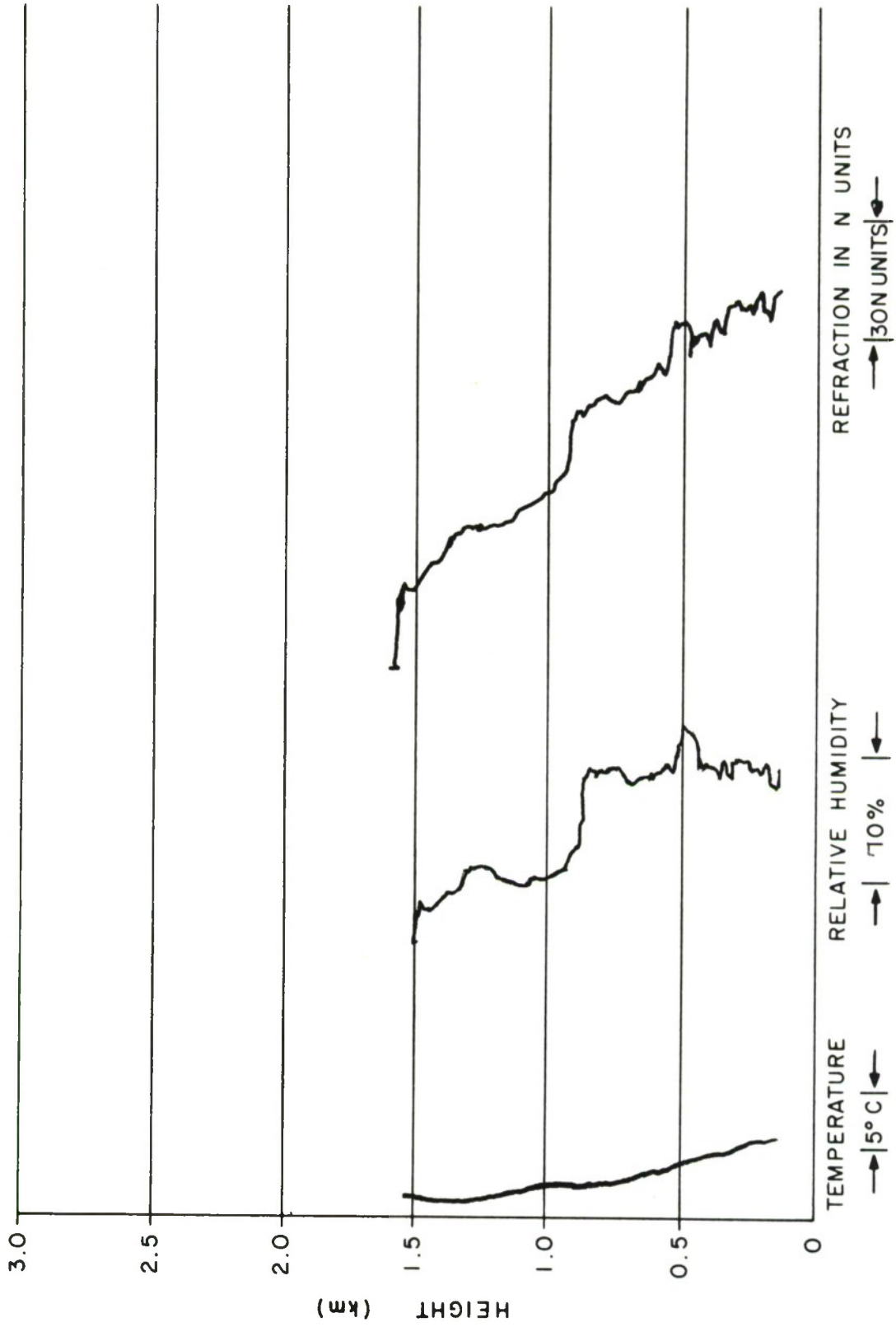


A6880

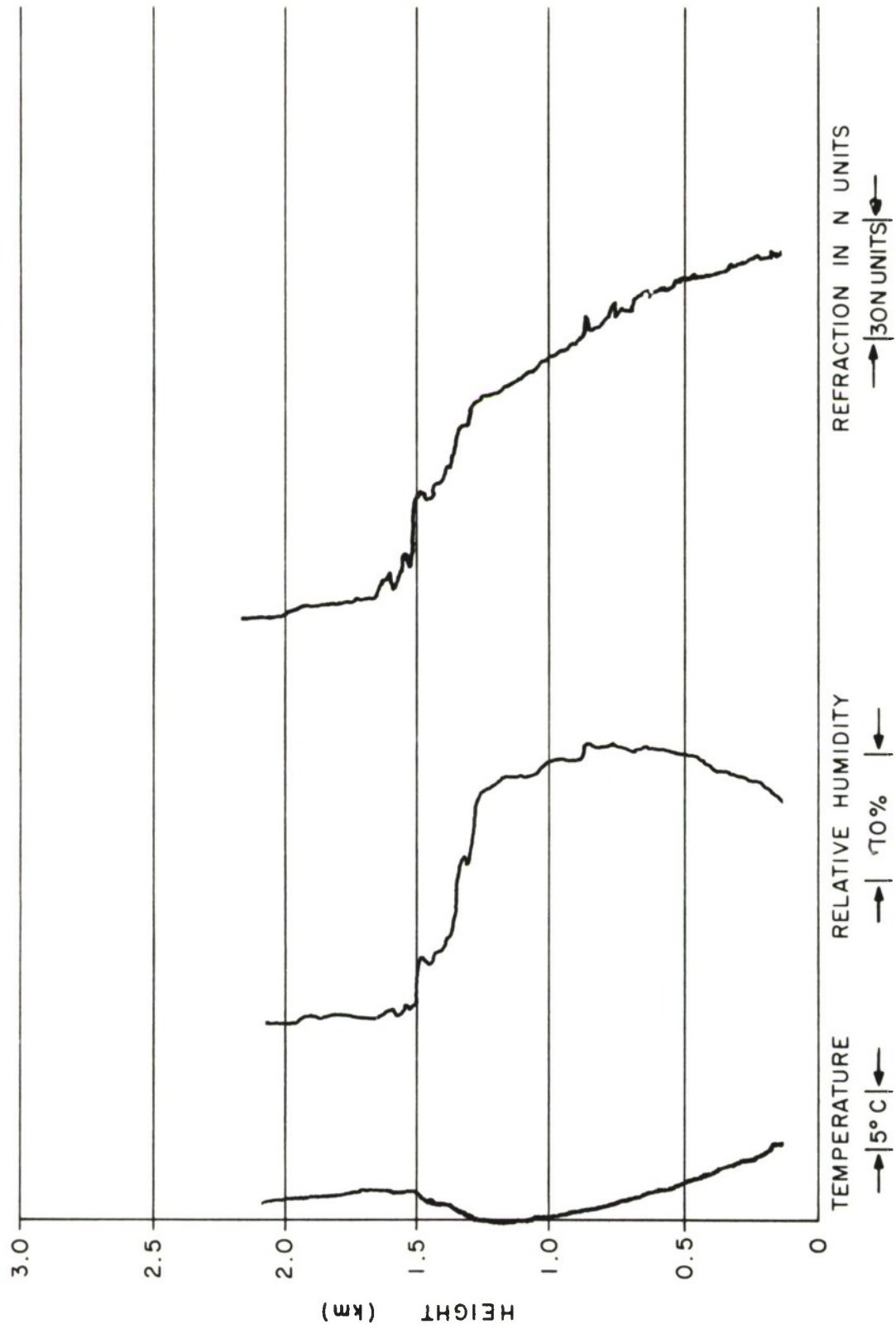


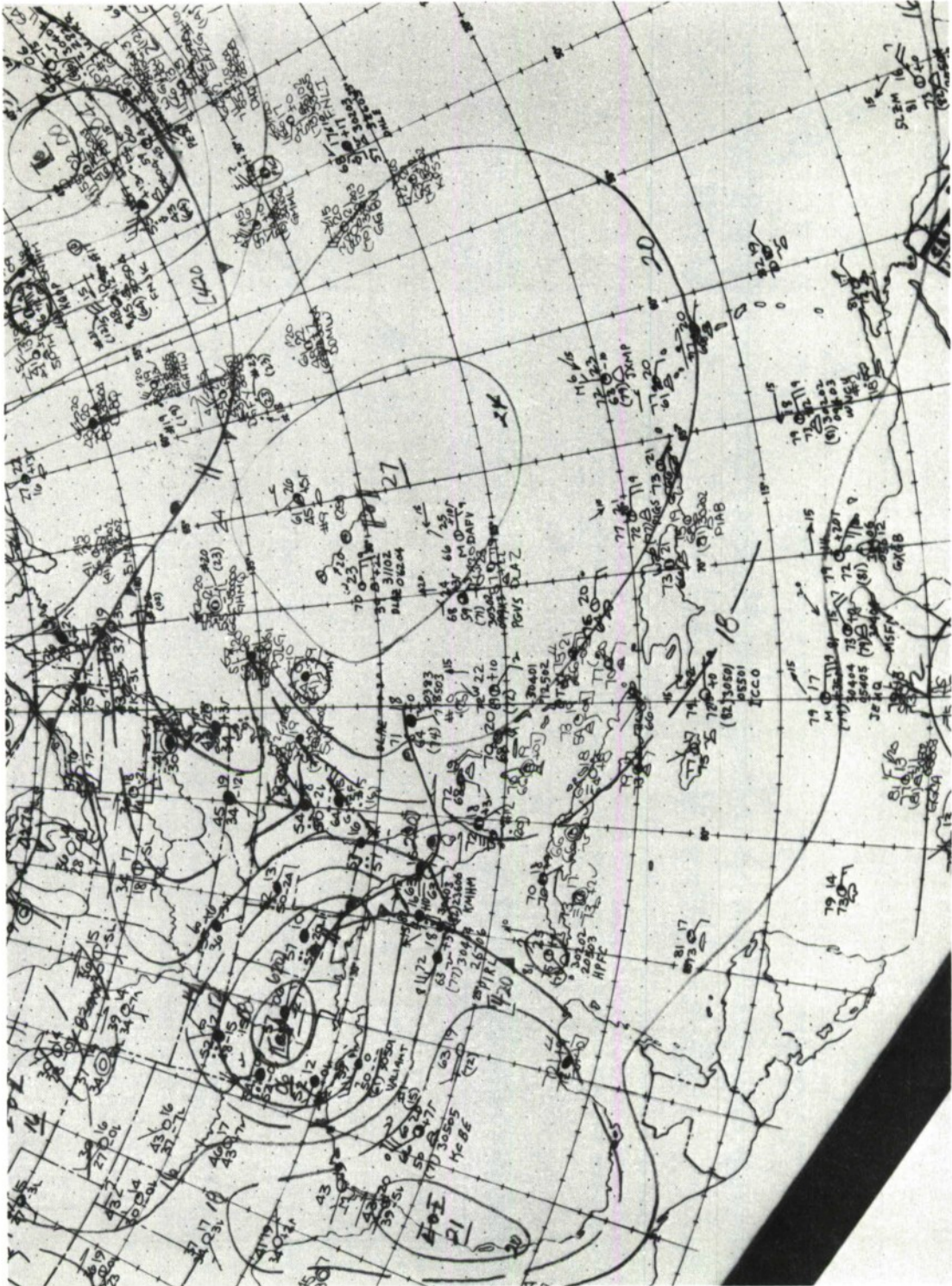
MISSION 7 - SPIRAL E

A6881



A6882





SURFACE CHART
18 March 1969

MISSION NO. 8

Date: 18 March 1969

Data were obtained on four spirals and three ascents along Flight Path VII, from Grand Turk Island to Nassau, Bahamas.

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. Grand Turk	1447	0947
B	b. 22-35 N, 73-07 W	1547	1047
Climb 1	b-c	1606	1106
C	c. 23-08 N, 74-00 W	1630	1130
Climb 2	c-d	1650	1150
D	d. 24-00 N, 75-35 W	1723	1223
Climb 3	d. Nassau	1741	1241

80883

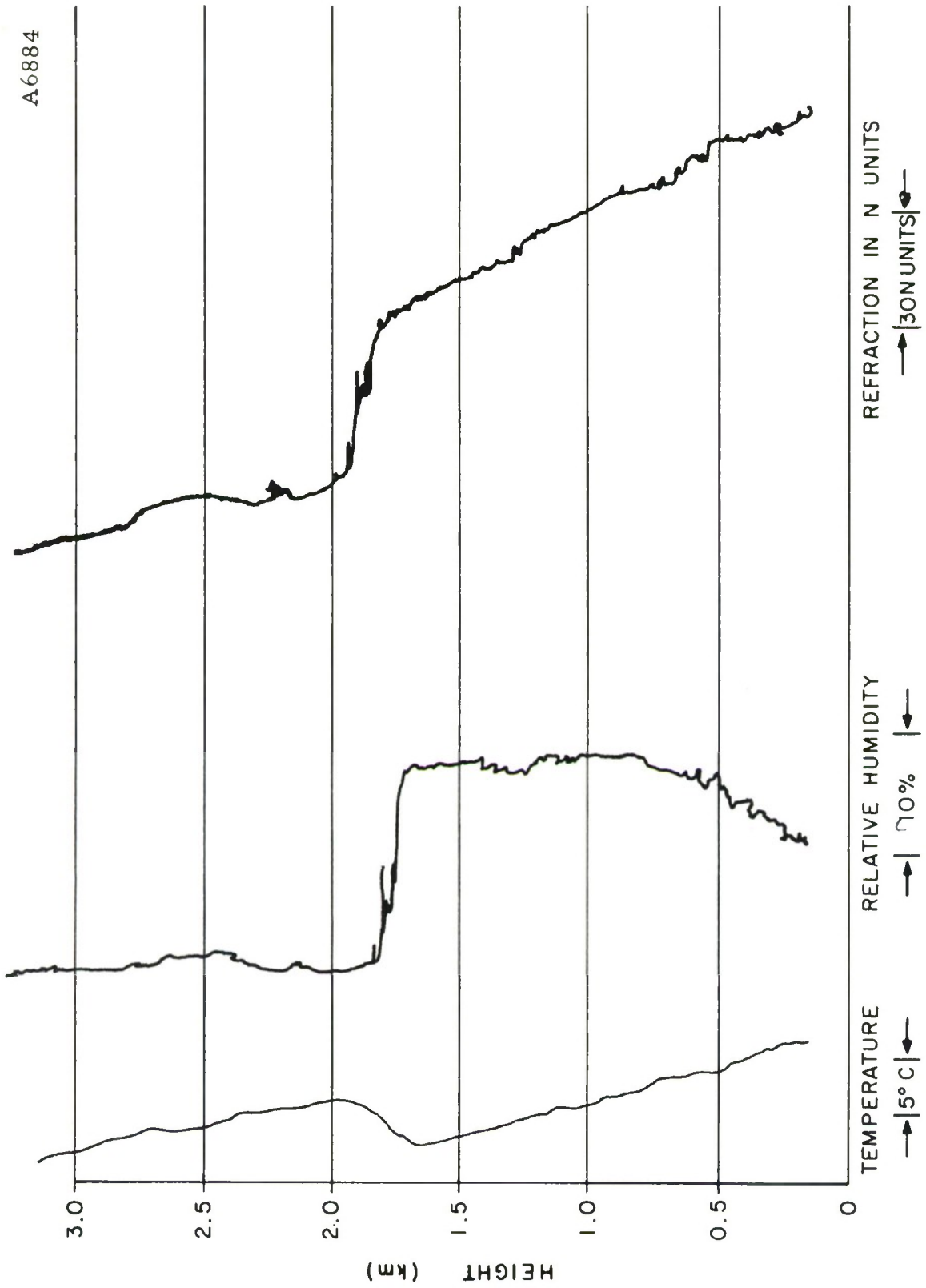


SCALE 1:5,702,400 OR 90 MILES TO 1 INCH



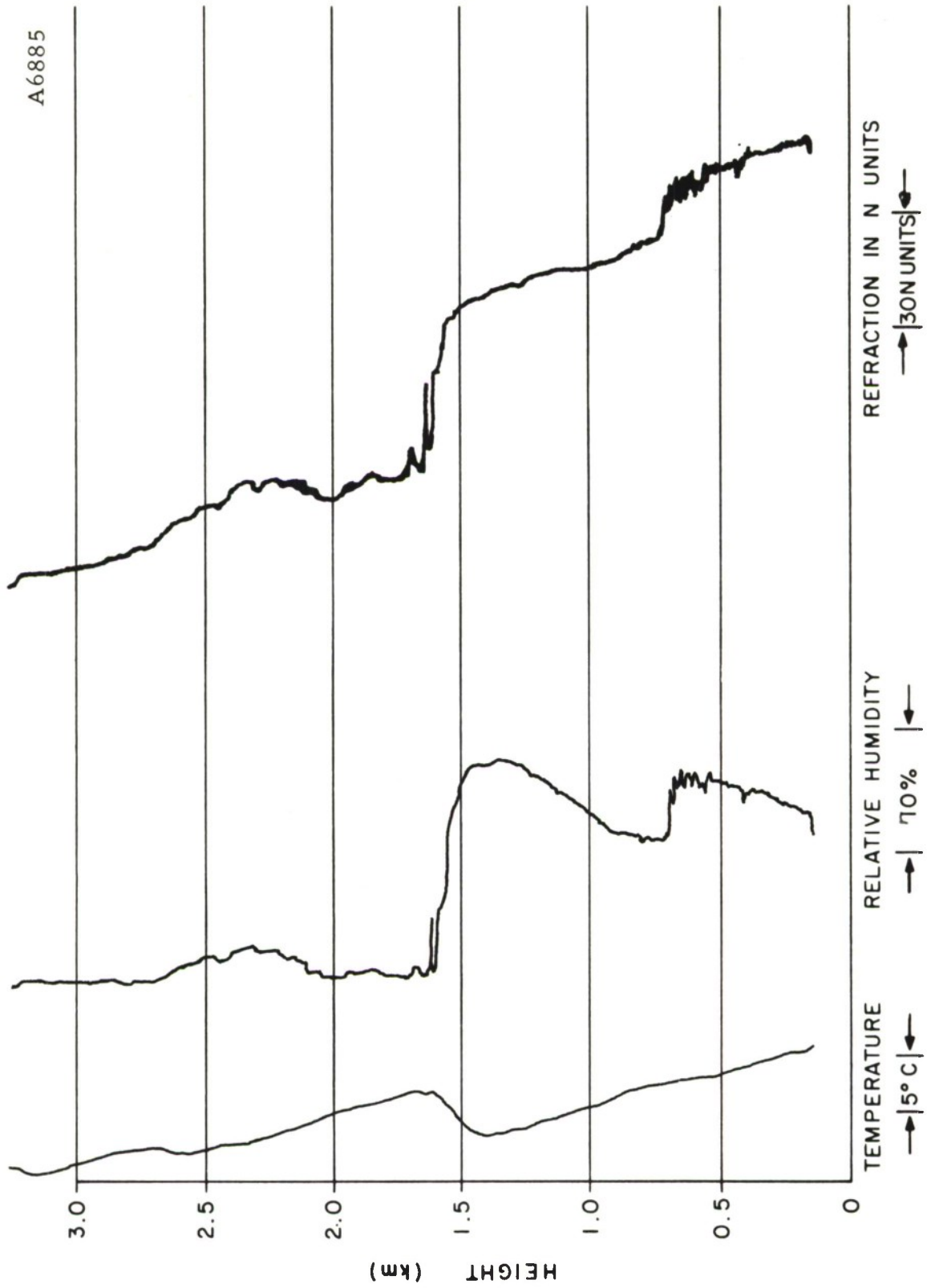
FLIGHT PATH VII
MISSION 8 - 18 MARCH 1969

A6884



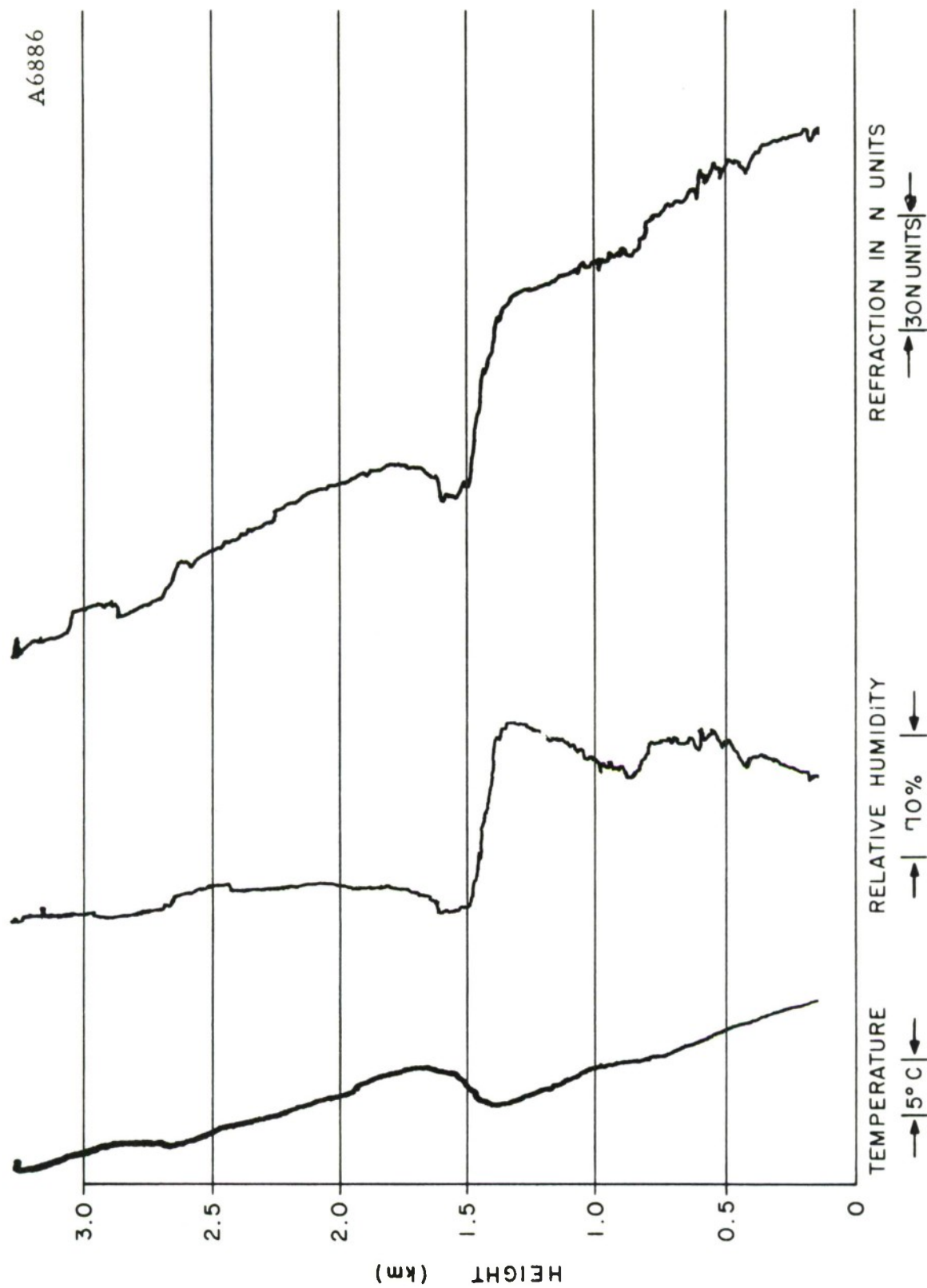
MISSION 8 - SPIRAL A

A6885



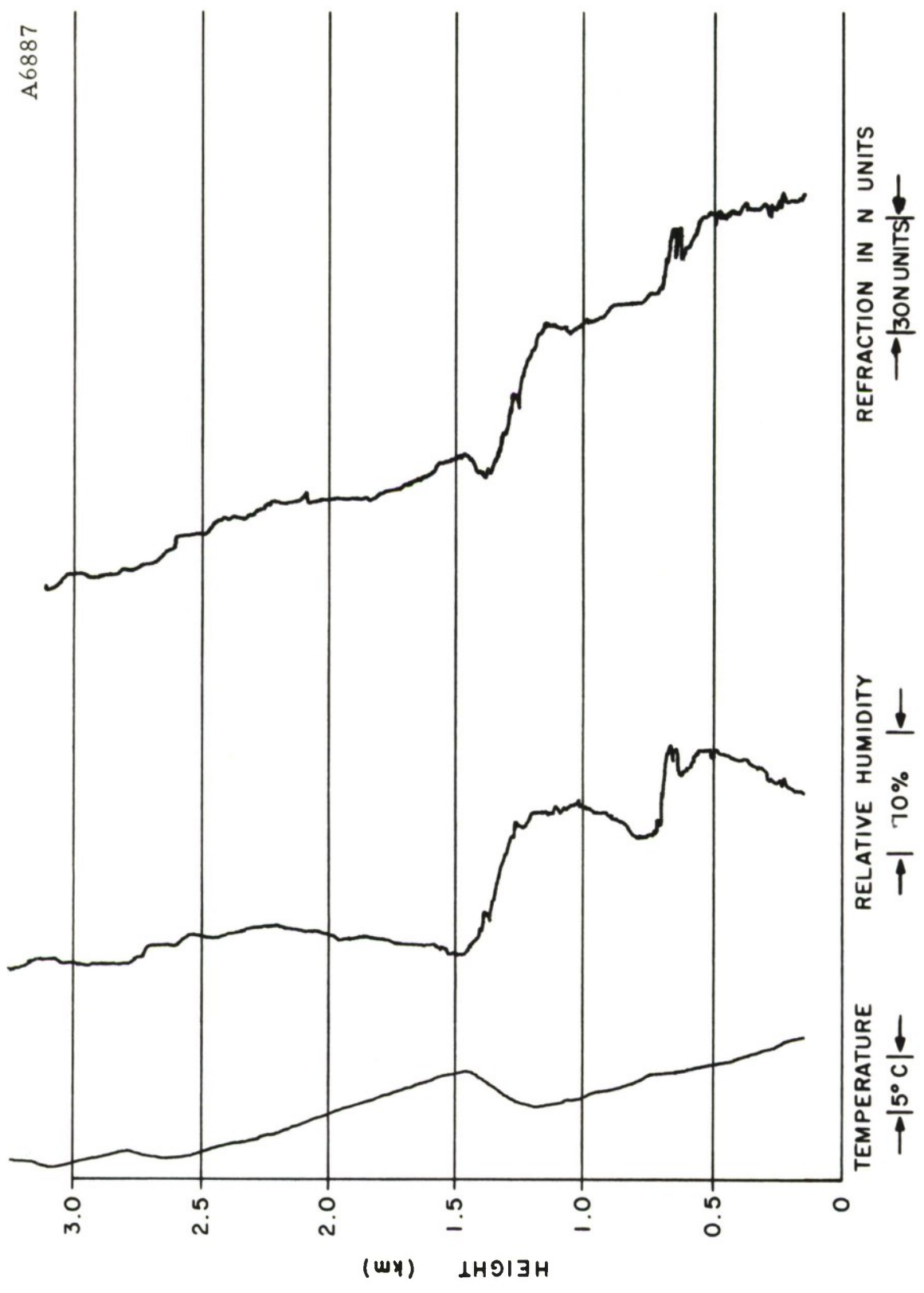
MISSION 8 - SPIRAL B

A6886

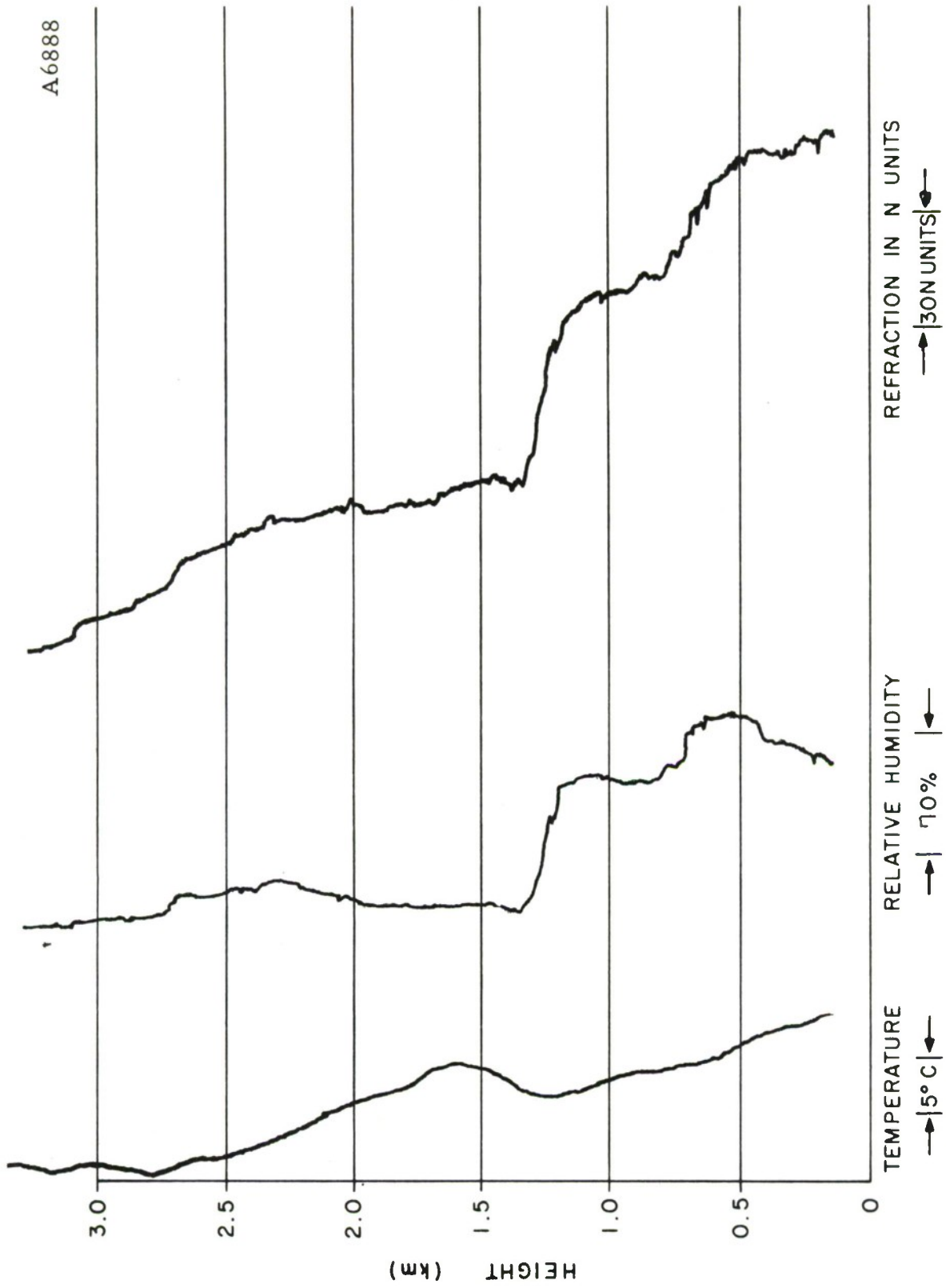


MISSION 8 - CLIMB 1

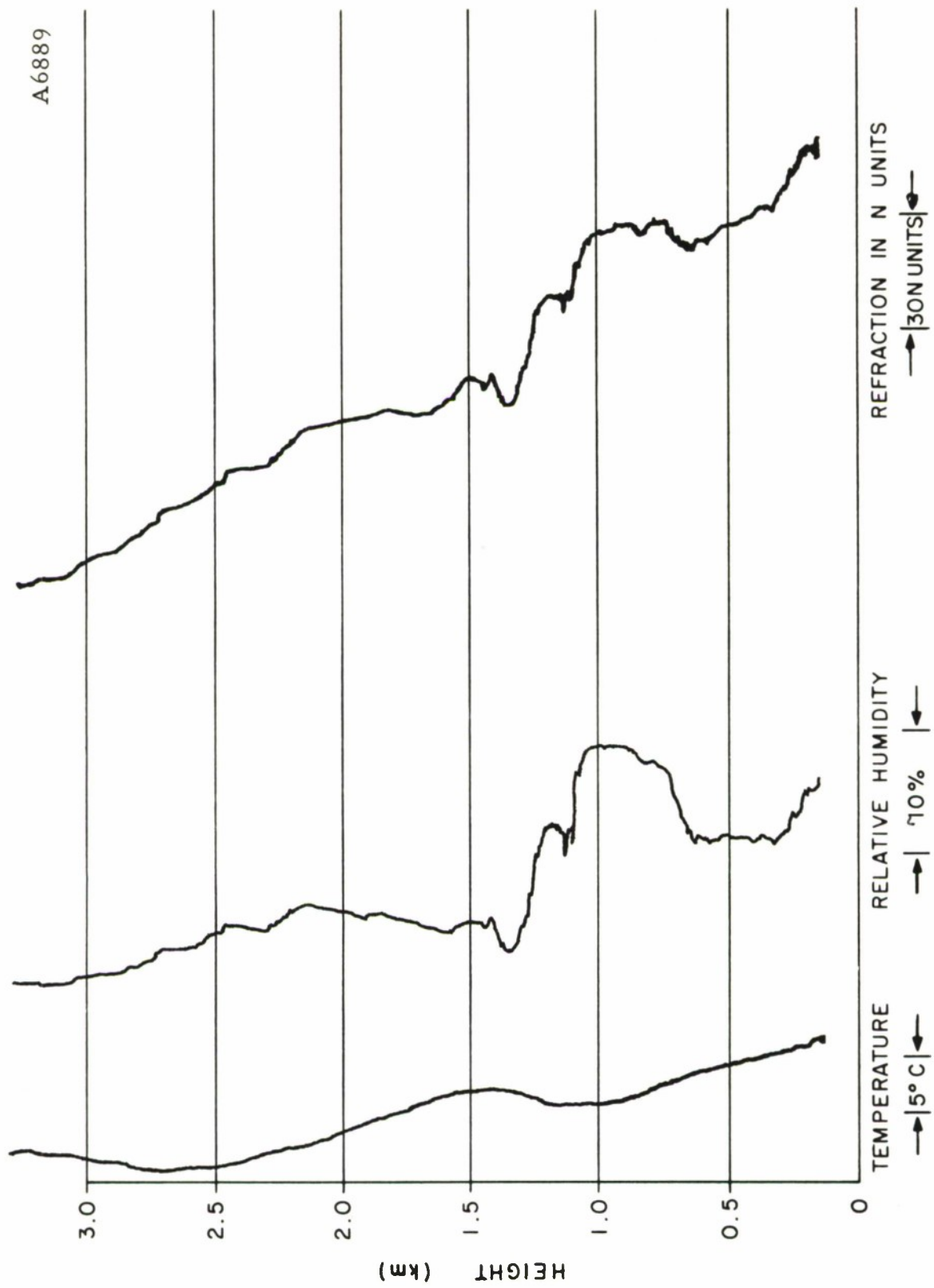
A6887



MISSION 8 - SPIRAL C

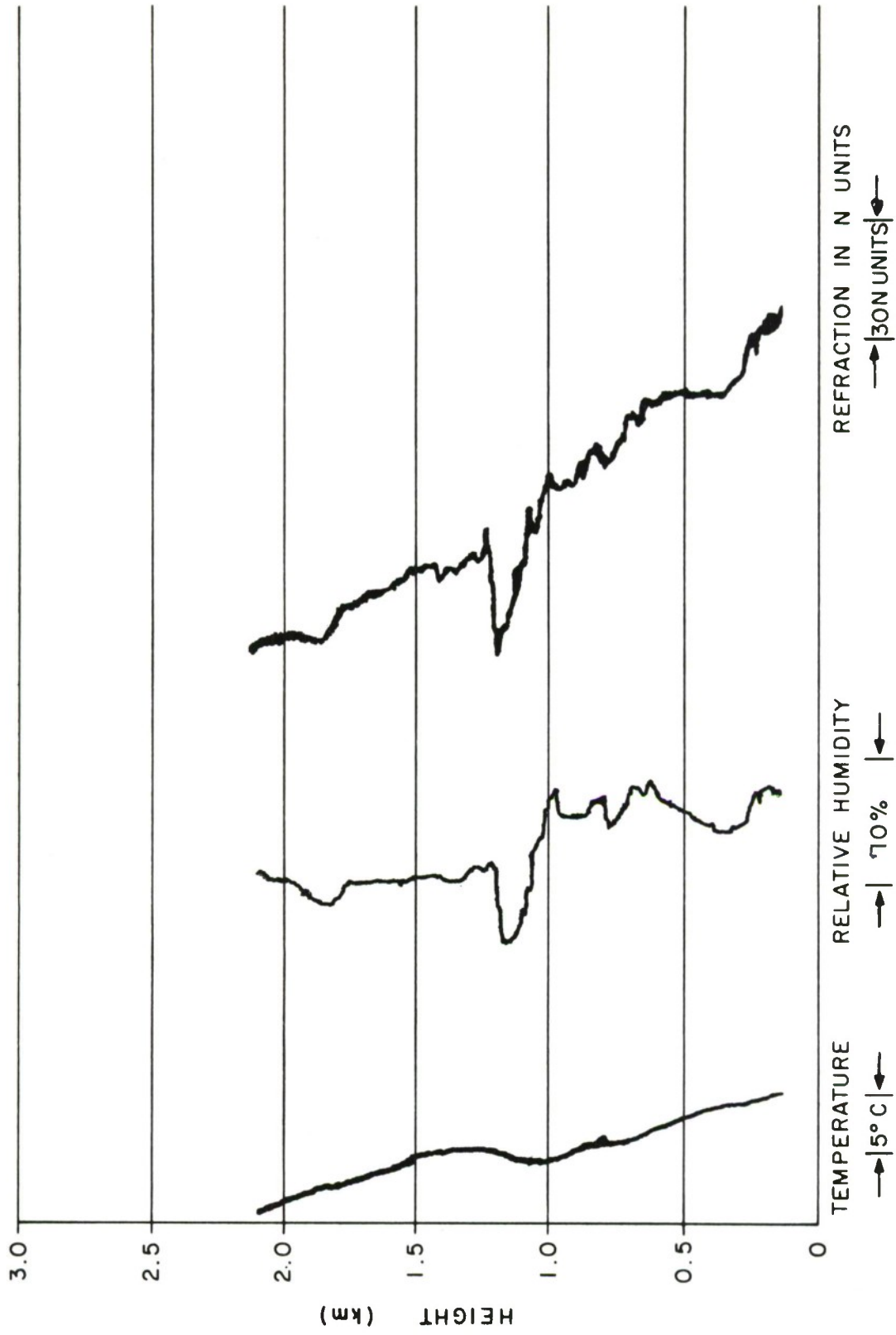


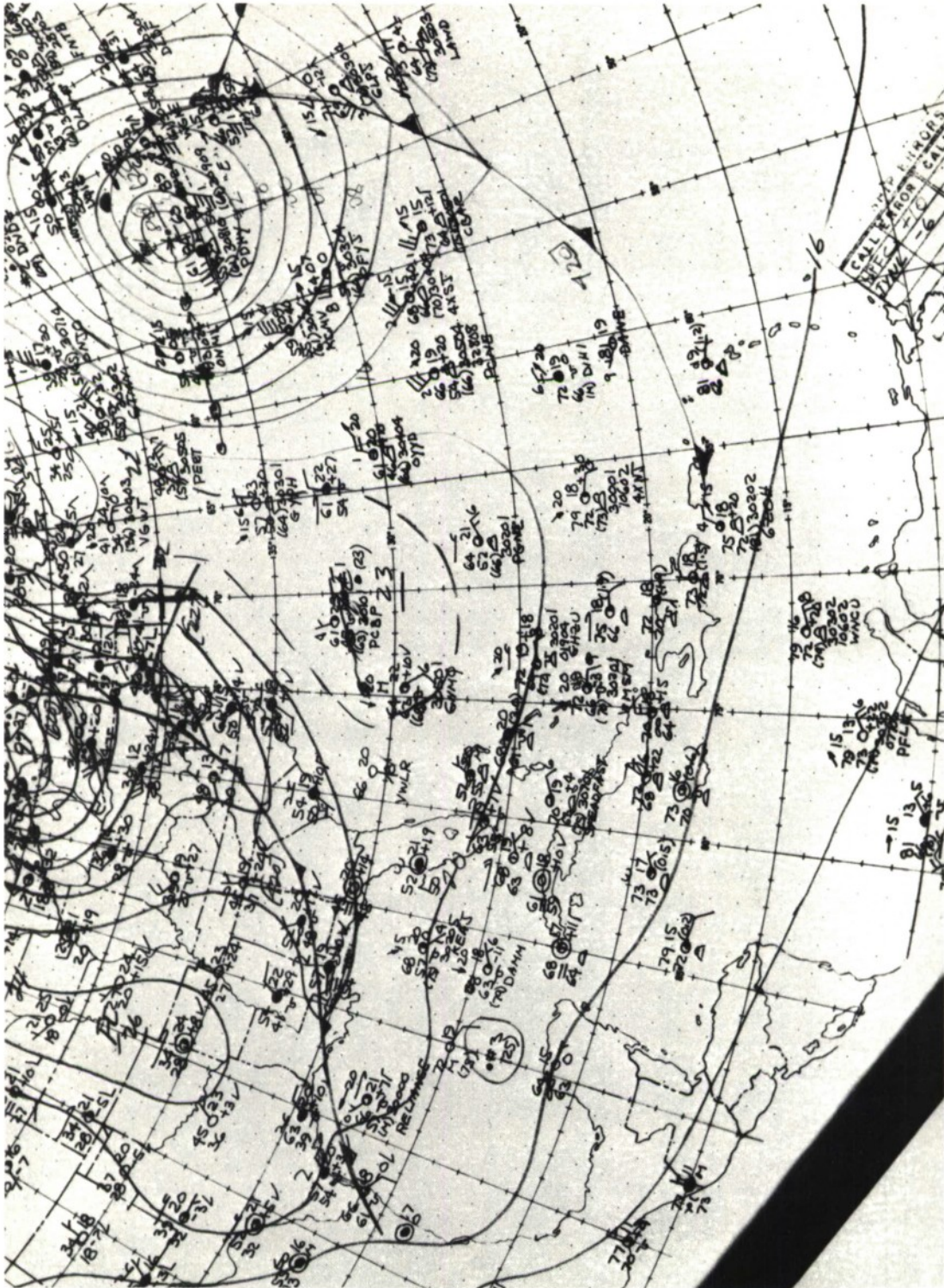
A6889



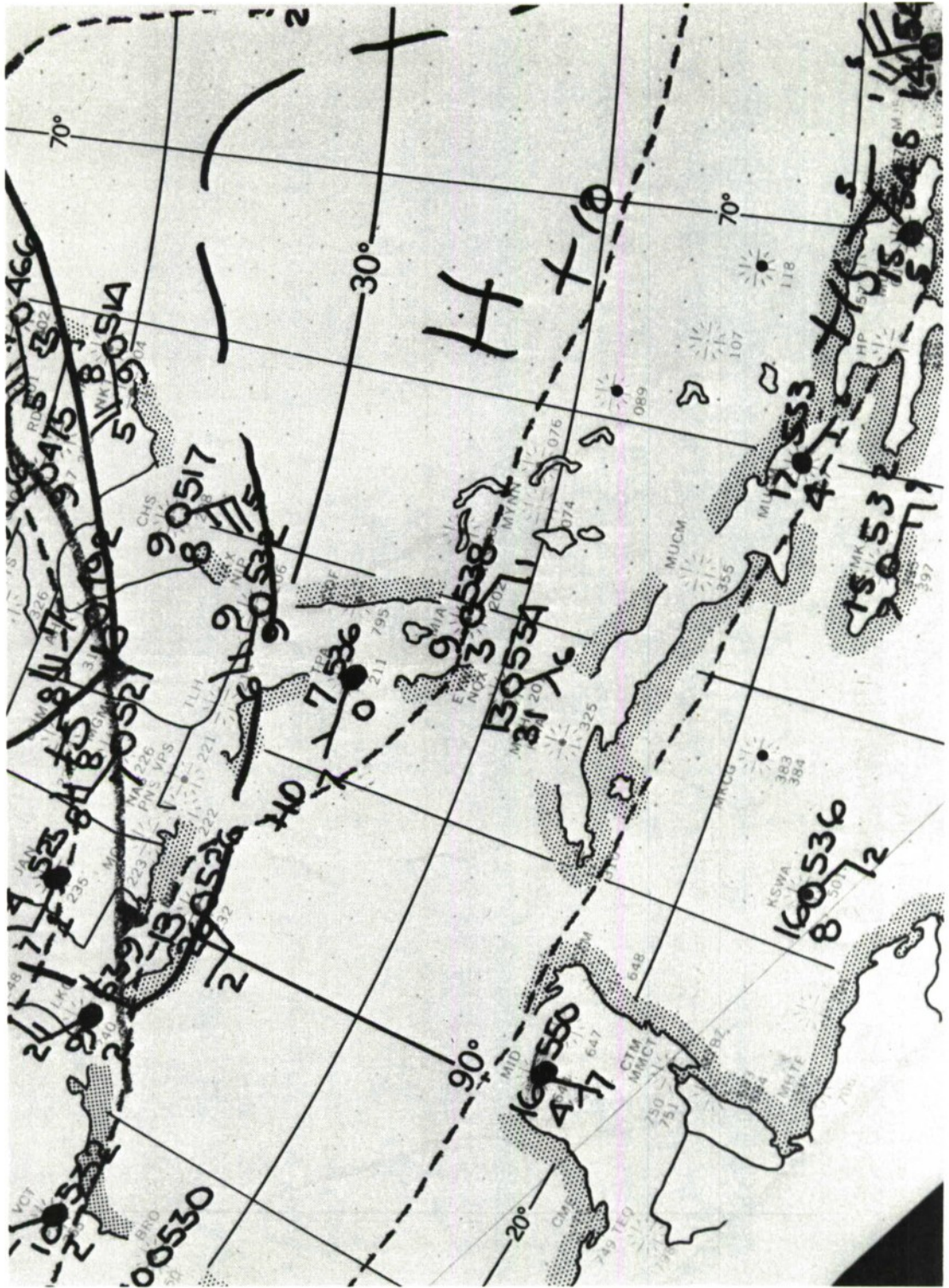
MISSION 8 - SPIRAL D

A6890





SURFACE CHART
21 March 1969



850 mb CHART
21 March 1969

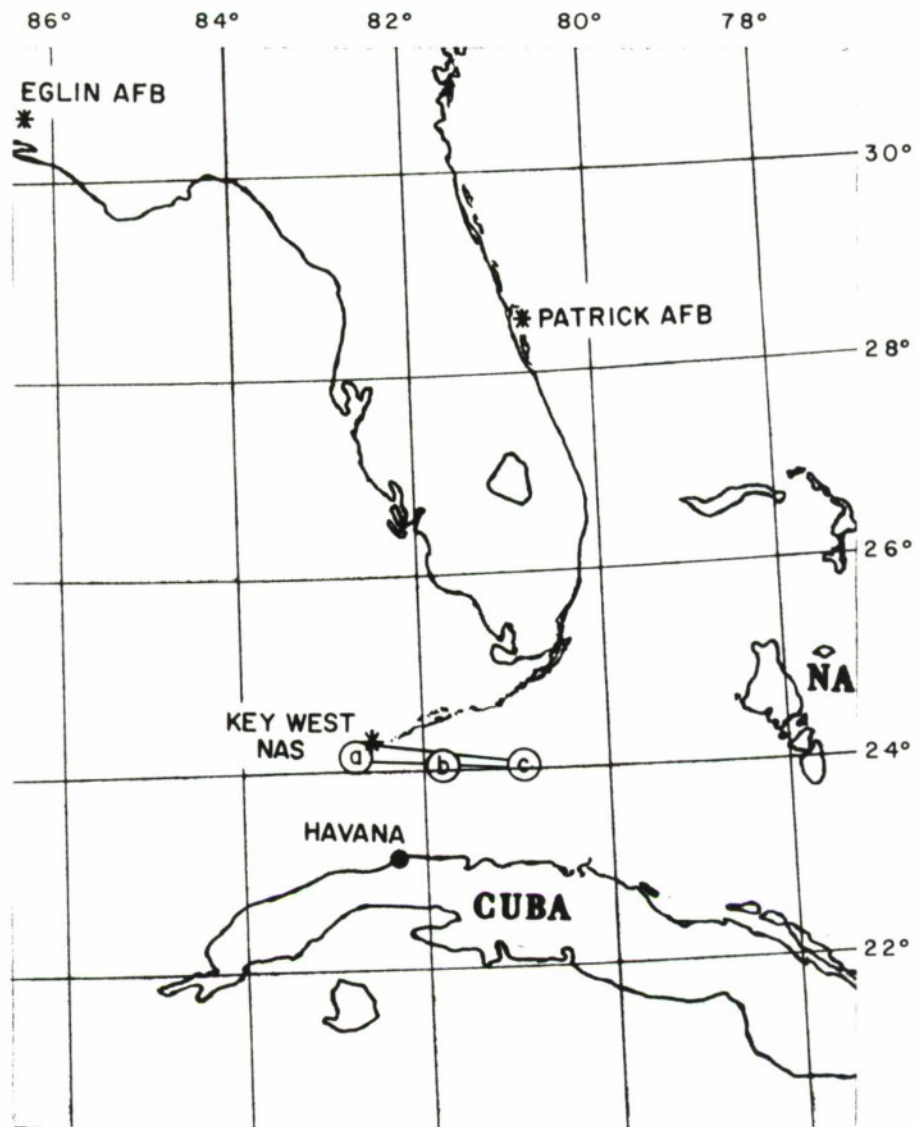
MISSION NO. 9

Date: 21 March 1969

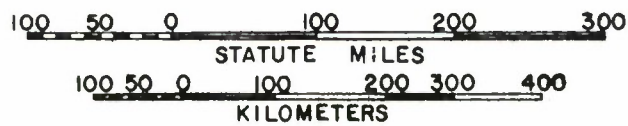
Data were obtained on three spirals and one ascent on the triangular Flight Path I out of Key West.

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. Key West	1135	0635
B	b. 24-06 N, 81-51 W	1200	0700
Climb 1	b-c	1218	0718
C	c. 24-06 N, 81-08 W	1235	0735

B 6831



SCALE 1:5,702,400 OR 90 MILES TO 1 INCH

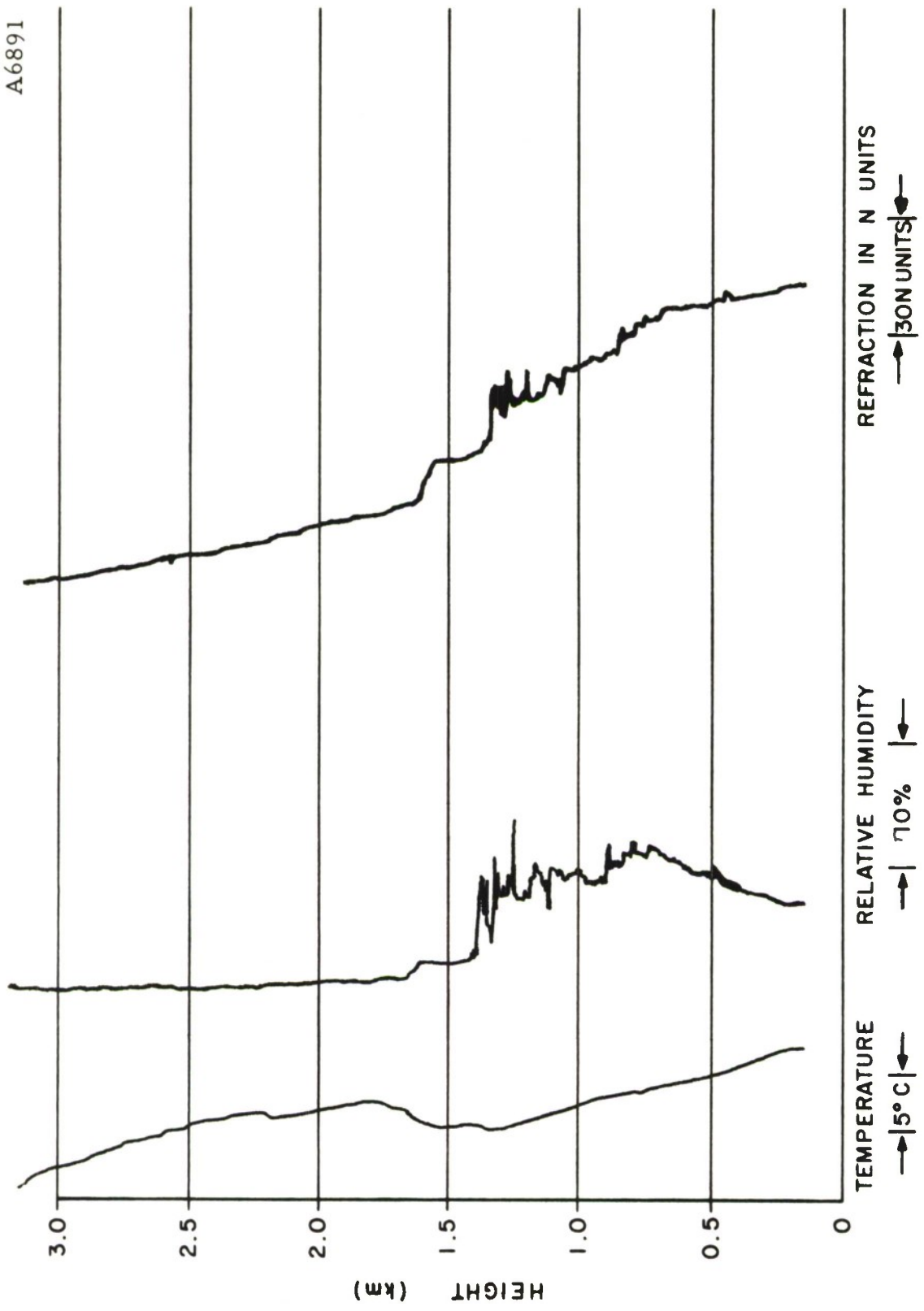


FLIGHT PATH I

MISSIONS 1 AND 2 - 6 MARCH 1969

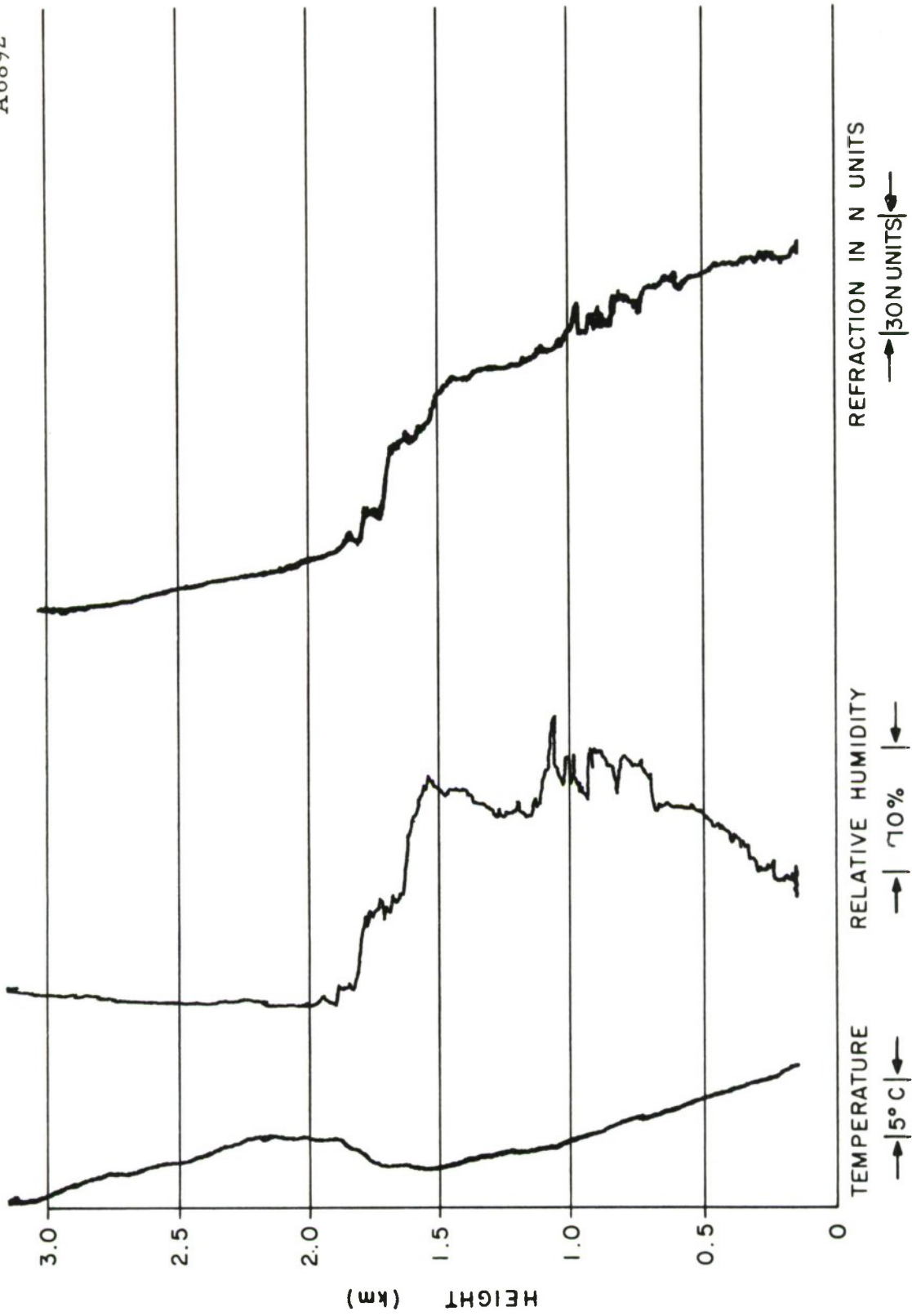
MISSIONS 9, 10, AND 11 - 21 MARCH 1969

A6891



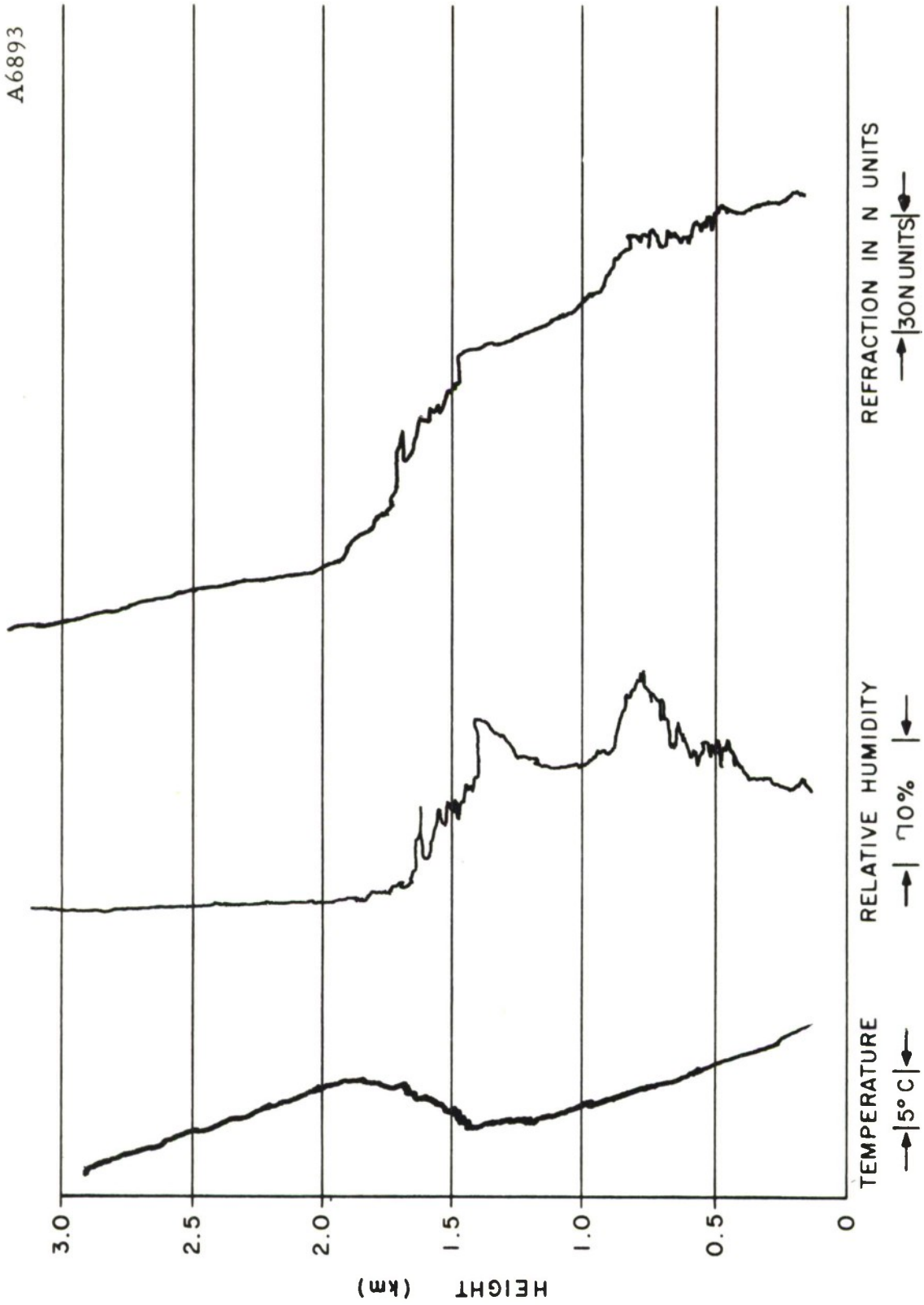
MISSION 9 - SPIRAL A

A6892



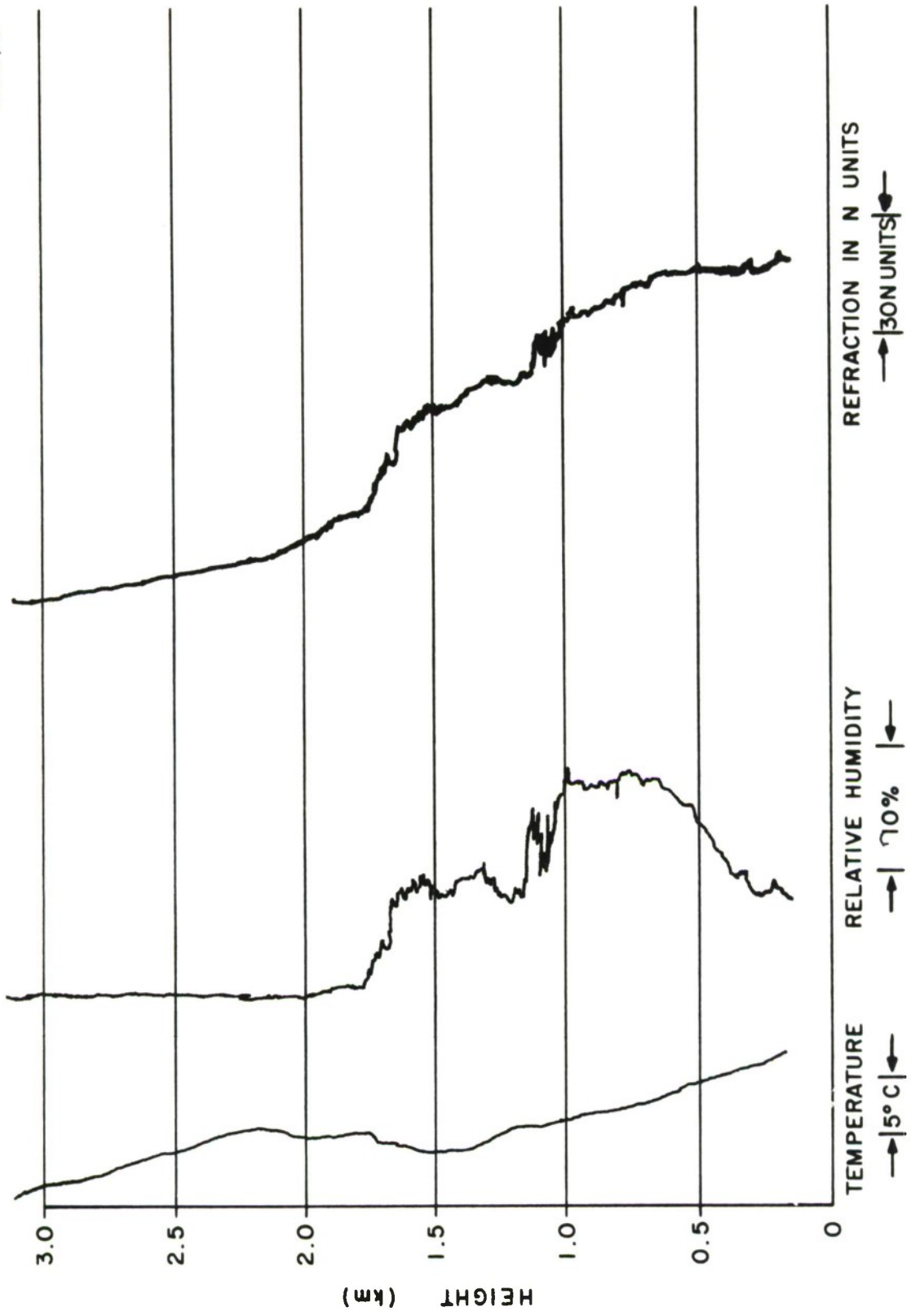
MISSION 9 - SPIRAL B

A6893



MISSION 9 - CLIMB 1

A6894



MISSION 9 - SPIRAL C

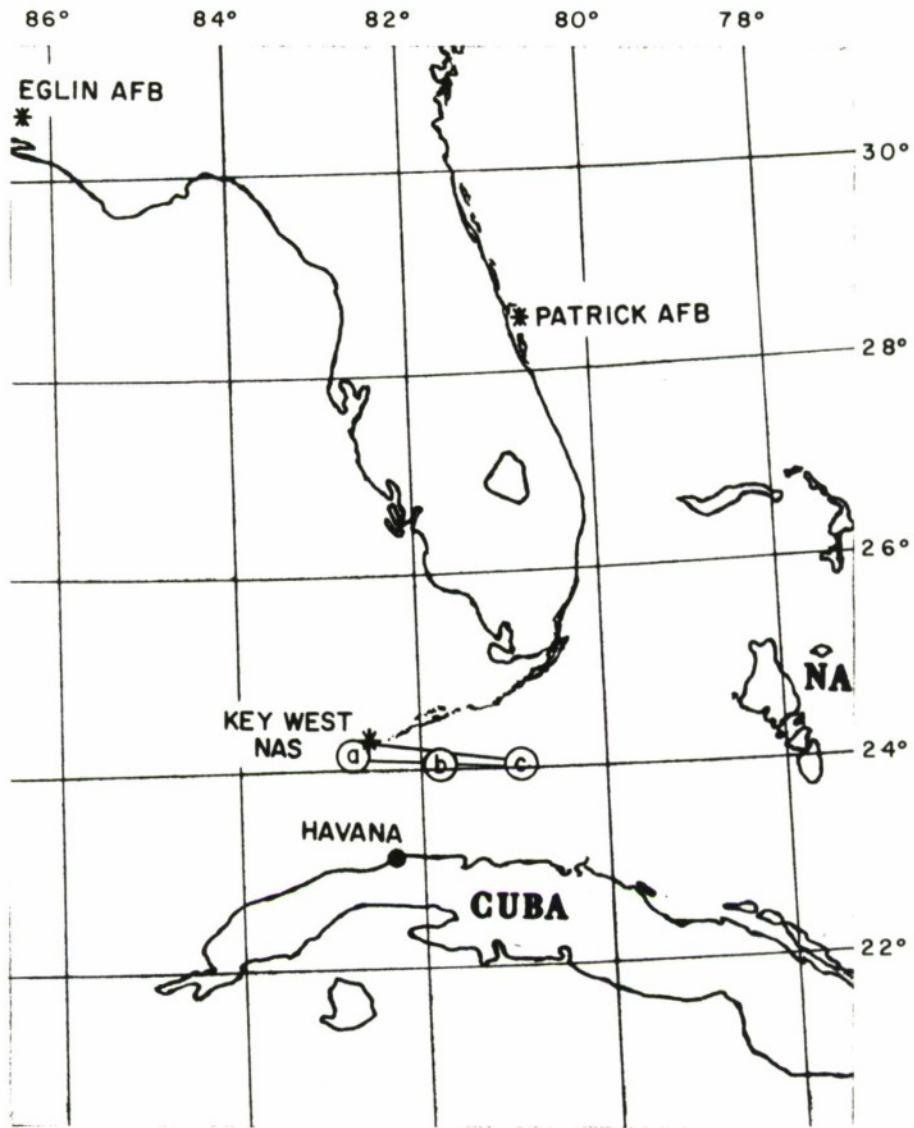
MISSION NO. 10

Date: 21 March 1969

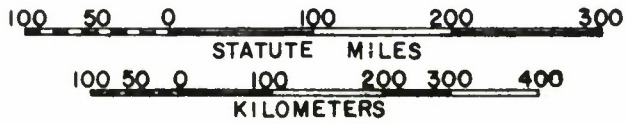
Data were obtained on three spirals and one ascent along Flight Path I.

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	b. 24-06 N, 81-51 W	1608	1108
Climb 1	b-c	1626	1126
B	c. 24-06 N, 81-08 W	1645	1145
C	a. Key West	1720	1220

86831



SCALE 1:5,702,400 OR 90 MILES TO 1 INCH

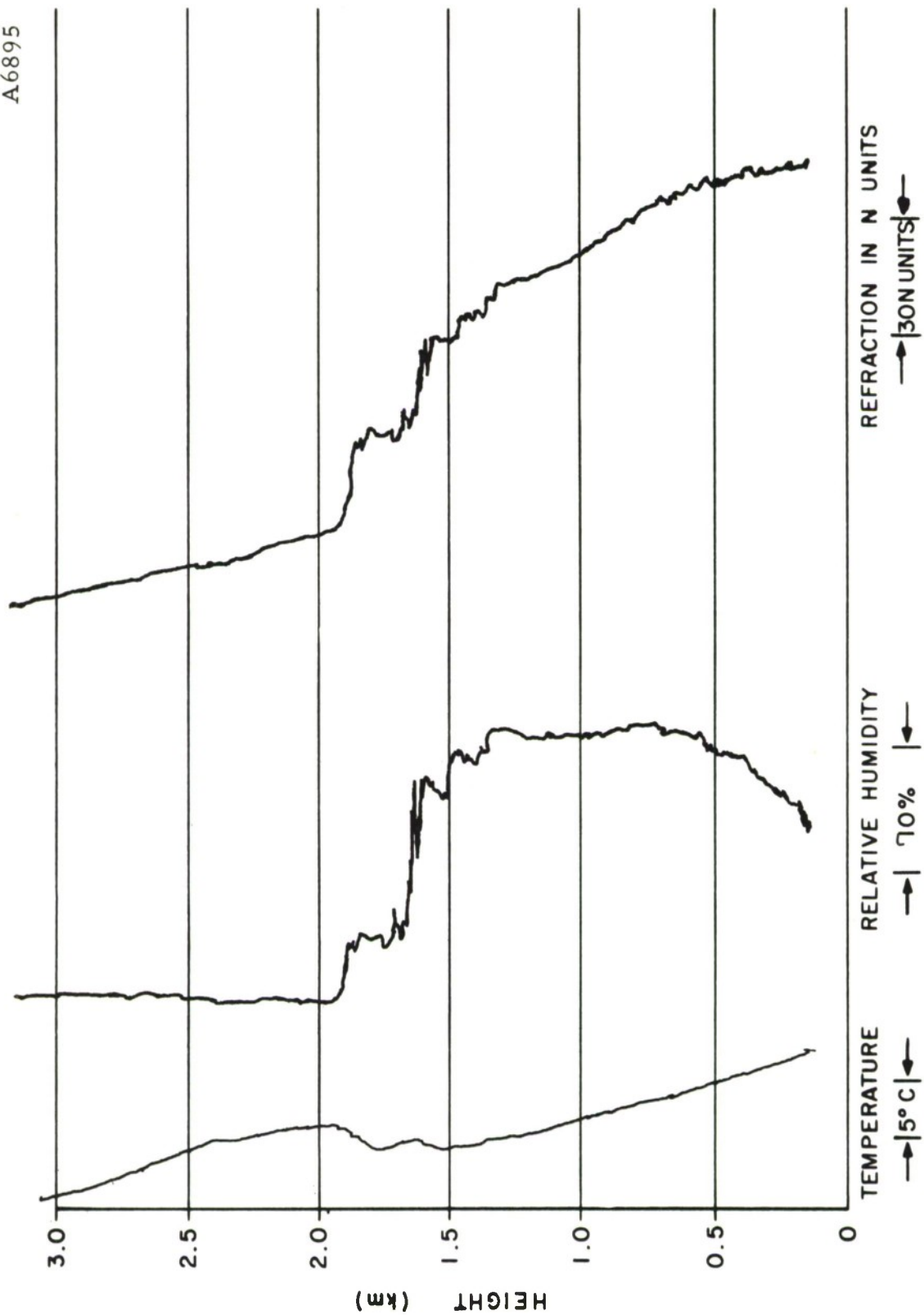


FLIGHT PATH I

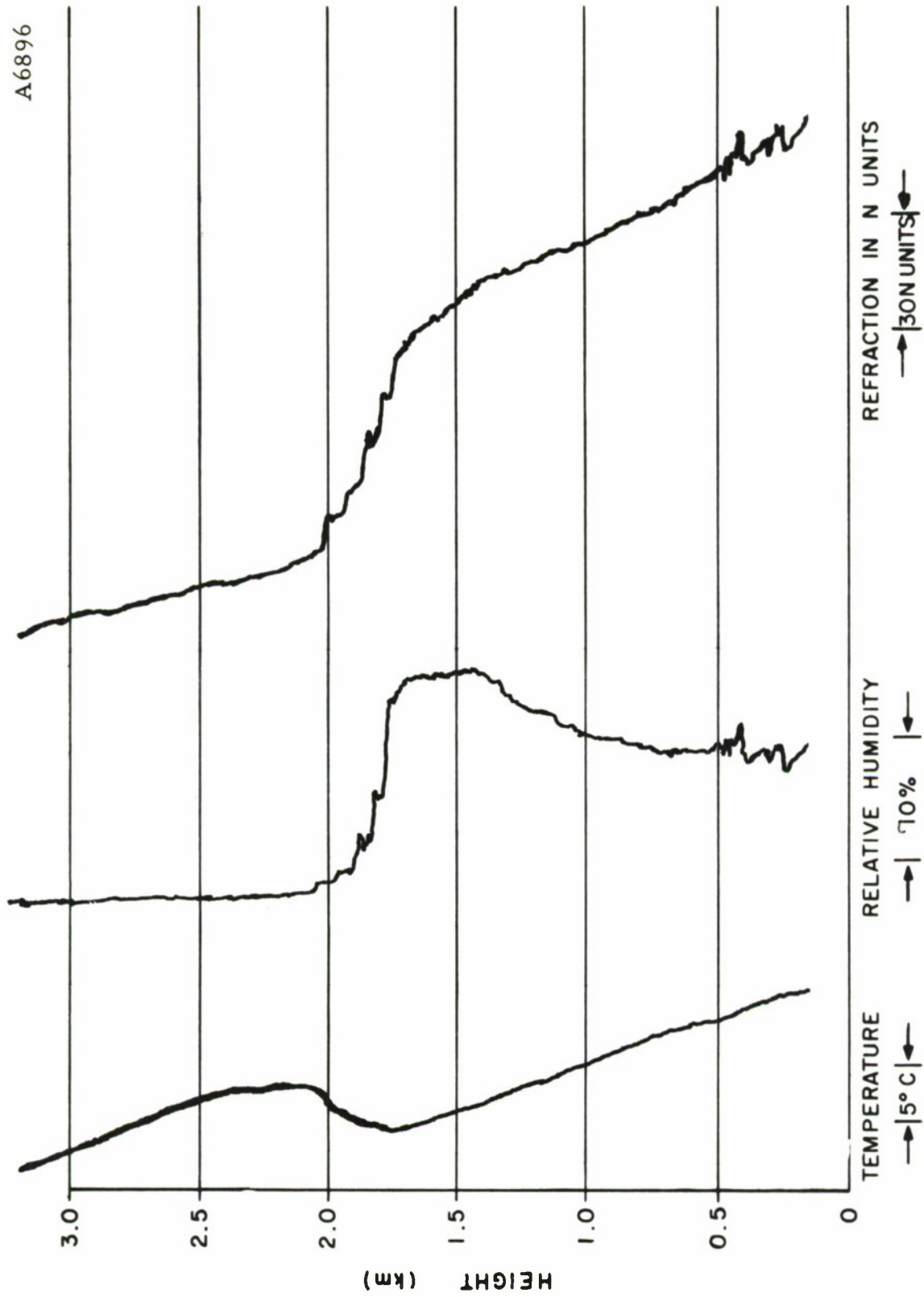
MISSIONS 1 AND 2 - 6 MARCH 1969

MISSIONS 9, 10, AND 11 - 21 MARCH 1969

A6895

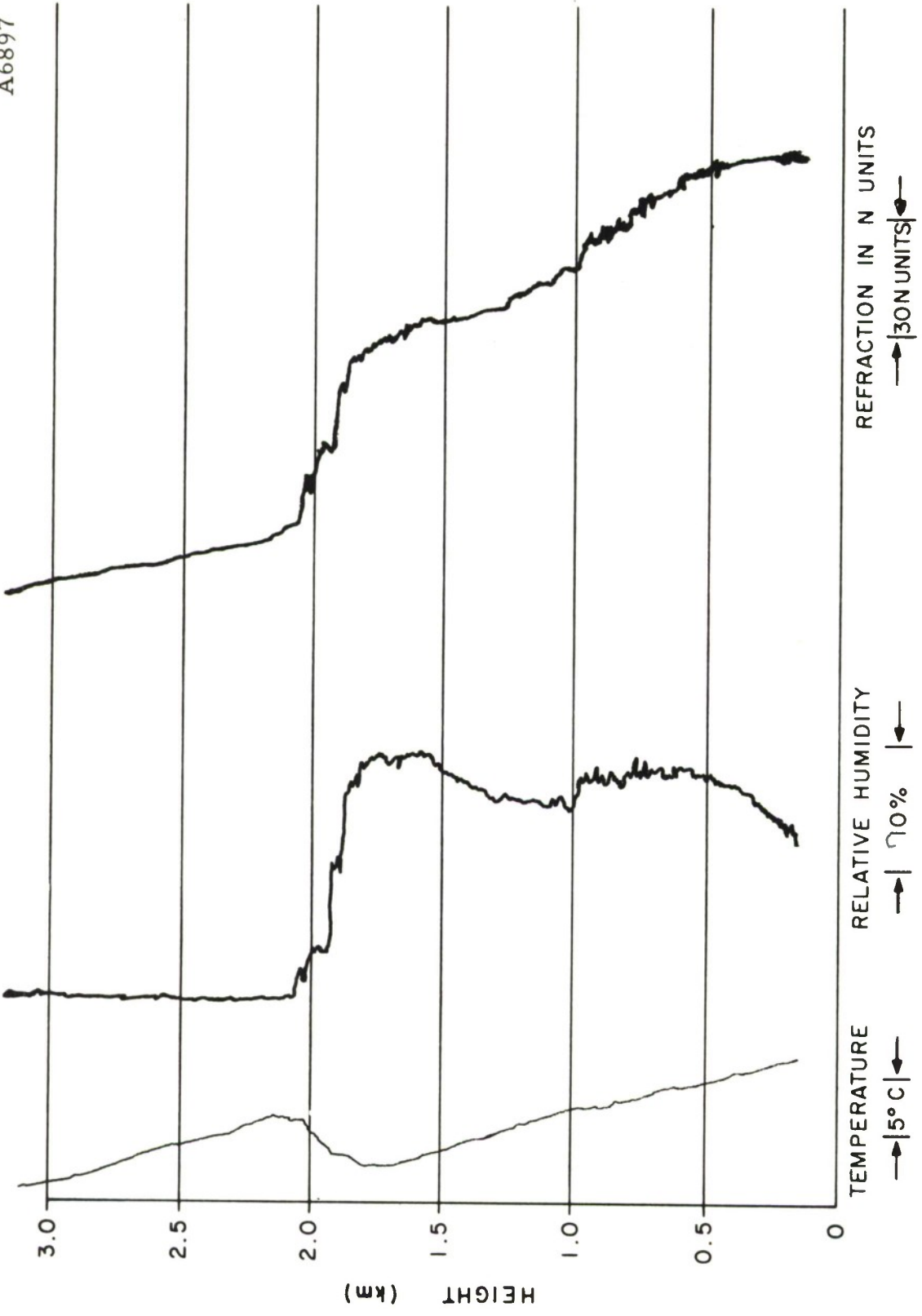


A6896



MISSION 10 - CLIMB 1

A6897



MISSION 10 - SPIRAL B

MISSION NO. 11

Date: 21 March 1969

Data were obtained on three spirals and one ascent along Flight Path I.

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	b. 24-06 N, 81-51 W	2159	1659
Climb 1	b-c	2216	1716
B	c. 24-06 N, 81-08 W	2233	1733
C	a. Key West	2318	1818

B 6831



SCALE 1:5,702,400 OR 90 MILES TO 1 INCH

100 50 0 100 200 300

STATUTE MILES

100 50 0 100 200 300 400

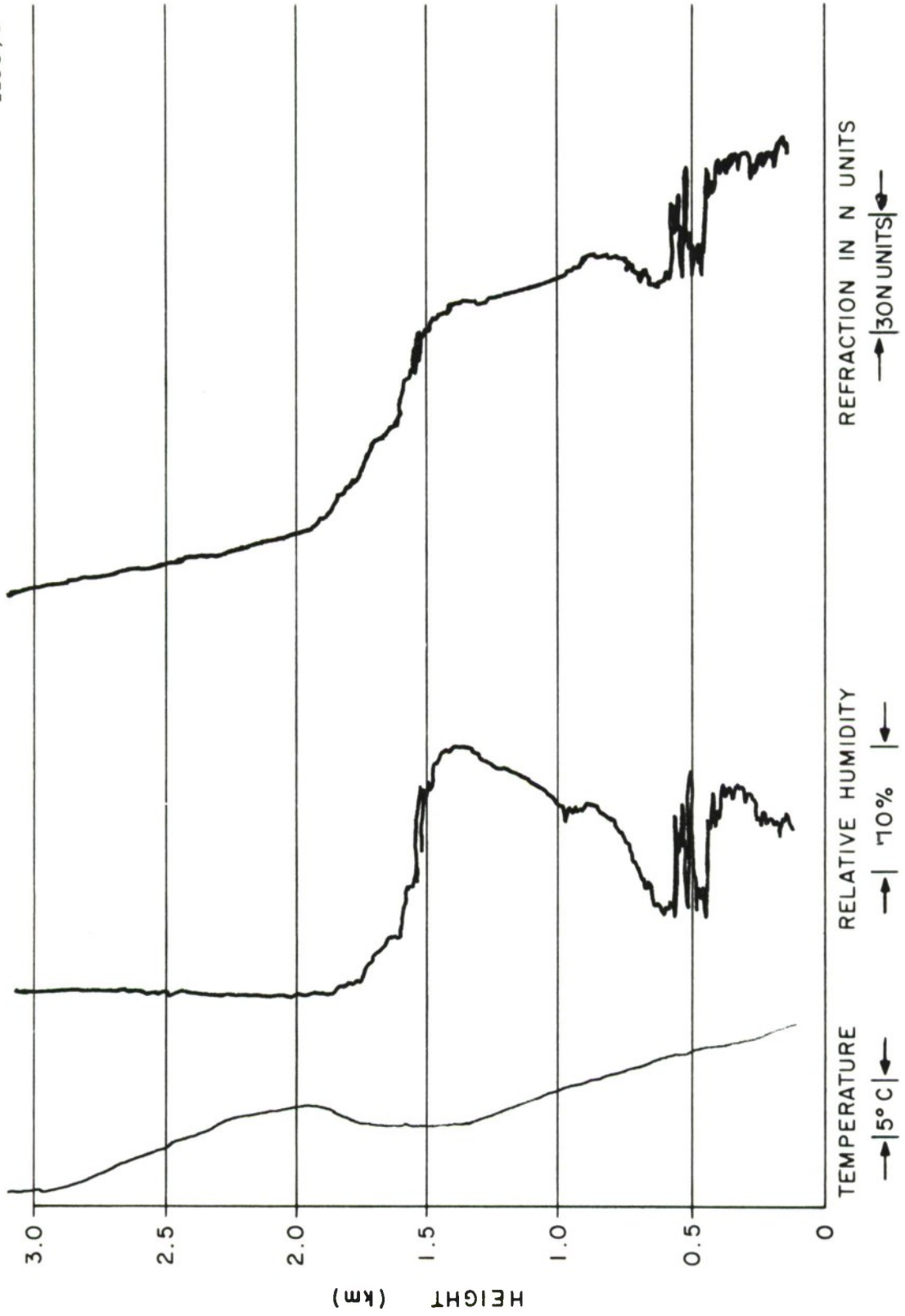
KILOMETERS

FLIGHT PATH I

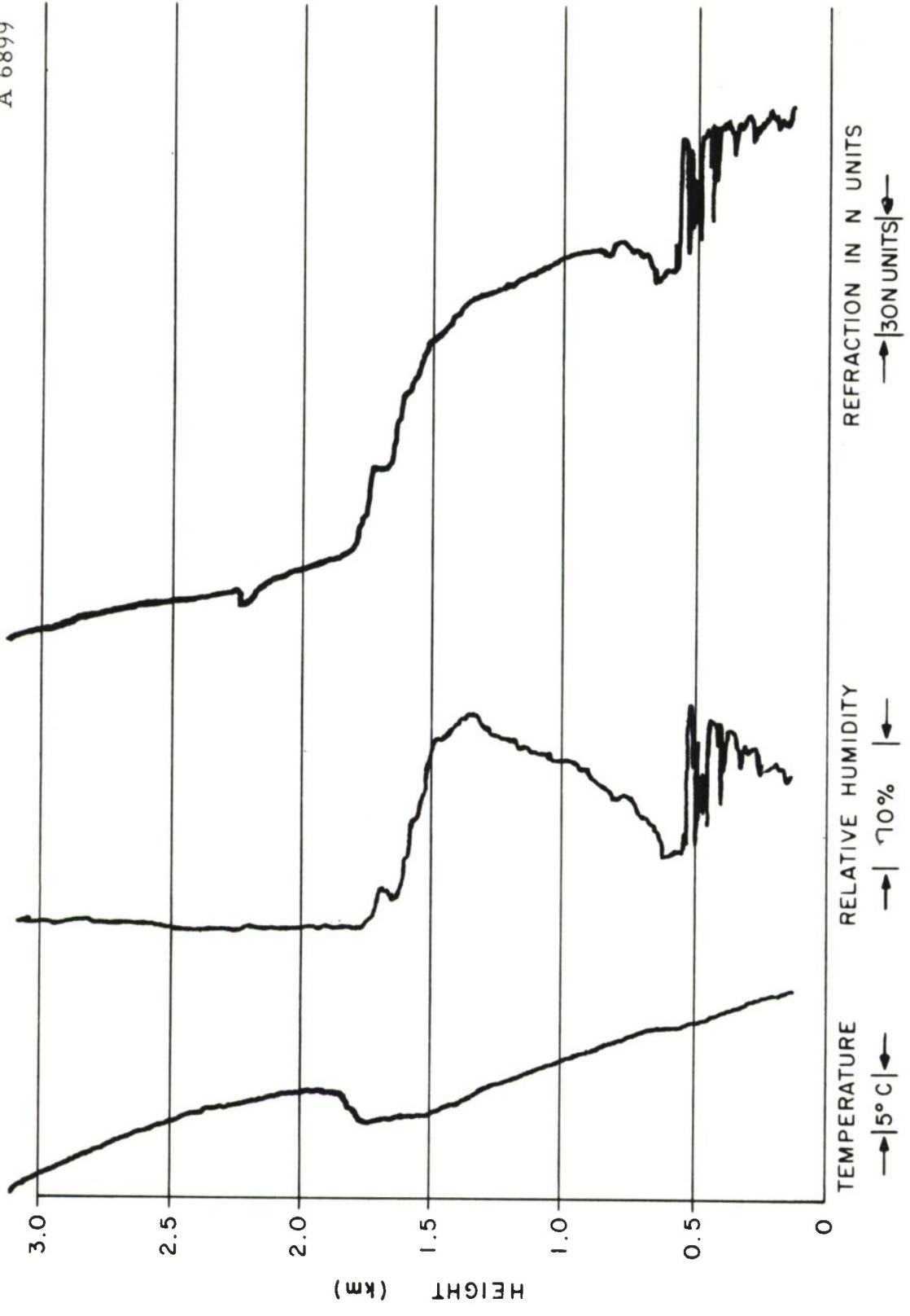
MISSIONS 1 AND 2 - 6 MARCH 1969

MISSIONS 9, 10, AND 11 - 21 MARCH 1969

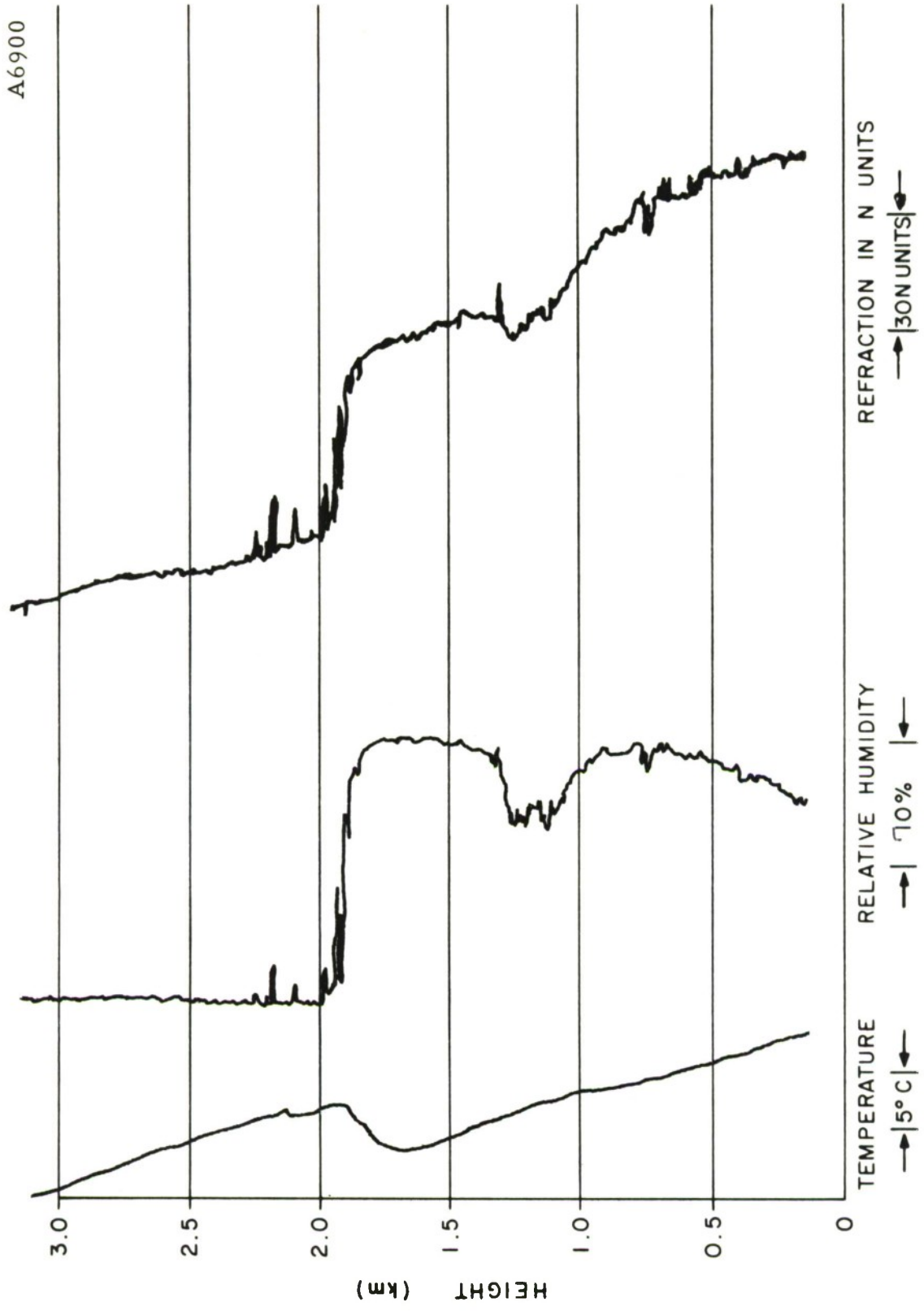
A6898



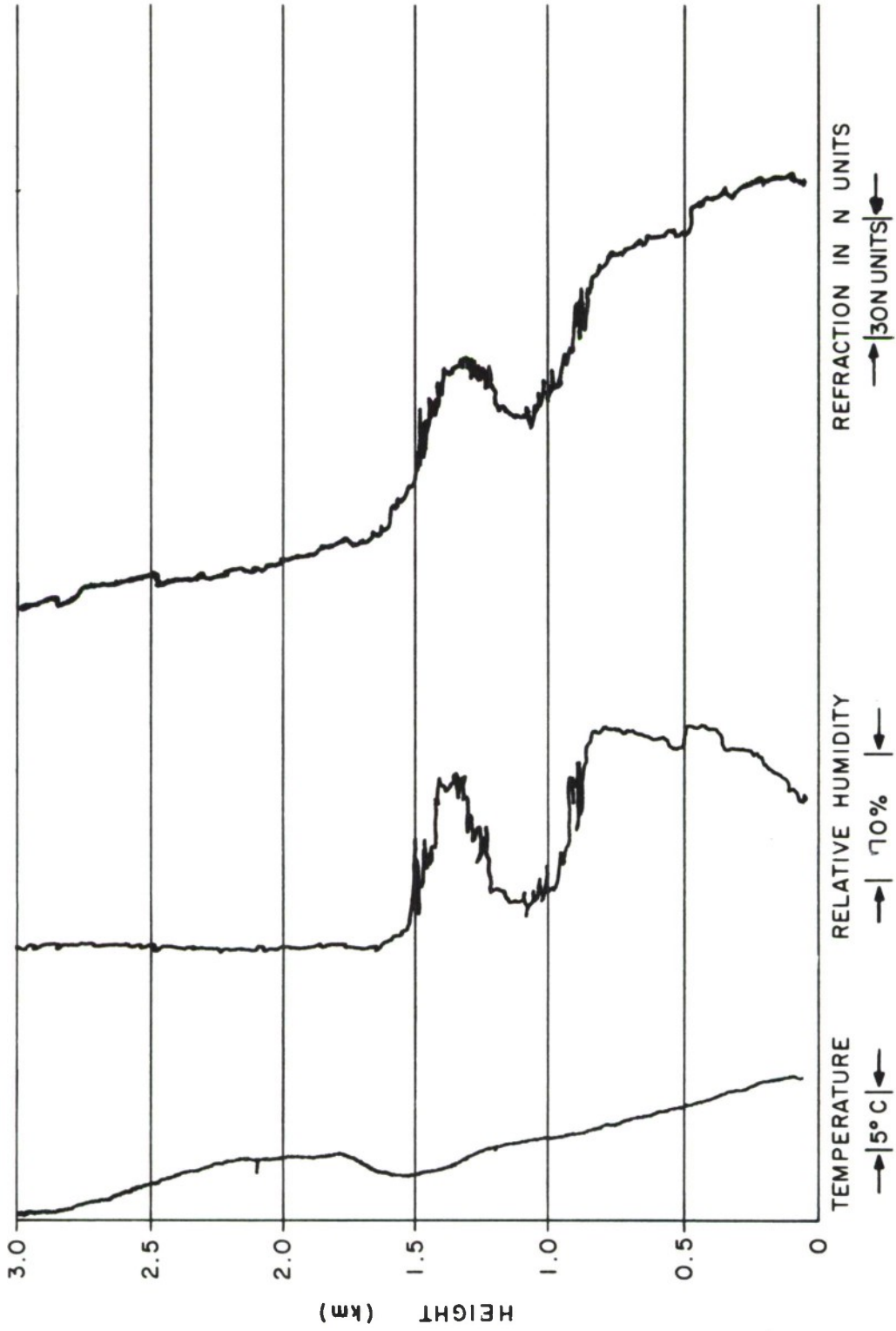
A 6899



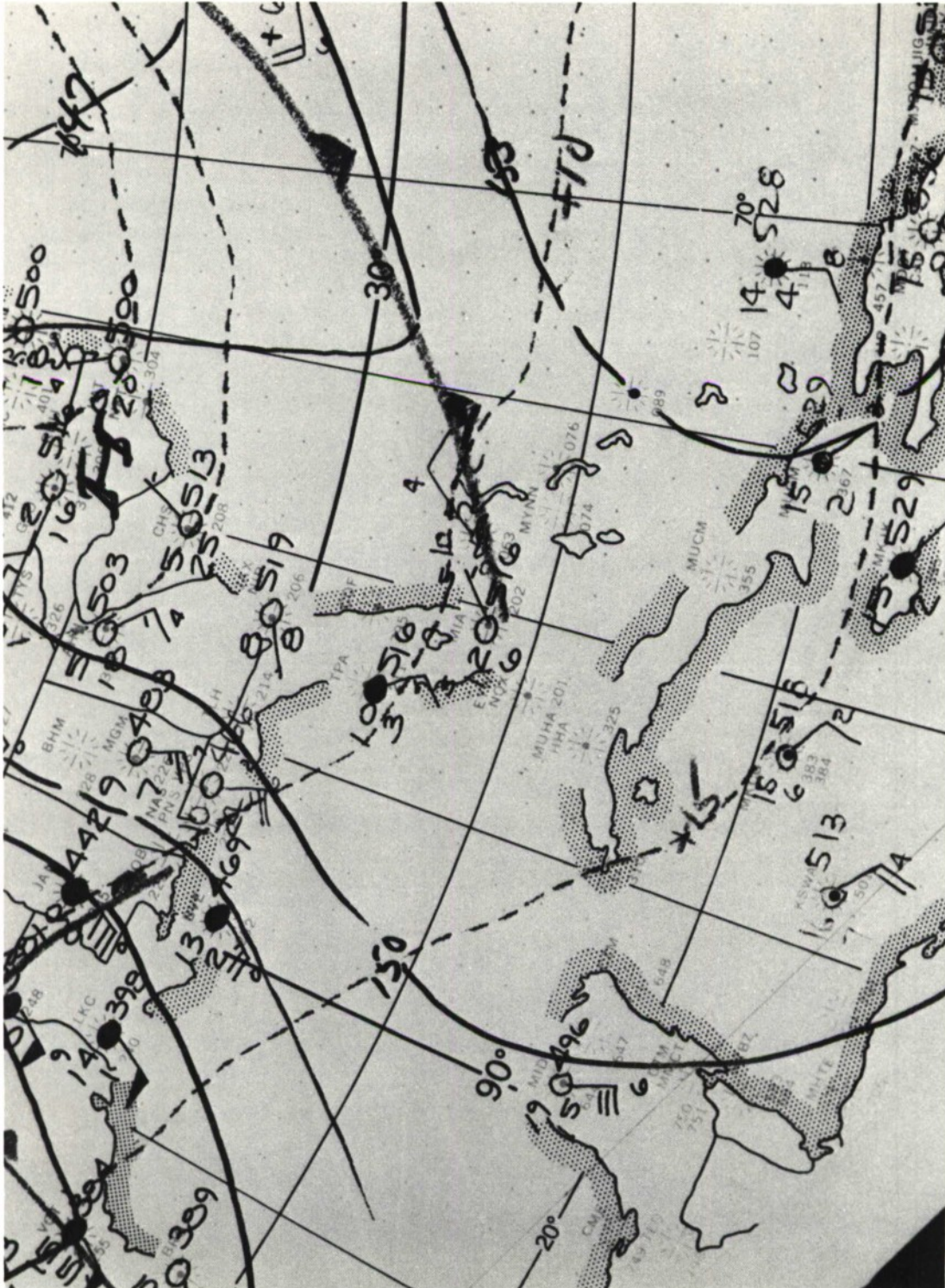
MISSION 11 - CLIMB 1



A6901



MISSION 11 - SPIRAL C



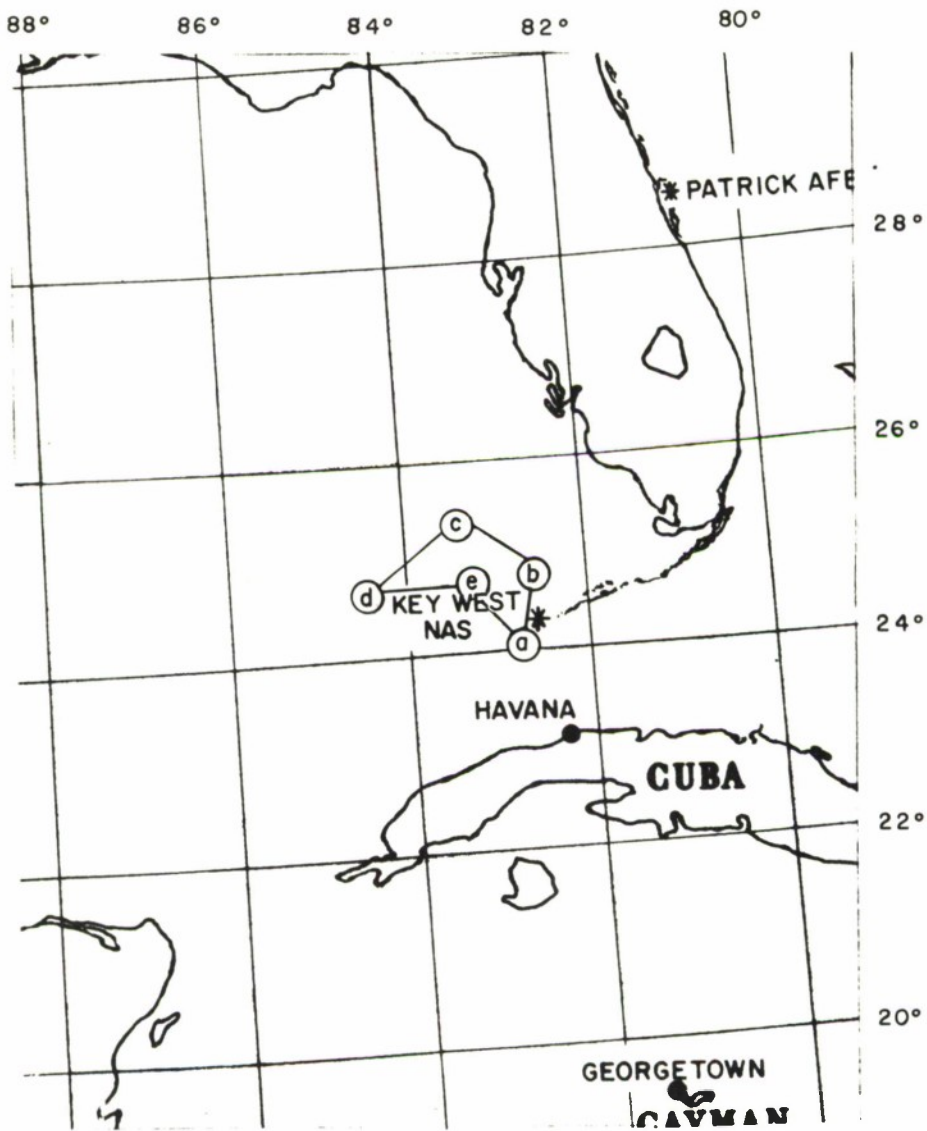
850 mb CHART
23 March 1969

MISSION NO. 12

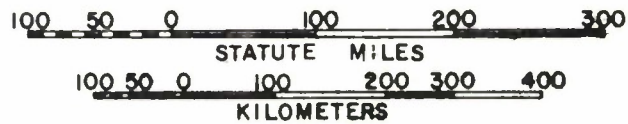
Date: 23 March 1969

Data were obtained for seven spirals and five ascents along Flight Path VIII, westerly from Key West

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. Key West	0712	0212
B	b. 24-35 N, 87-32 W	0748	0248
Climb 1	b-c	0806	0306
C	c. 24-35 N, 83-32 W	0828	0328
Climb 2	c-d	0845	0345
D	d. 24-35 N, 84-26 W	0909	0409
Climb 3	d-e	0926	0426
E	e. 24-35 N, 83-03 W	0952	0452
Climb 4	e-f	1011	0511
F	f. 24-43 N, 81-04 W	1043	0543
Climb 5	f-a	1101	0601
G	a. Key West	1119	0619



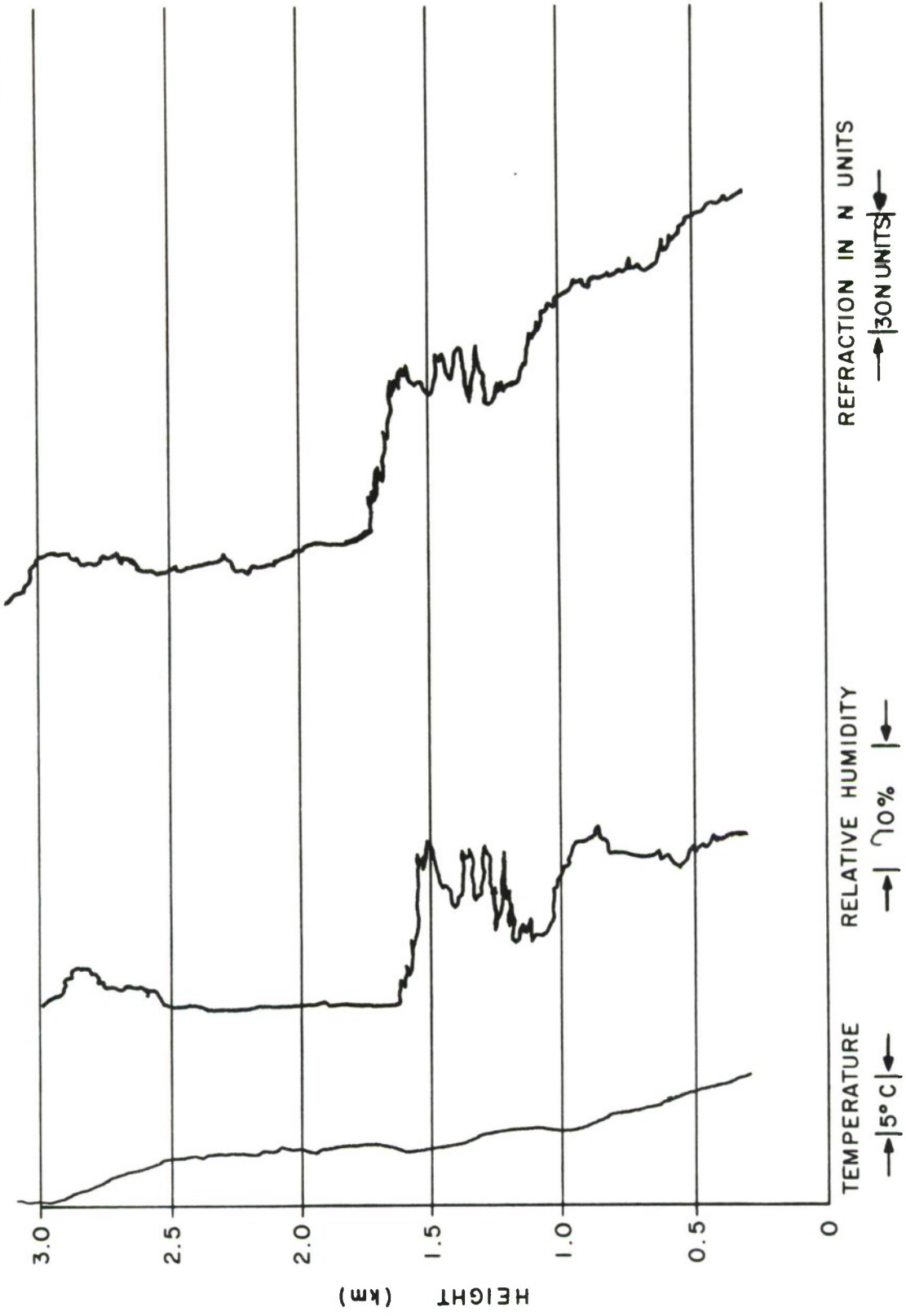
SCALE 1:5,702,400 OR 90 MILES TO 1 INCH



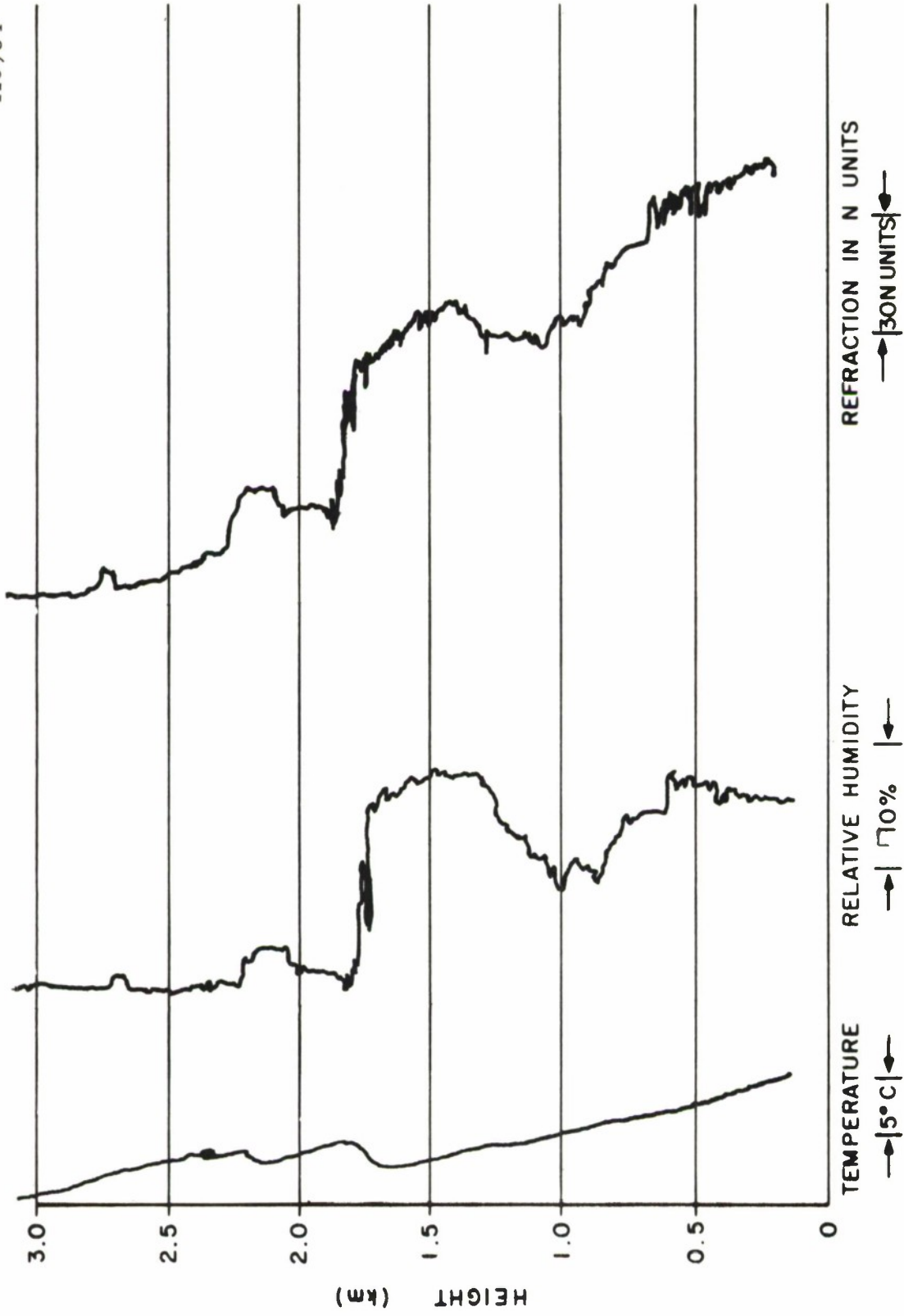
FLIGHT PATH VIII

- MISSION 12 — 23 MARCH 1969
- MISSION 13 — 24 MARCH 1969
- MISSION 14 — 25 MARCH 1969

A6903

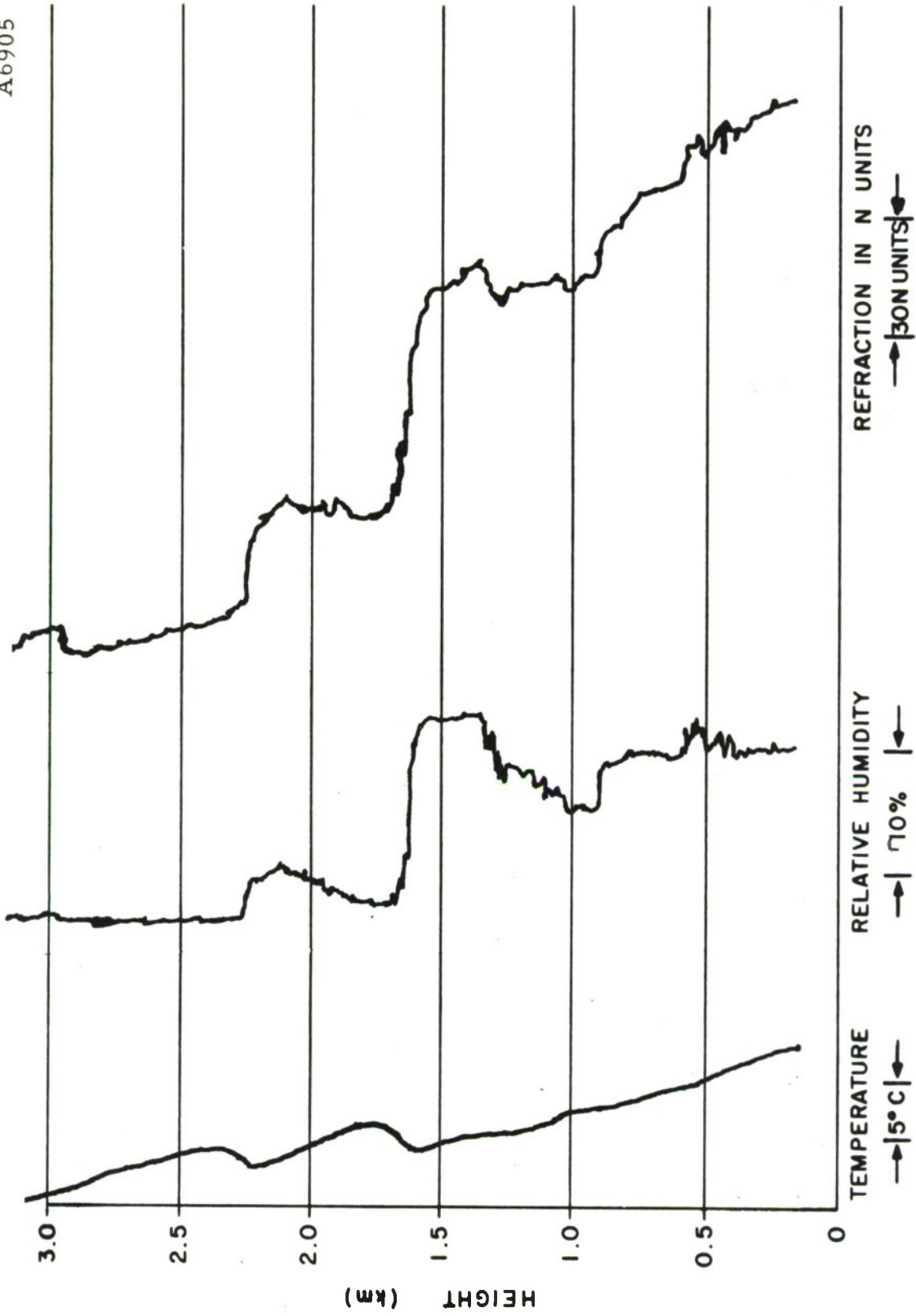


A6904



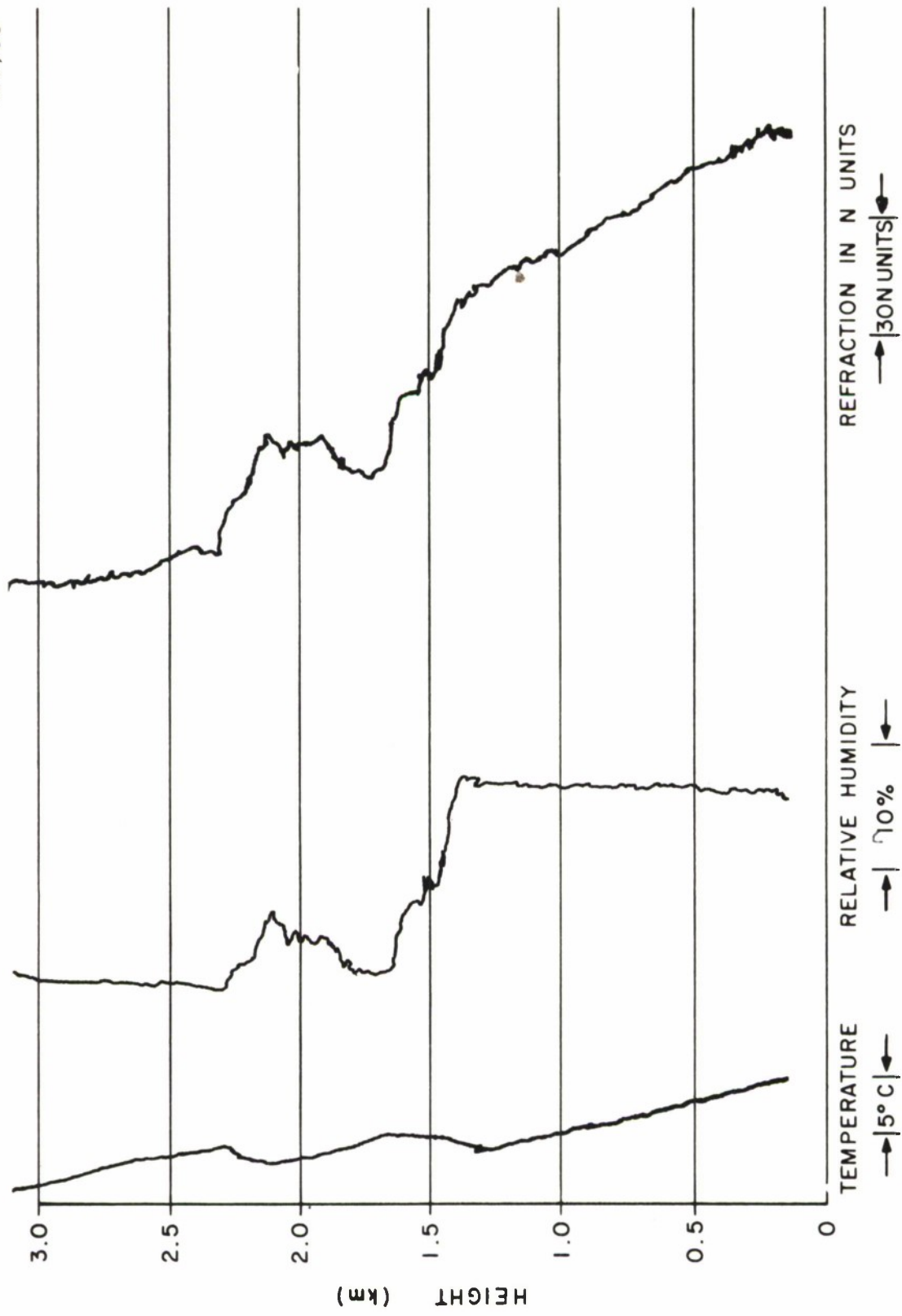
MISSION 12 - SPIRAL B

A6905



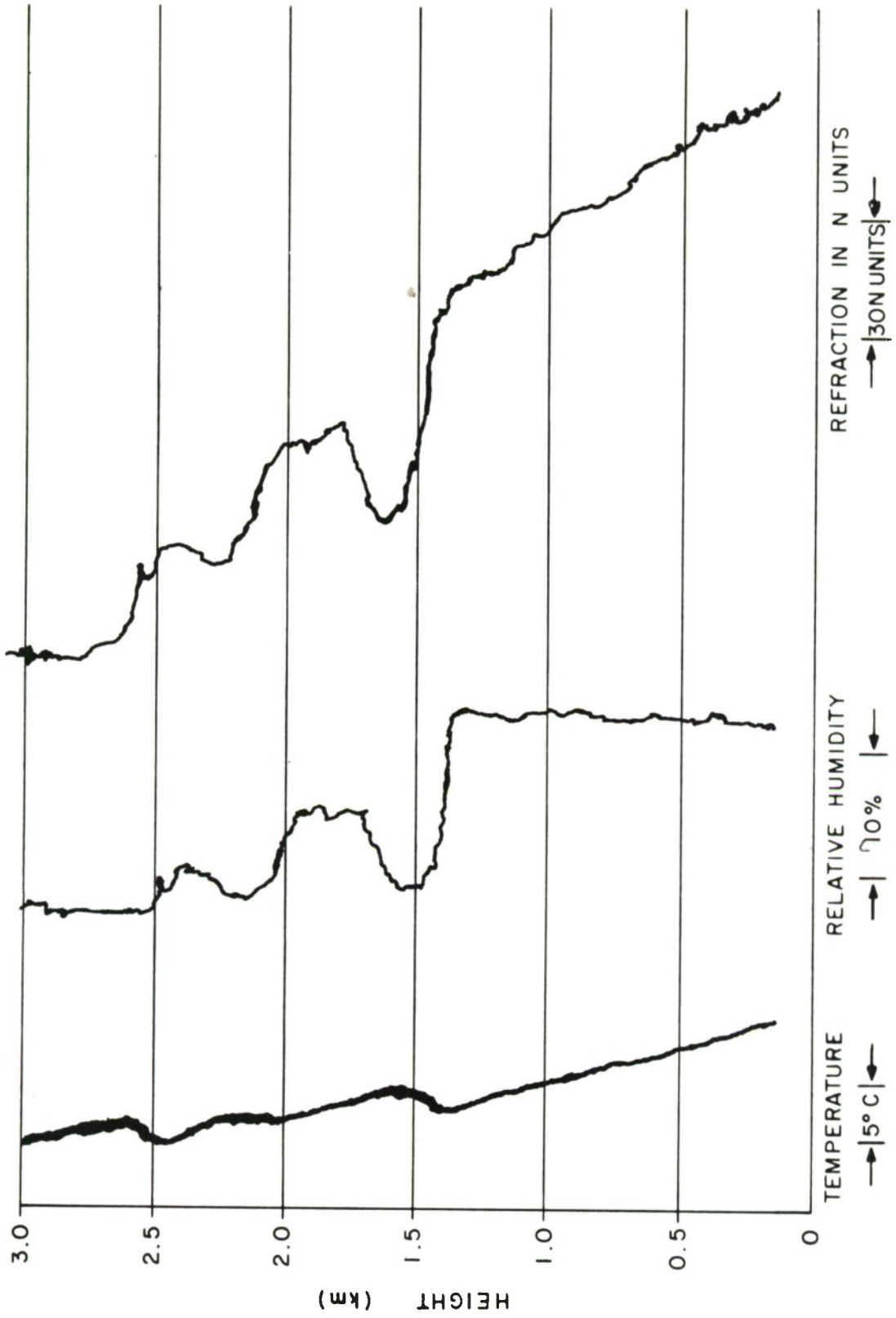
MISSION 12 - CLIMB 1

A6906

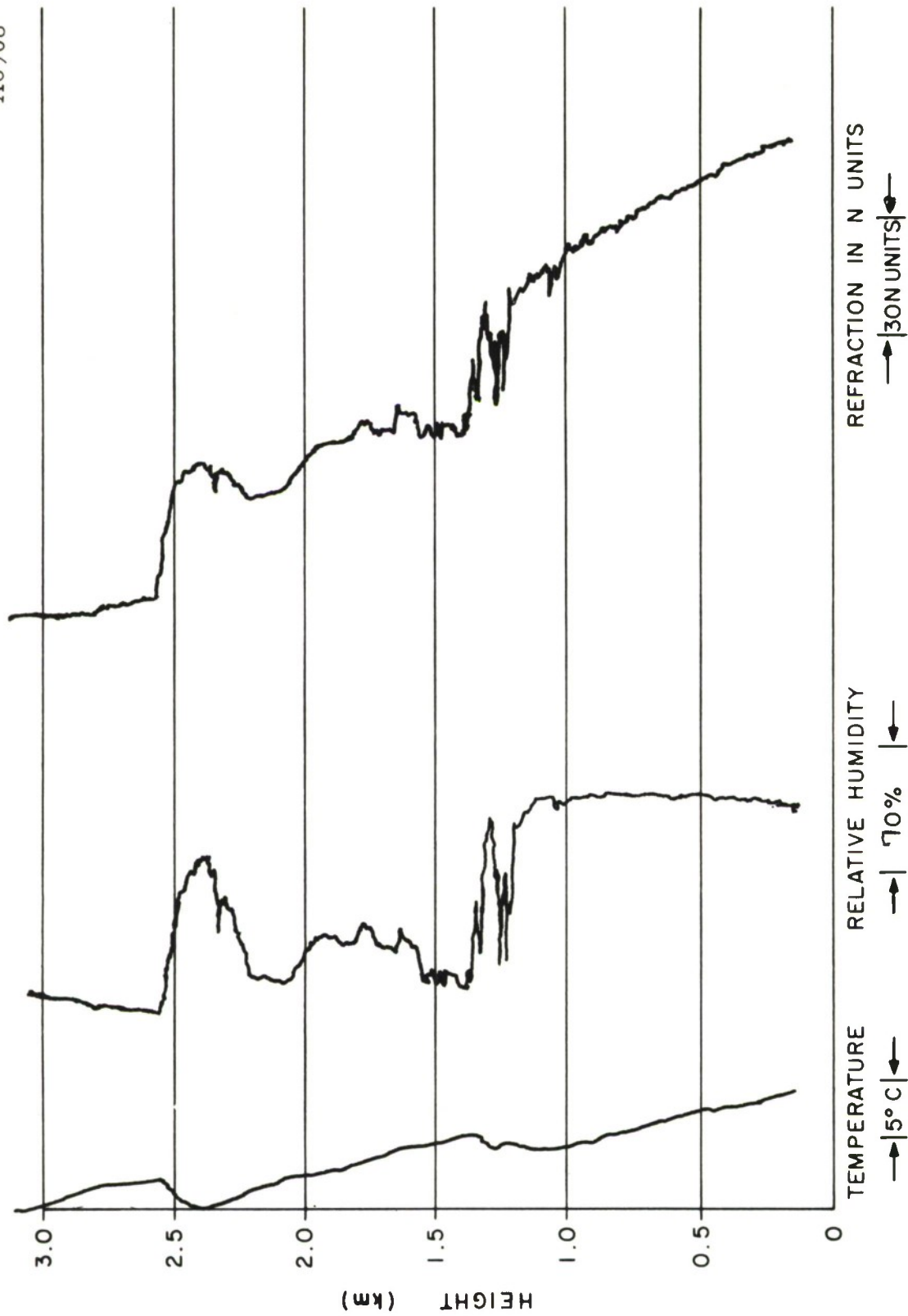


MISSION 12 - SPIRAL C

A6907

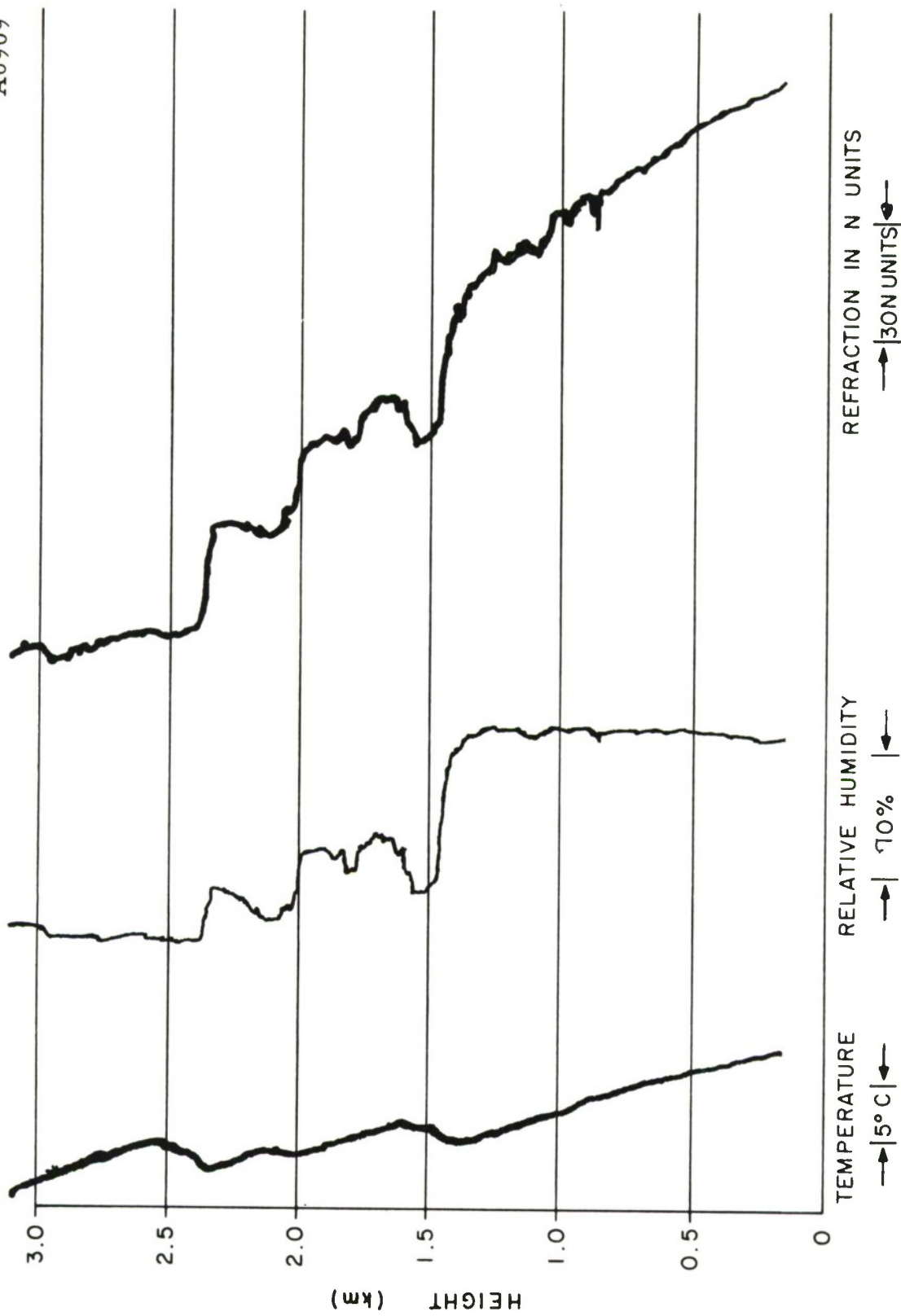


A6908

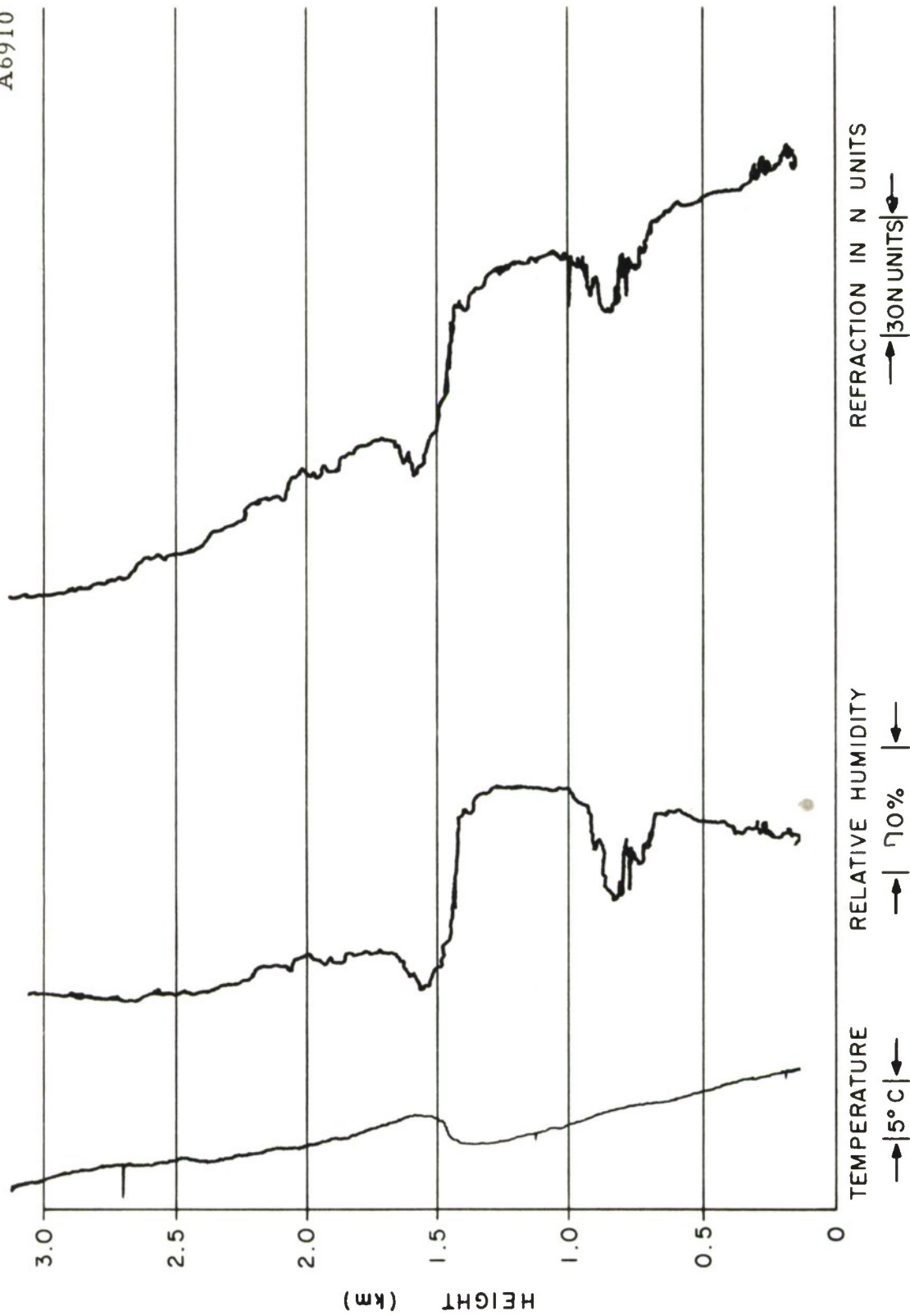


MISSION 12 - SPIRAL D

A6909

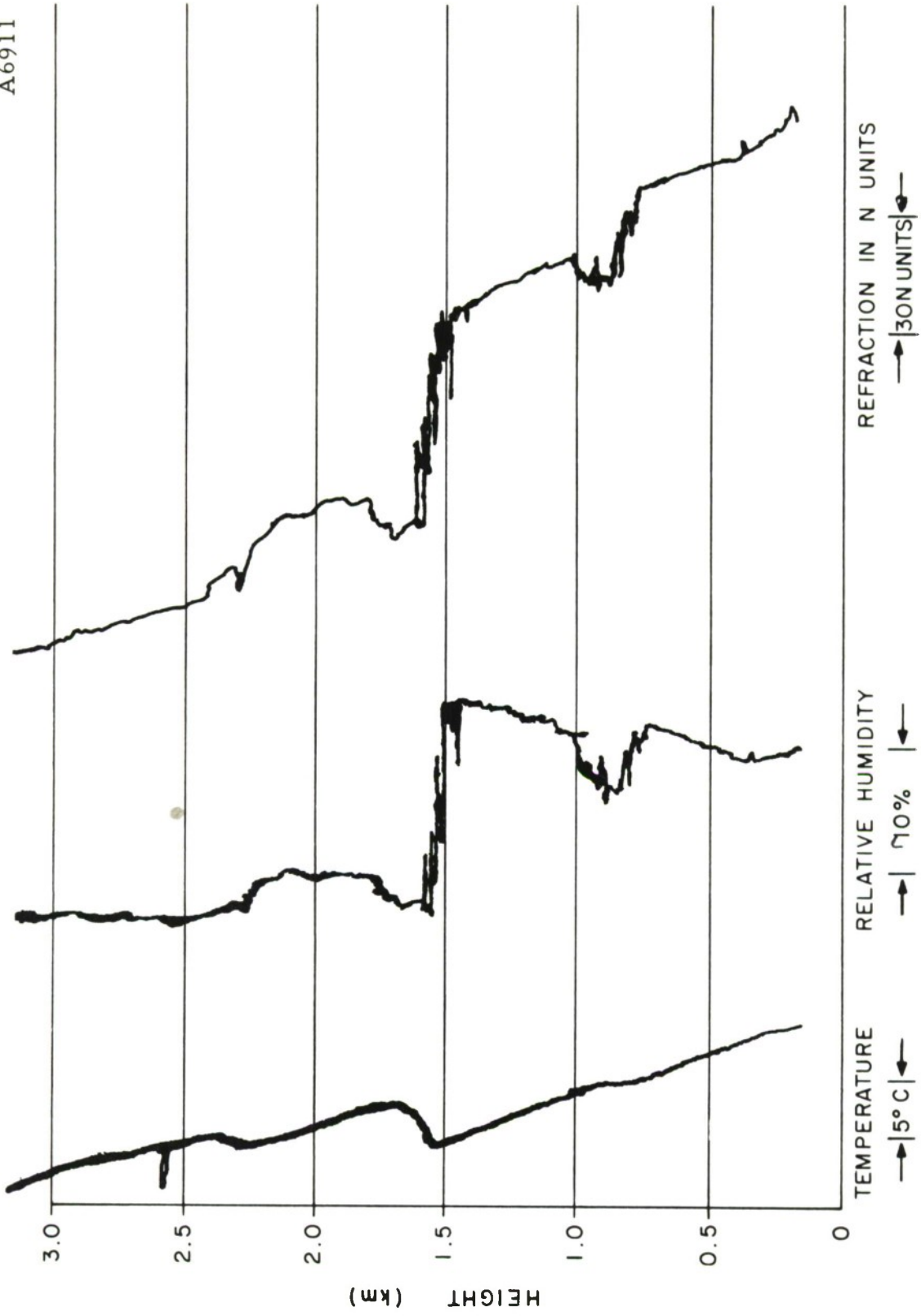


A6910



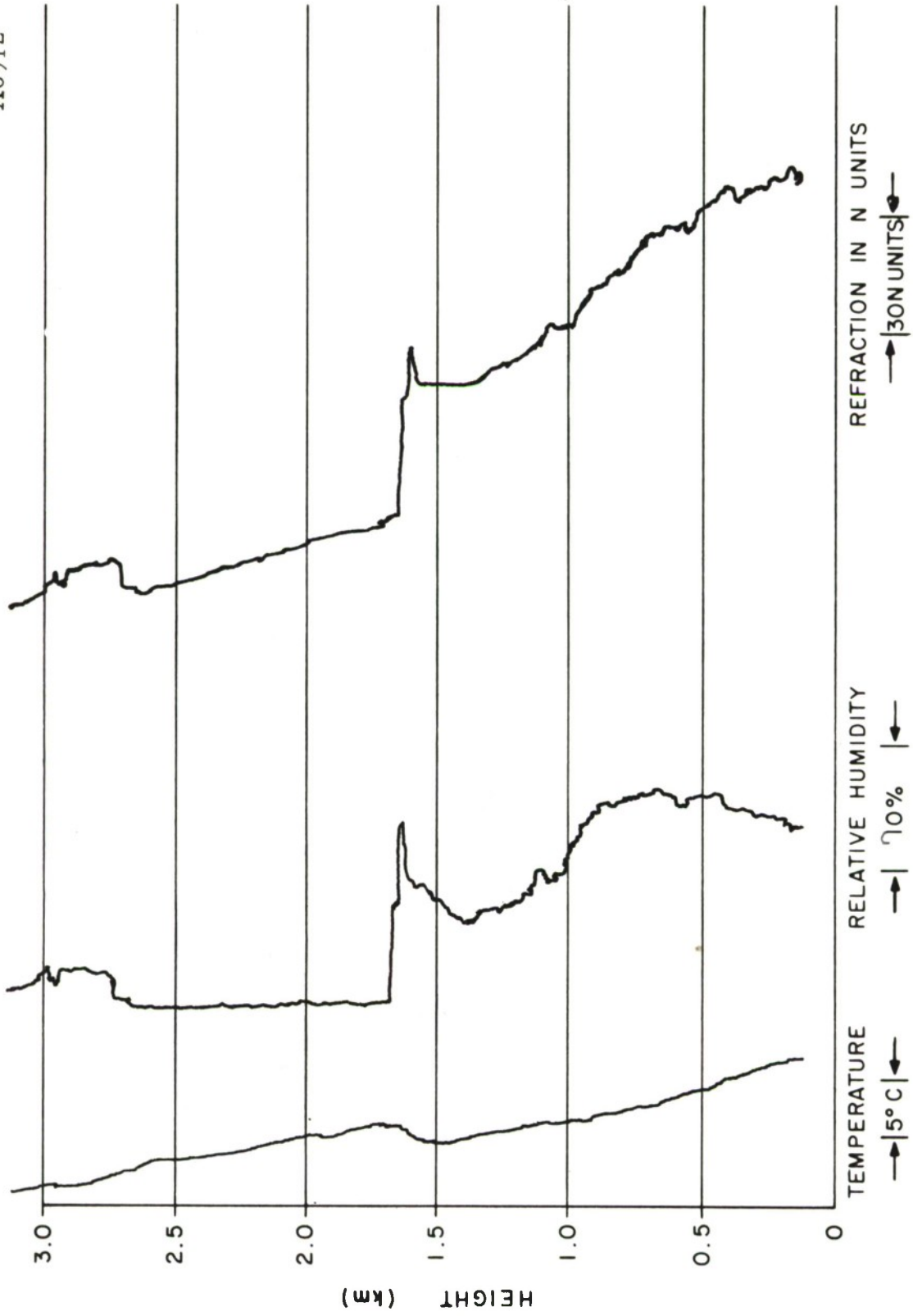
MISSION 12 - SPIRAL E

A6911



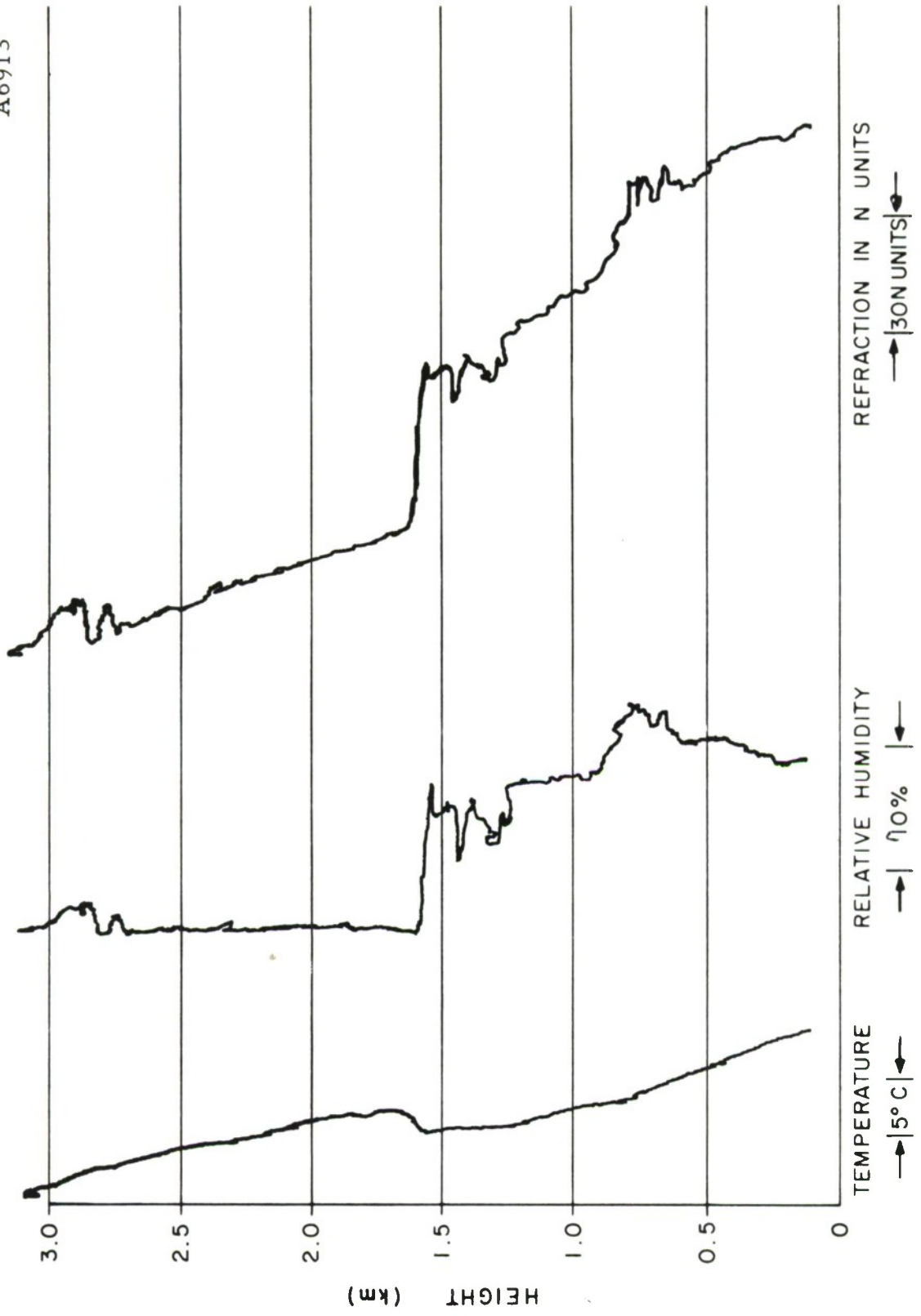
MISSION 12 - CLIMB 4

A6912

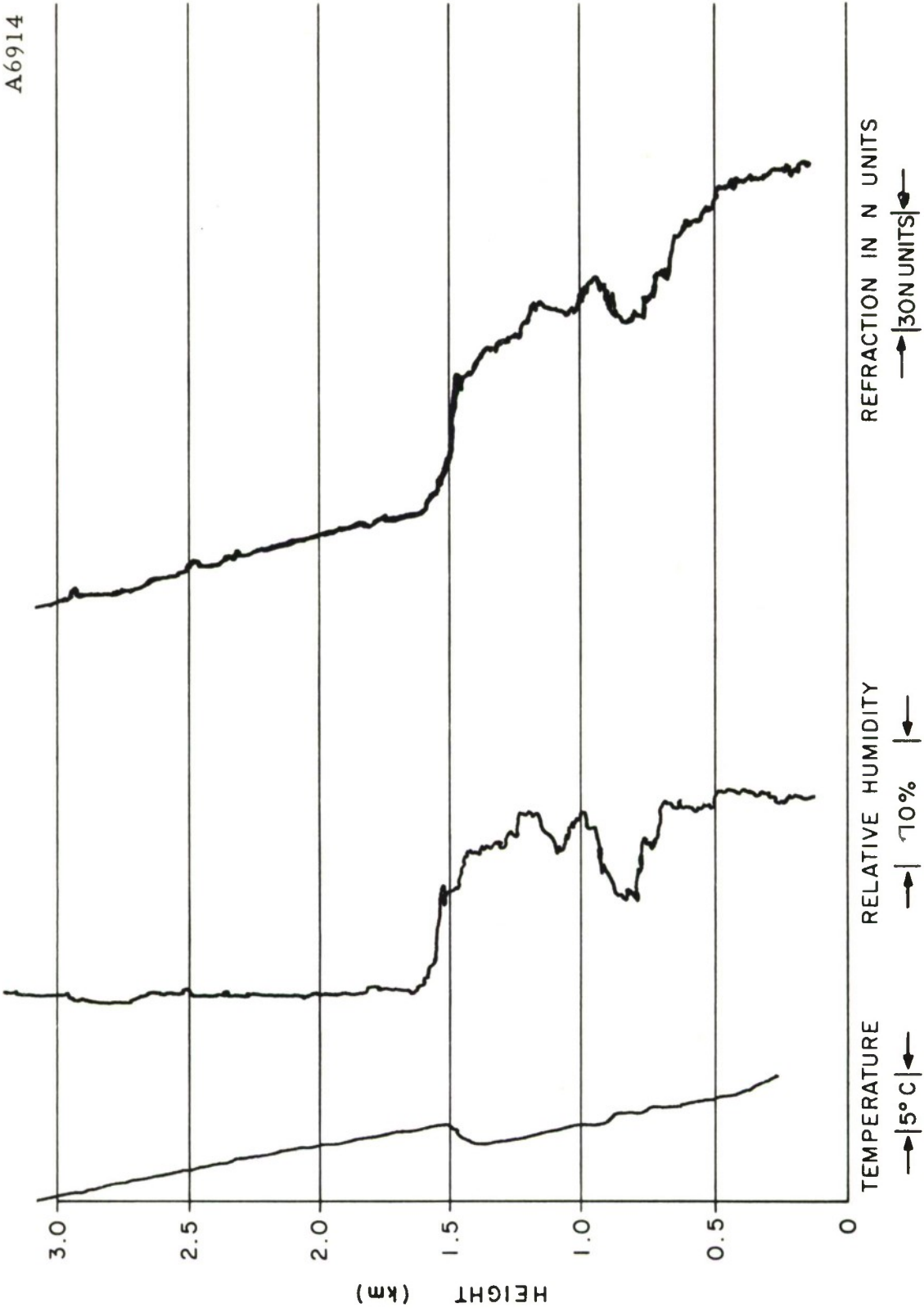


MISSION 12 - SPIRAL F

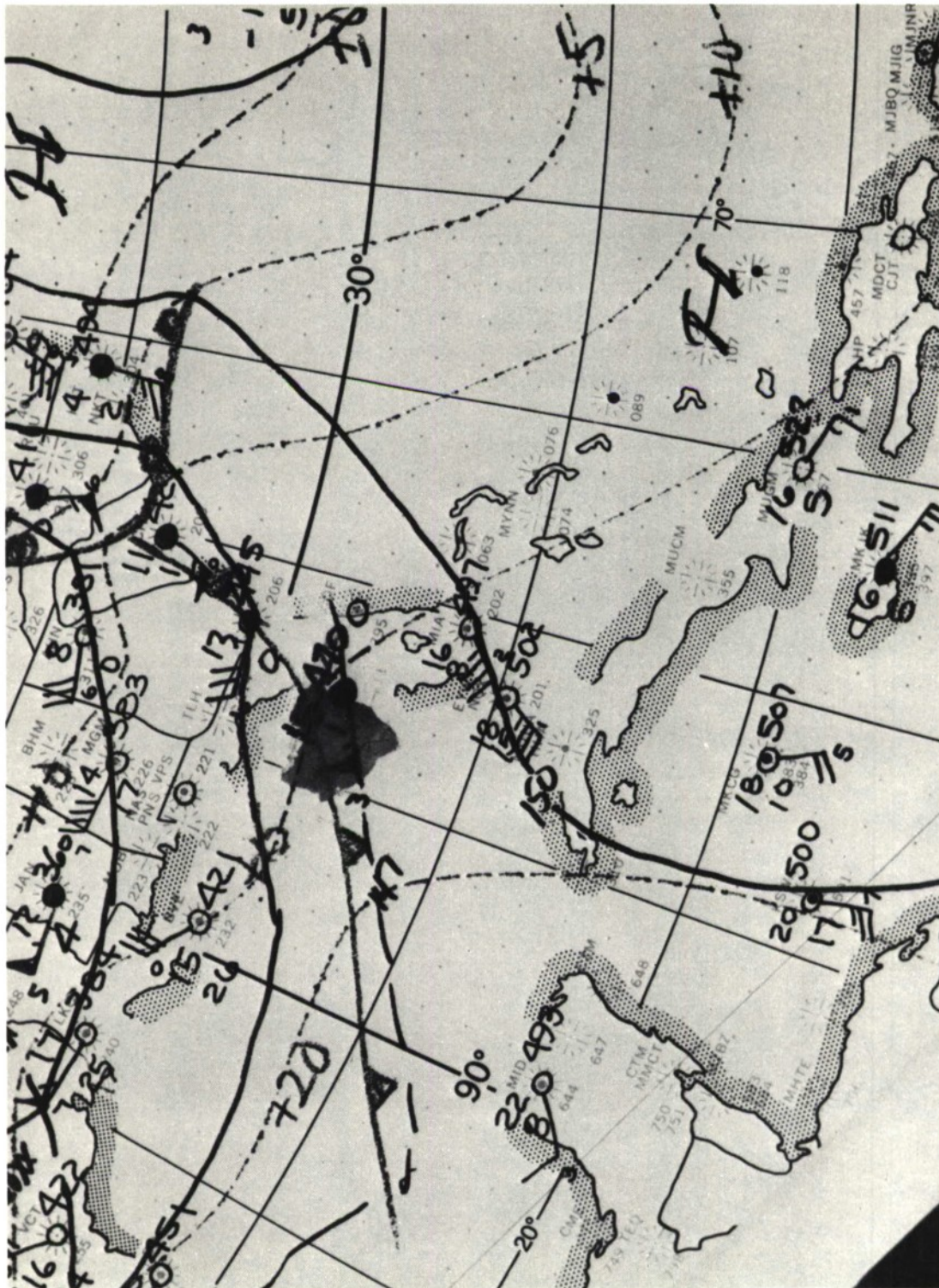
A6913



A6914



MISSION 12 - SPIRAL G



850 mb CHART
24 March 1969

MISSION NO. 13

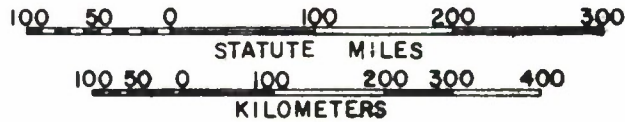
Date: 24 March 1969

Data were obtained for six spirals and three ascents along Flight Path VIII, westerly from Key West.

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. Key West	1132	0632
B	b. 24-35 N, 82-37 W	1212	0712
Climb 1	b-c	1236	0736
C	c. 24-35 N, 83-32 W	1257	0757 (data missing)
Climb 2	c-d	1321	0821
D	d. 24-35 N, 84-26 W	1348	0848
Climb 3	d-e	1406	0906
E	e. 24-35 N, 83-03 W	1430	0930
F	a. Key West	1511	1011



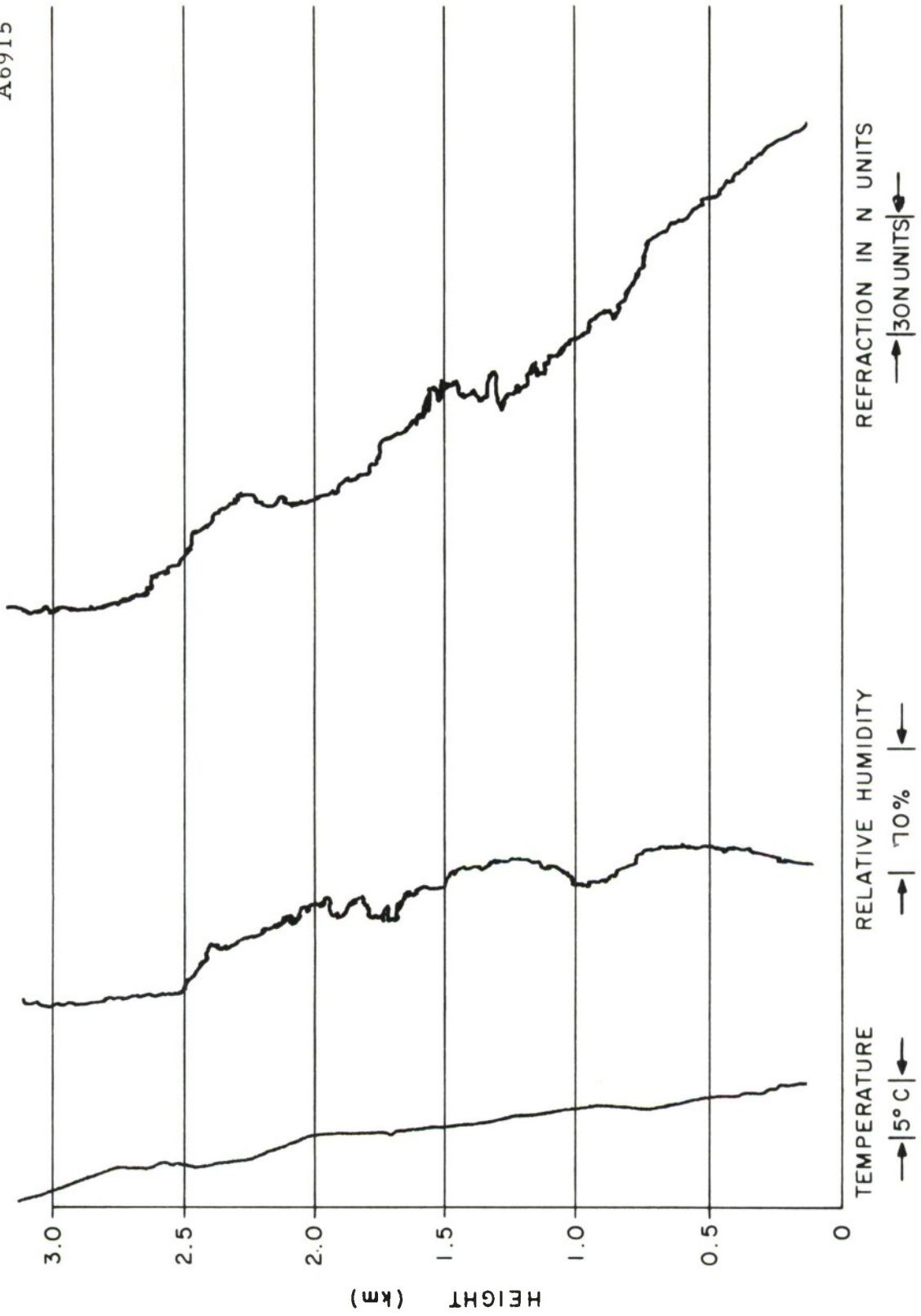
SCALE 1:5,702,400 OR 90 MILES TO 1 INCH



FLIGHT PATH VIII

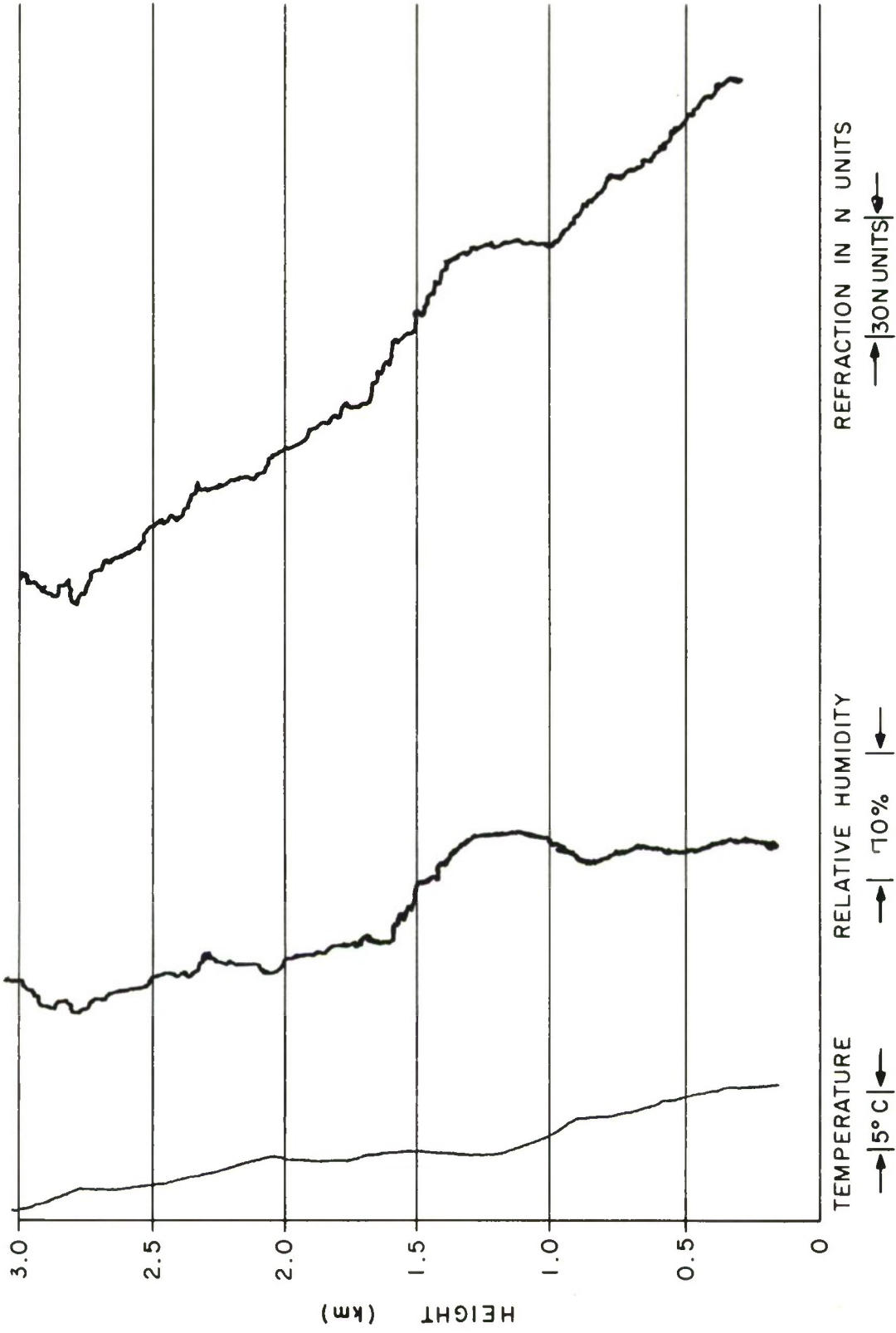
- MISSION 12 — 23 MARCH 1969
- MISSION 13 — 24 MARCH 1969
- MISSION 14 — 25 MARCH 1969

A6915



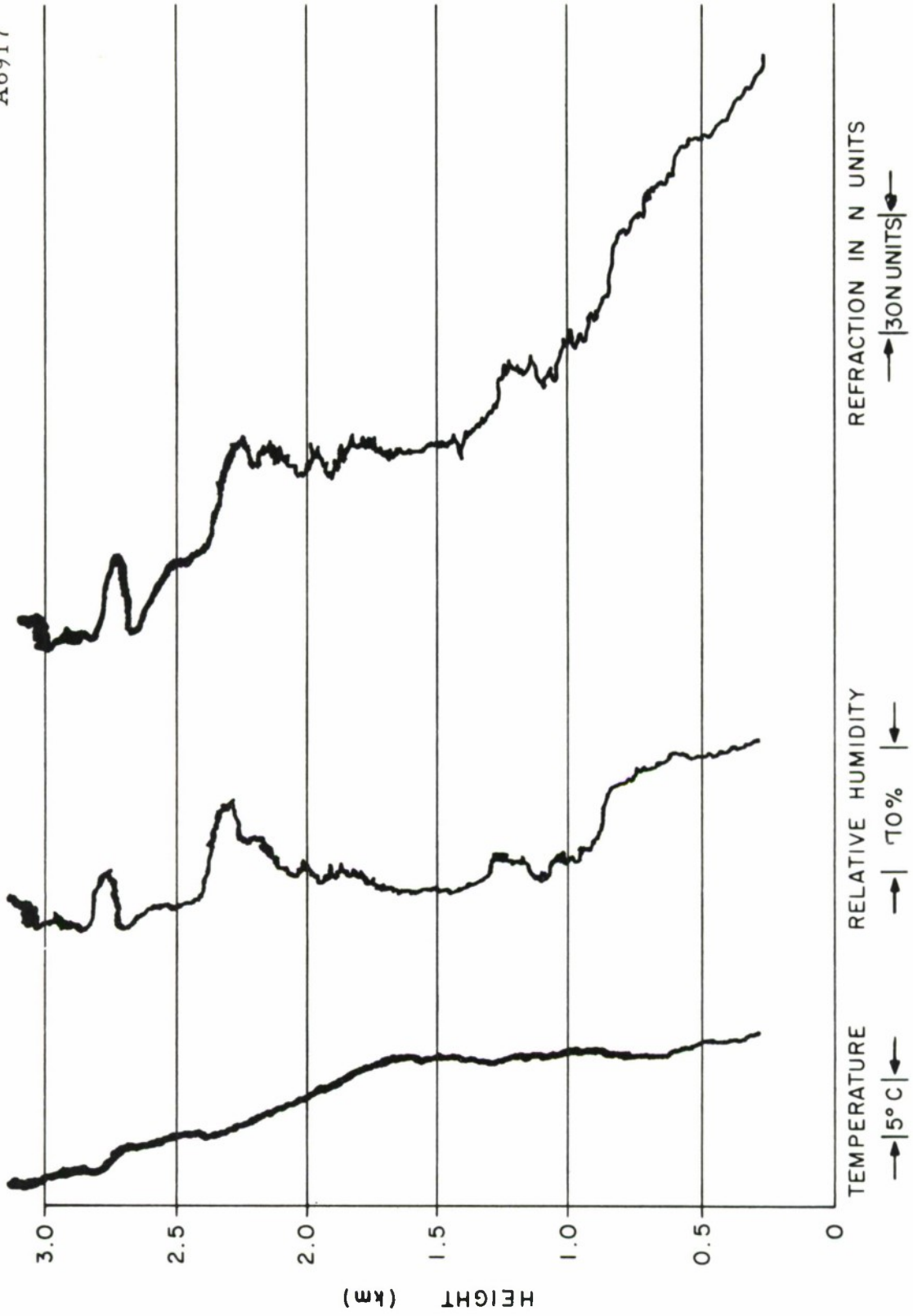
MISSION 13 - SPIRAL A

A6916



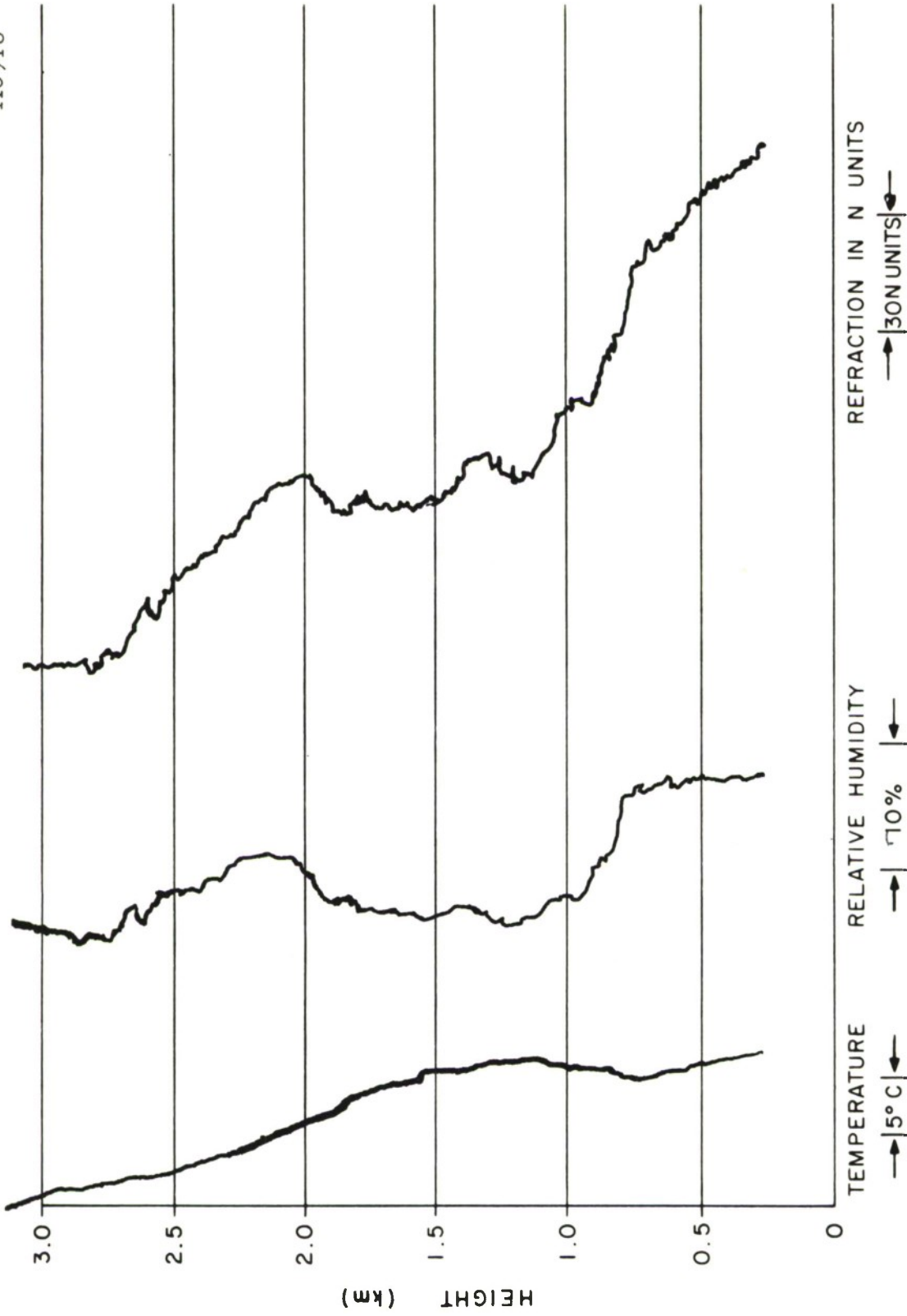
MISSION 13 - SPIRAL B

A6917



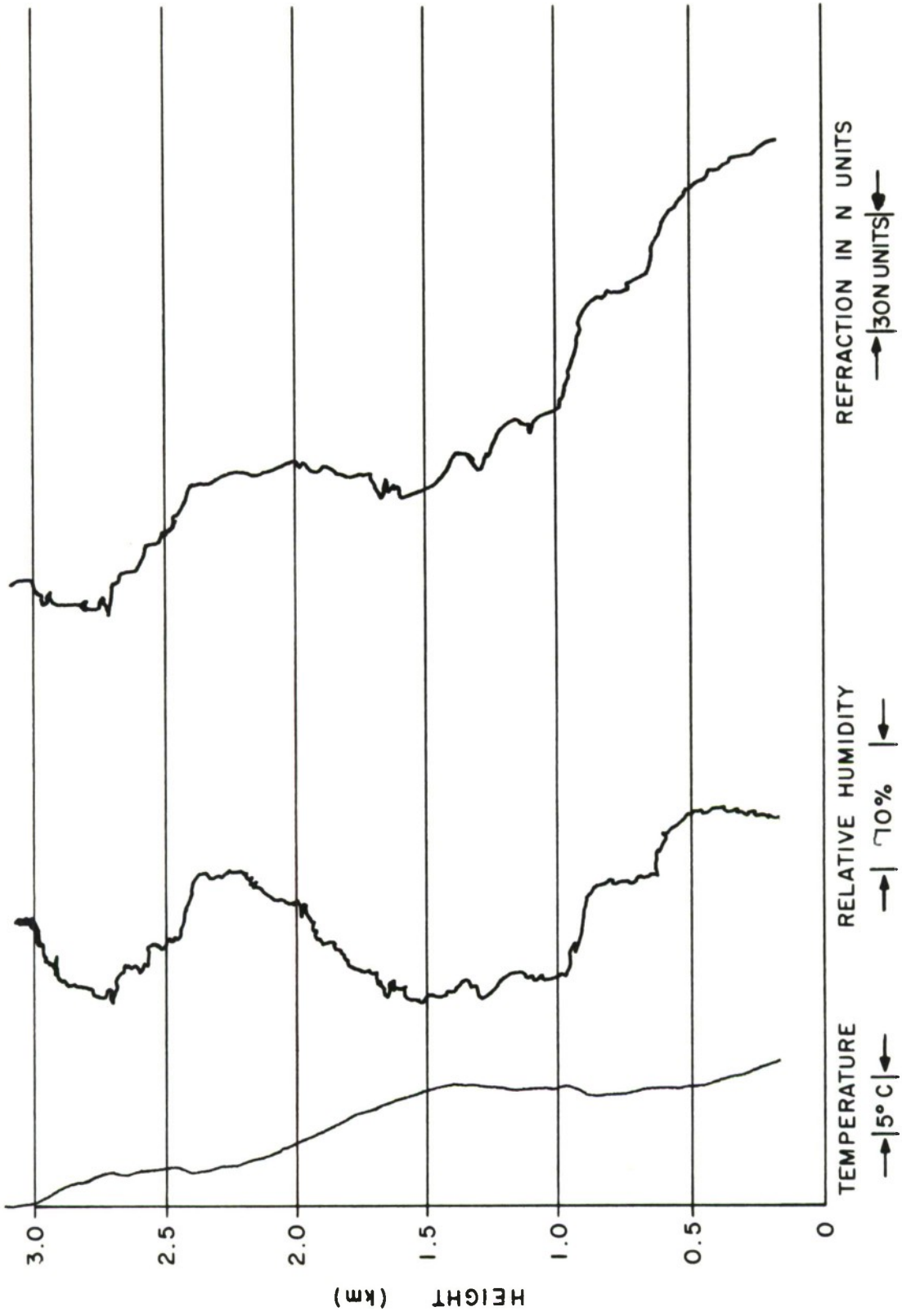
MISSION 13 - CLIMB 1

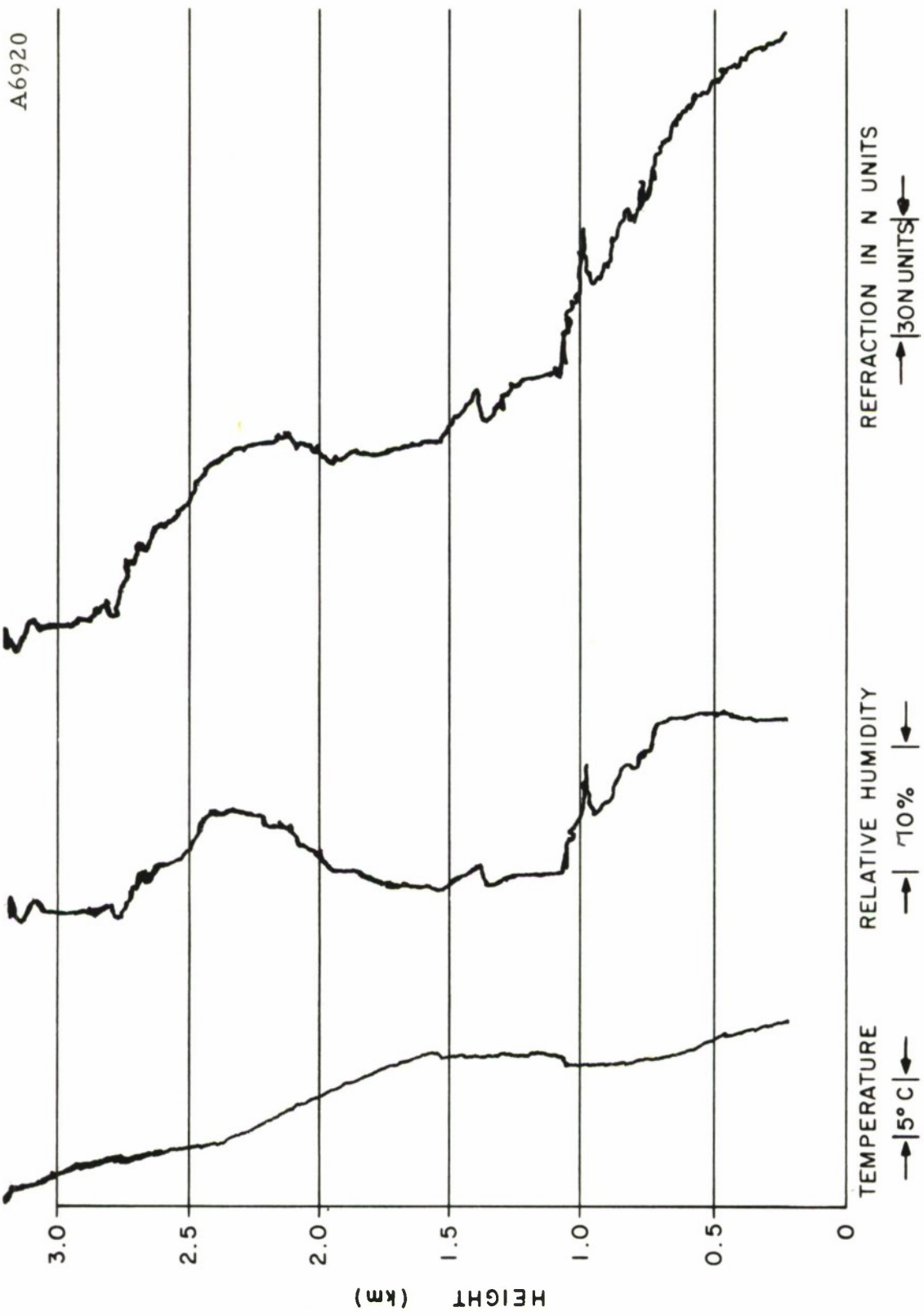
A6918



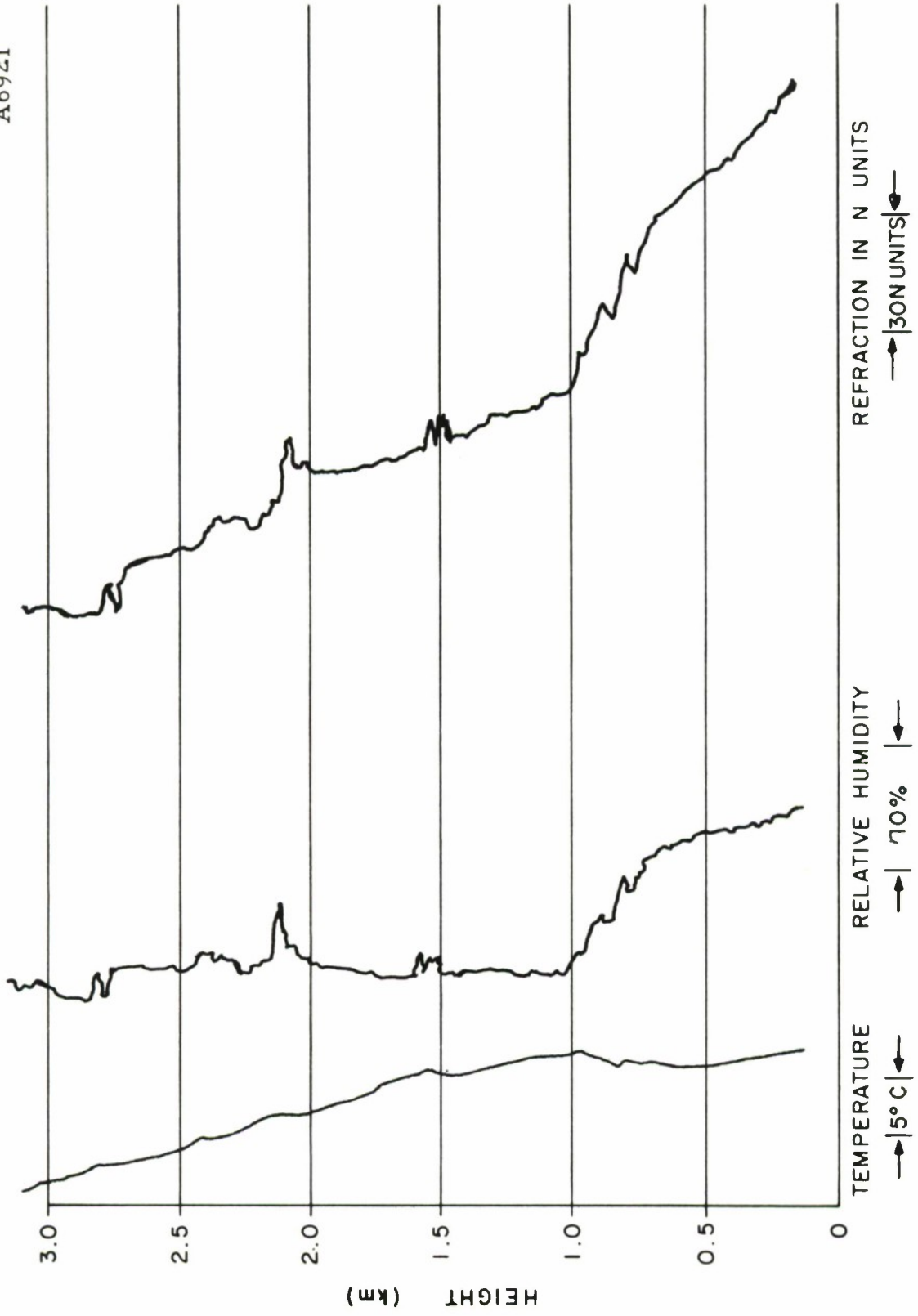
MISSION 13 - CLIMB 2

A6919



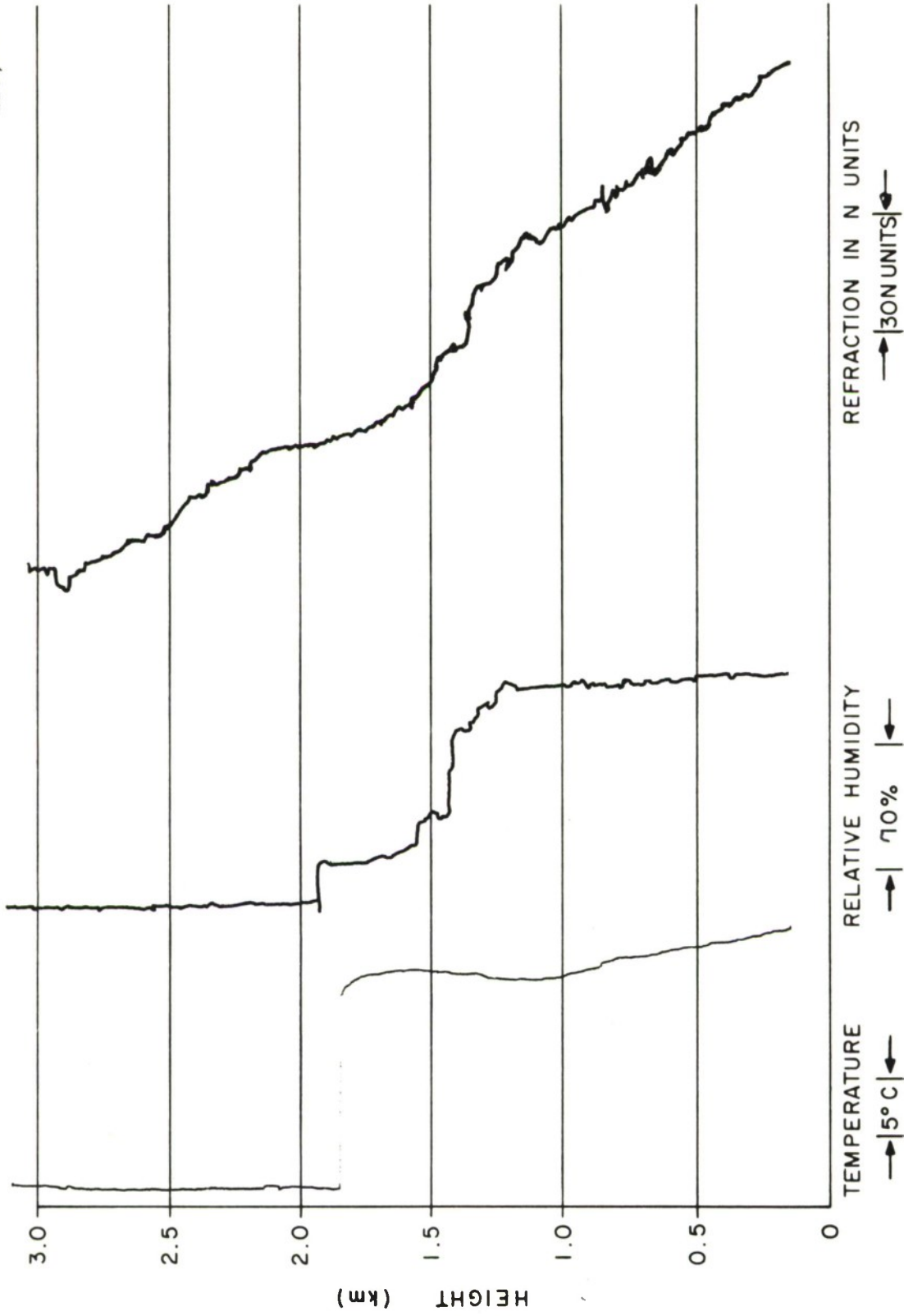


A6921

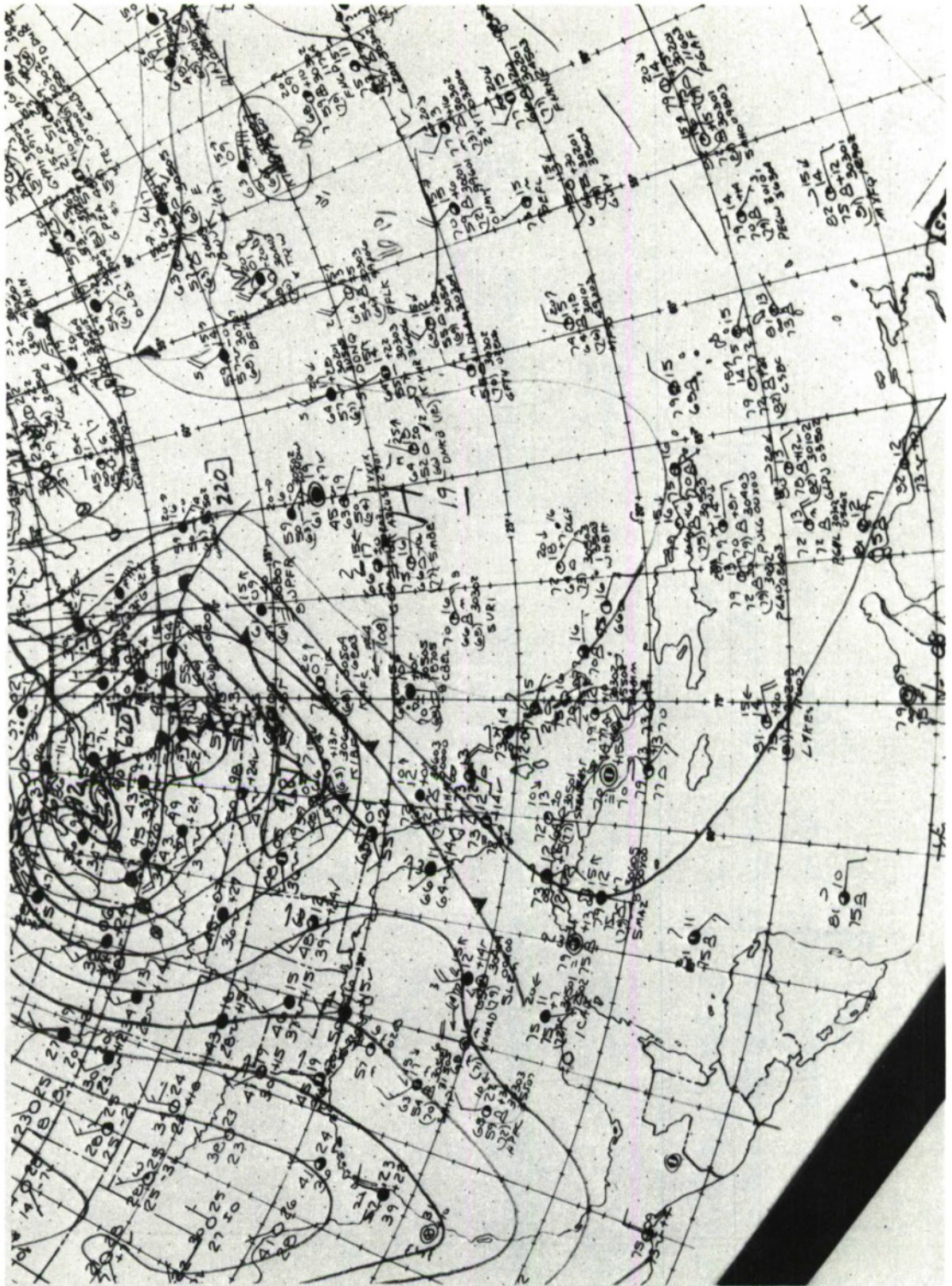


MISSION 13 - SPIRAL E

A6922



MISSION 13 - SPIRAL F



SURFACE CHART
25 March 1969



850 mb CHART
25 March 1969

MISSION NO. 14

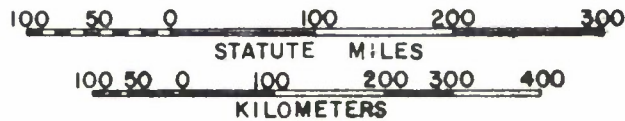
Date: 25 March 1969

Data were obtained for six spirals and three ascents along Flight Path VIII, westerly from Key West.

<u>Spiral</u>	<u>Location</u>	<u>Spiral Start Time</u>	
		<u>Z</u>	<u>Local</u>
A	a. Key West	1154	0654
B	b. 24-35 N, 82-37 W	1238	0738
Climb 1	b-c	1257	0757
C	c. 24-35 N, 83-32 W	1320	0820
Climb 2	c-d	1343	0843
D	d. 24-35 N, 84-26 W	1403	0903
Climb 3	d-e	1421	0921
E	e. 24-35 N, 83-03 W	1444	0944
F	a. Key West	1527	1027



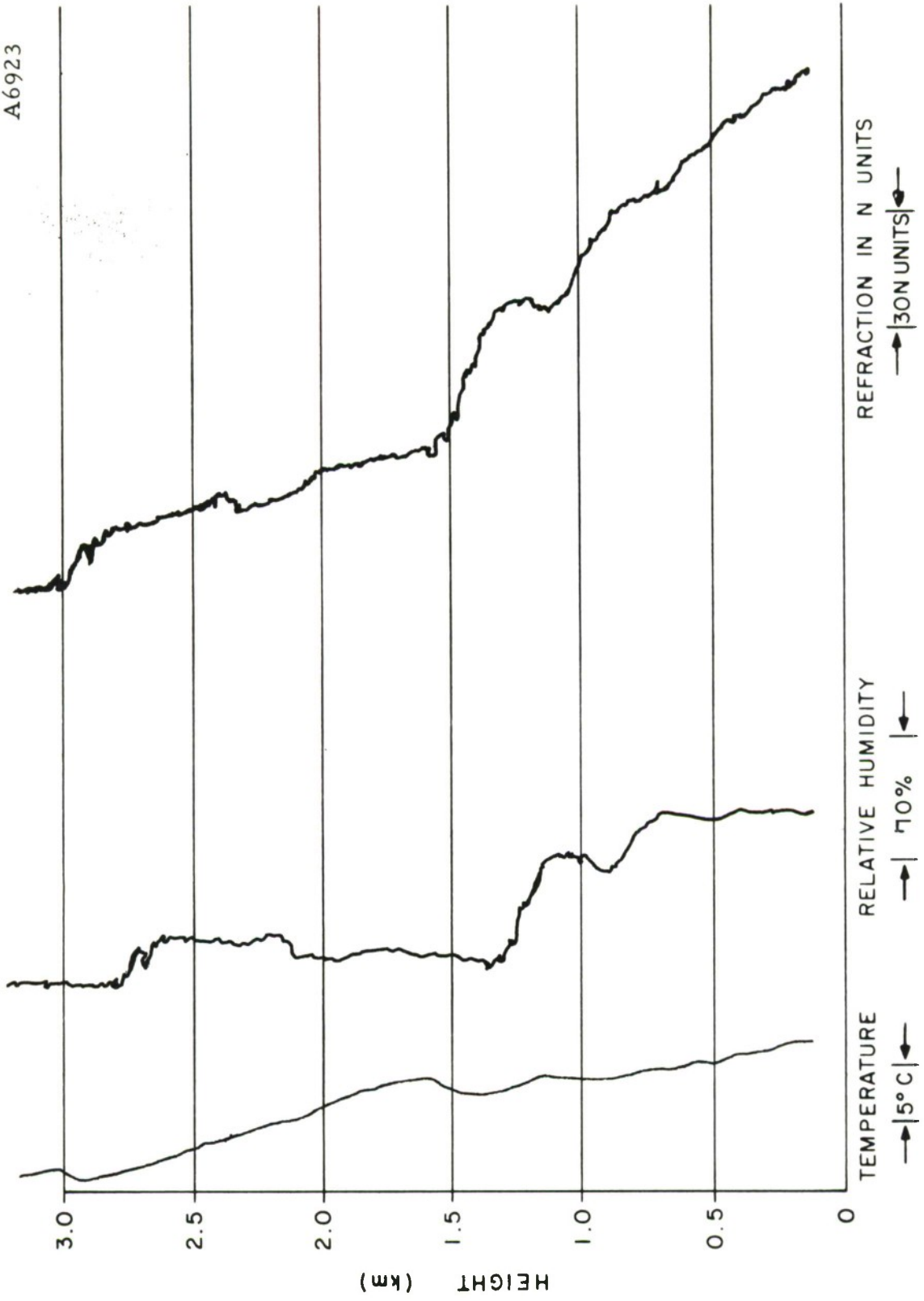
SCALE 1:5,702,400 OR 90 MILES TO 1 INCH



FLIGHT PATH VIII

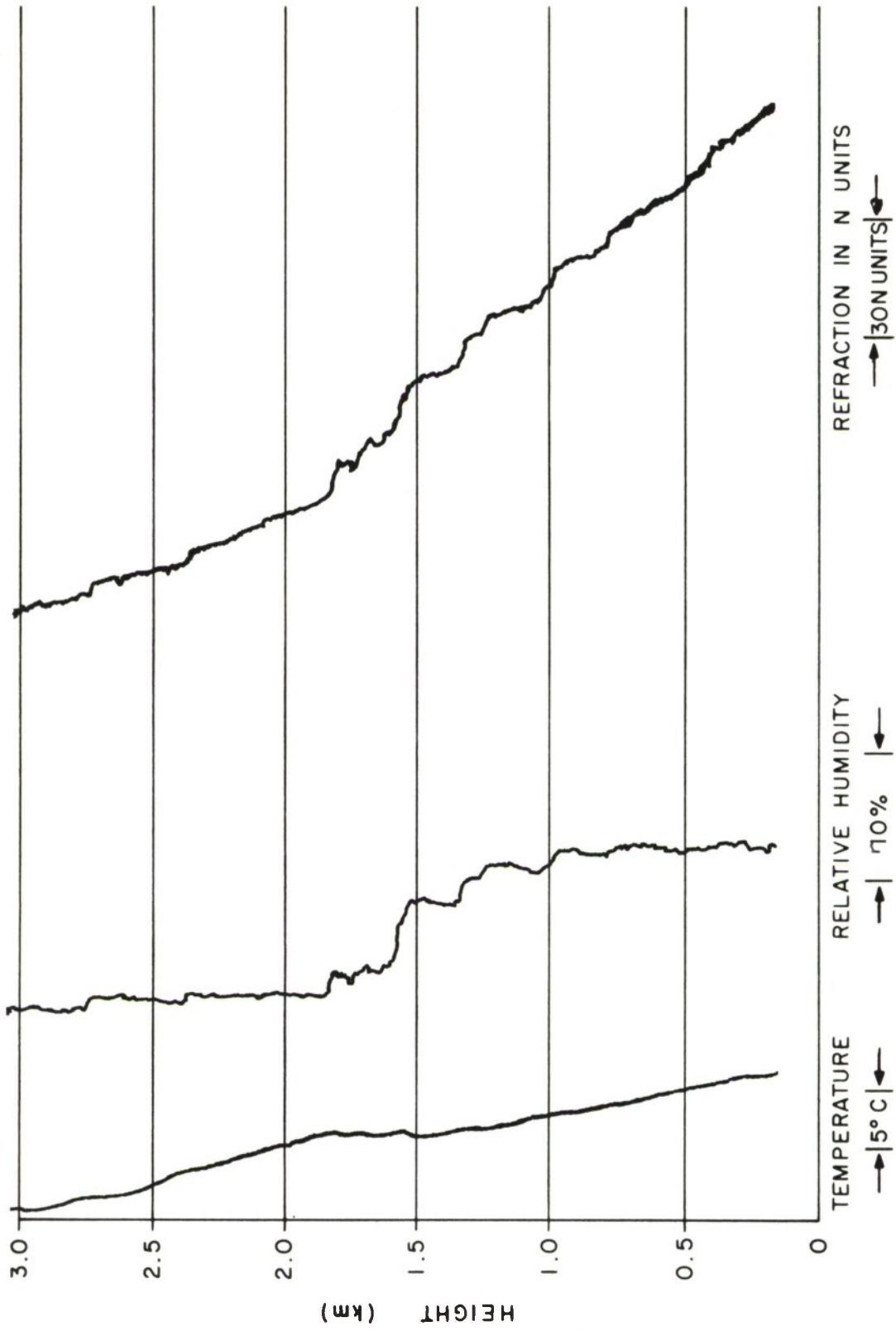
- MISSION 12 — 23 MARCH 1969
- MISSION 13 — 24 MARCH 1969
- MISSION 14 — 25 MARCH 1969

A6923



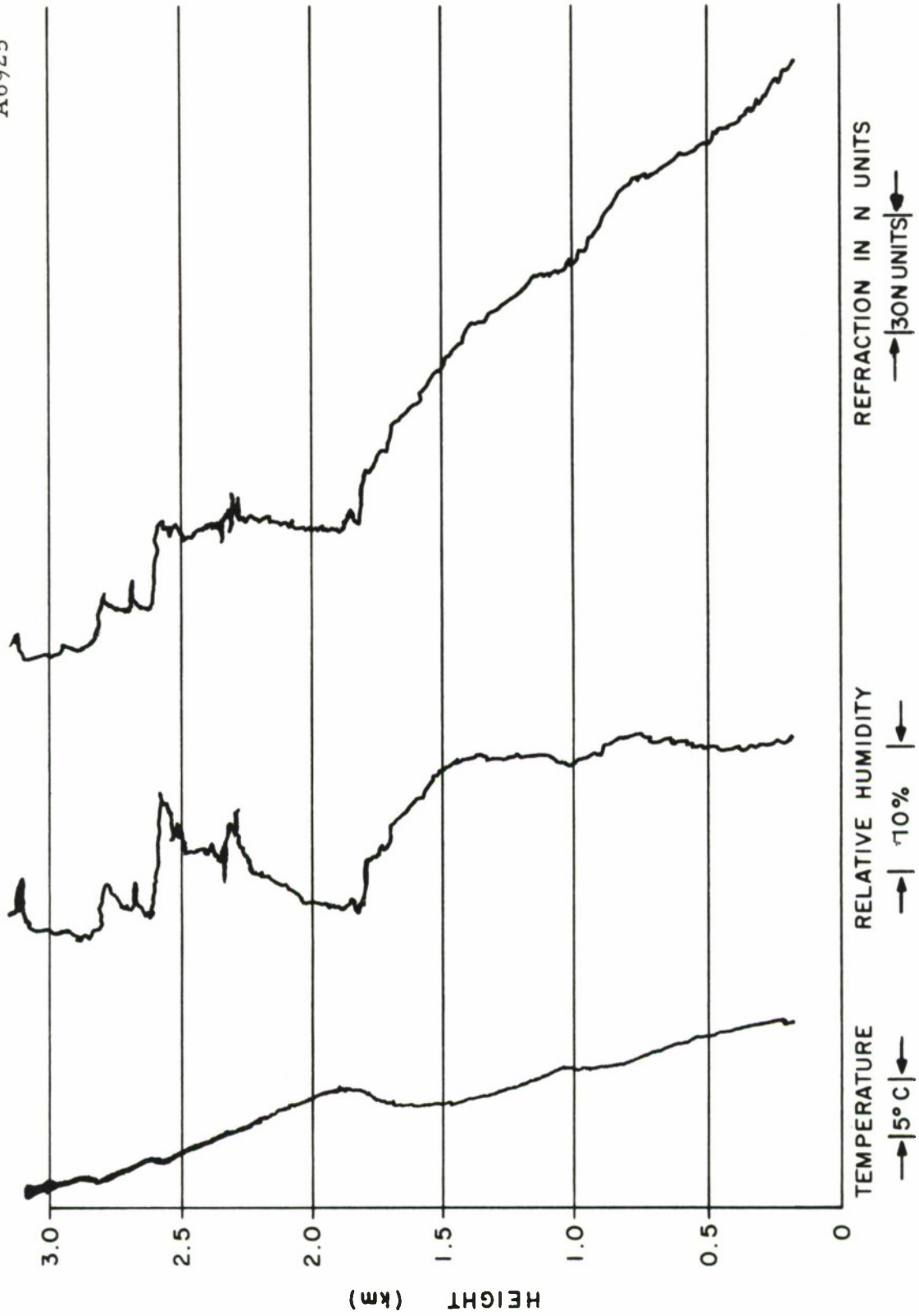
MISSION 14 - SPIRAL A

A6924

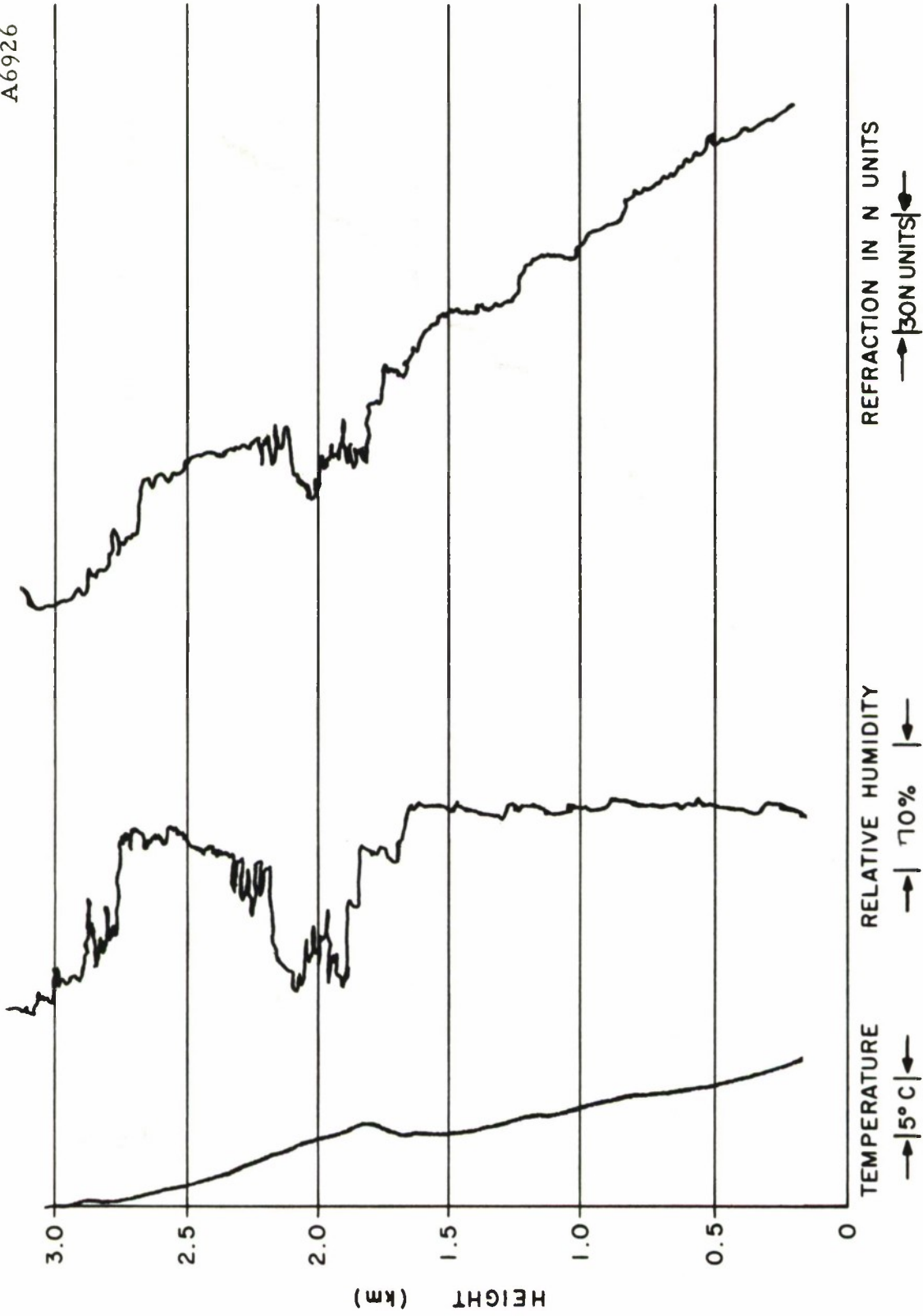


MISSION 14 - SPIRAL B

A6925

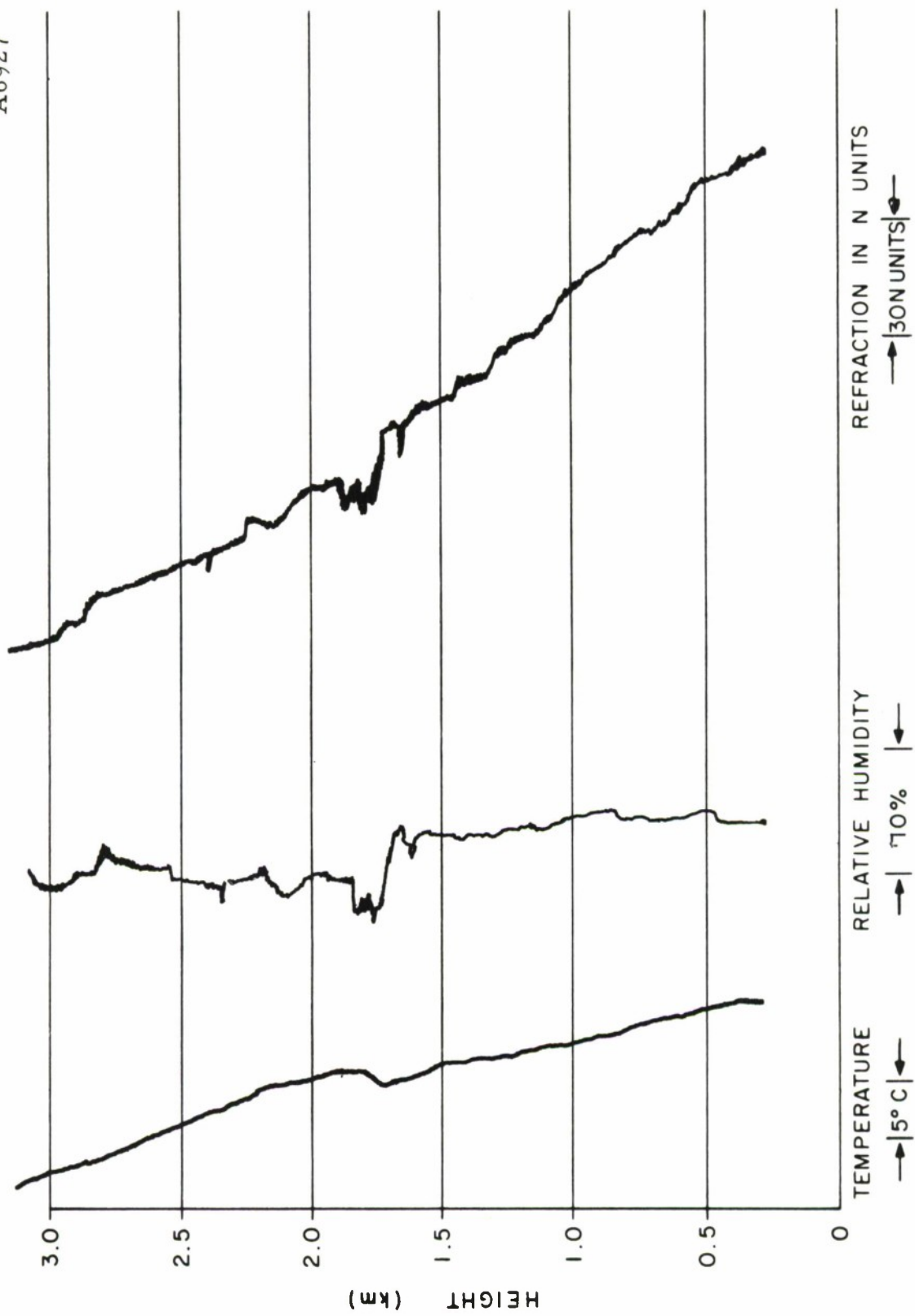


A6926

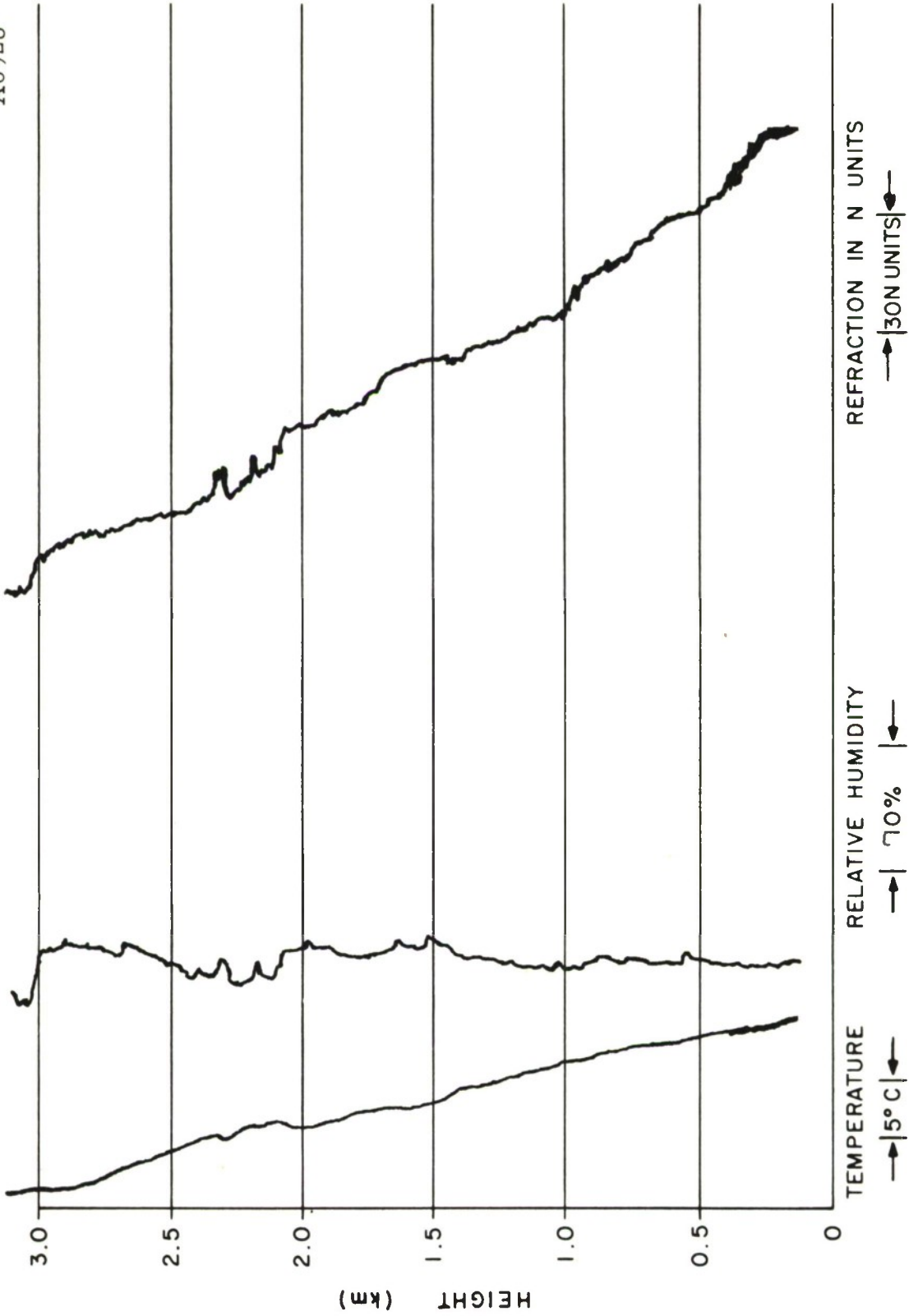


MISSION 14 - SPIRAL C

A6927

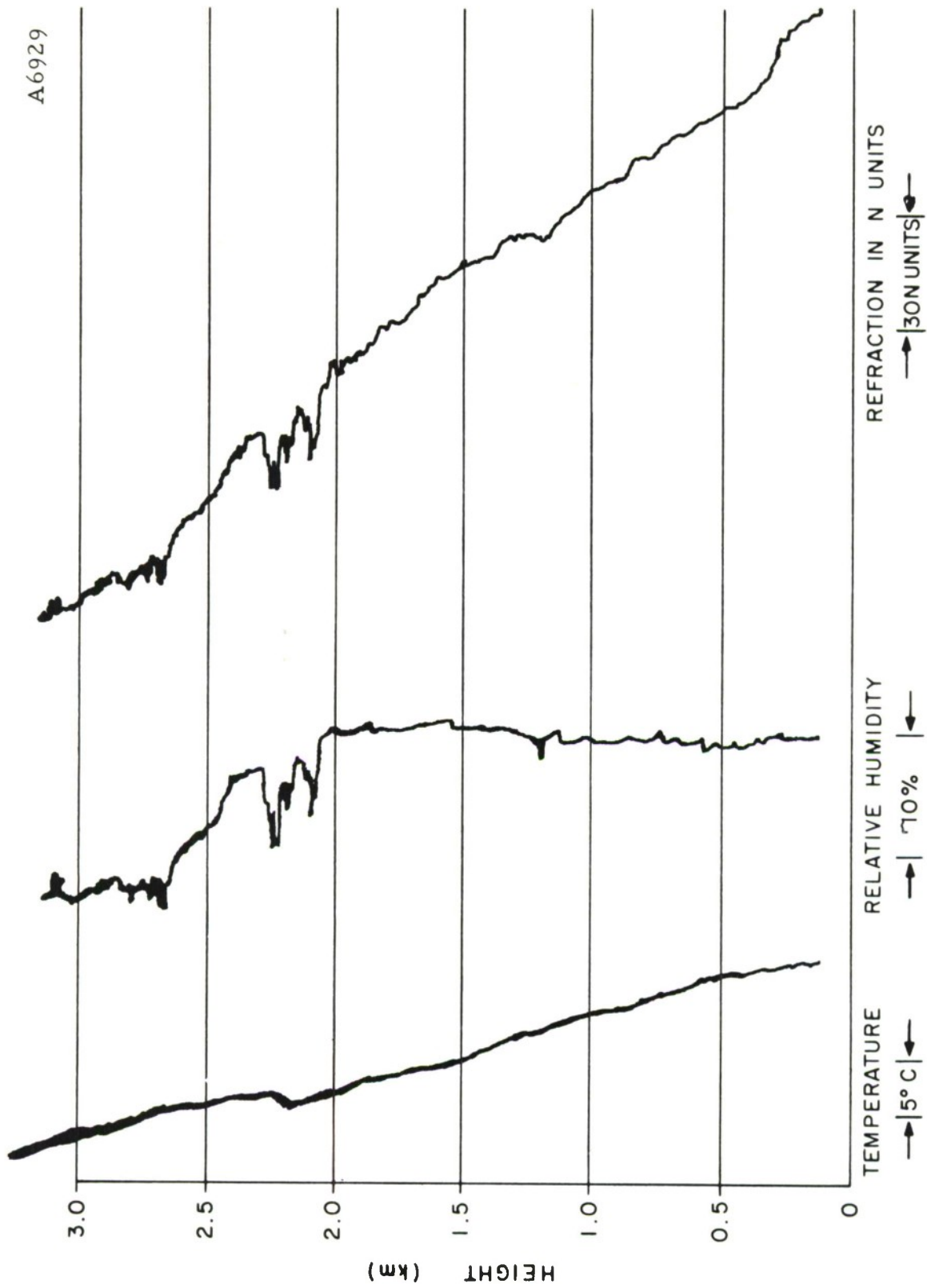


A6928

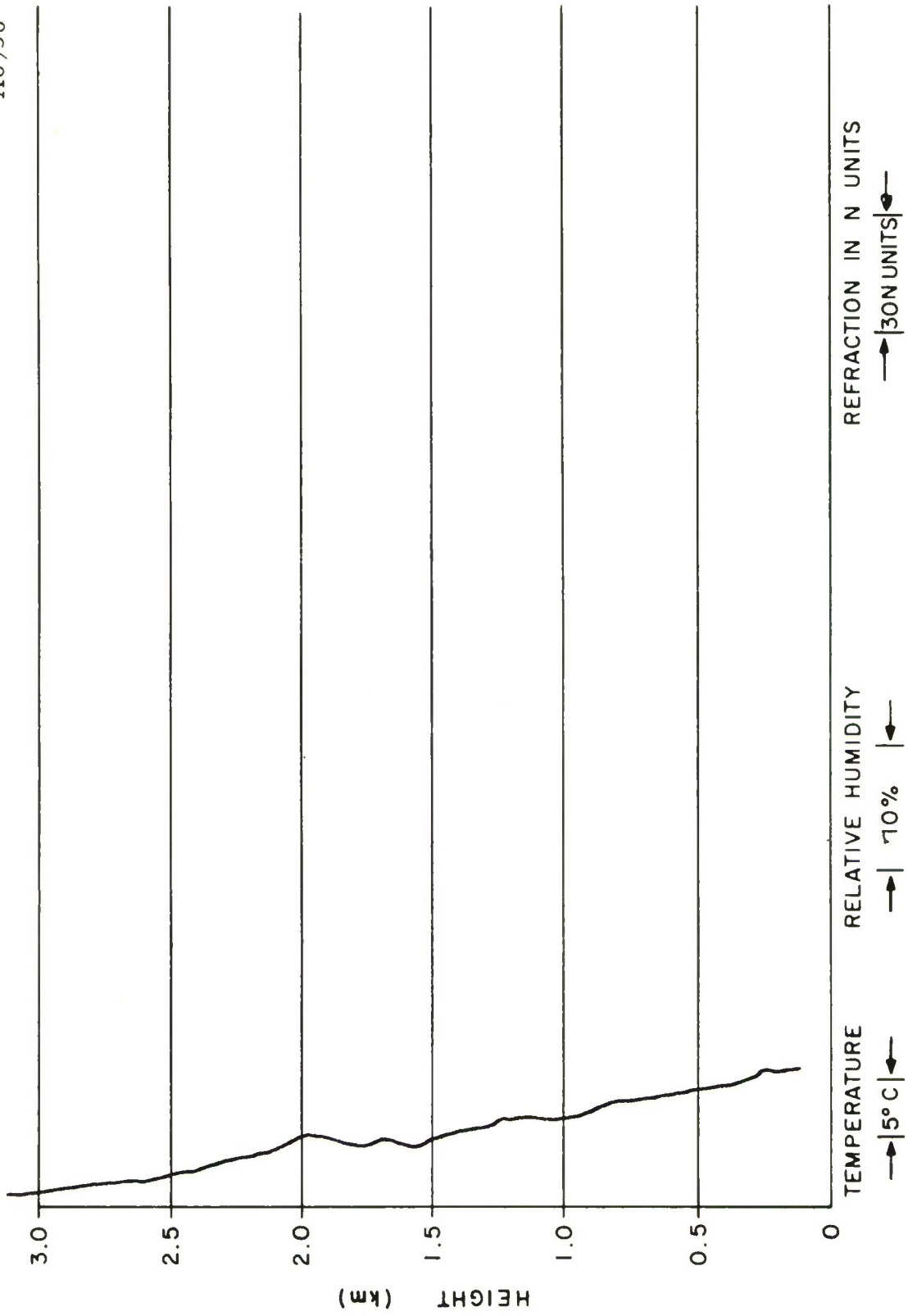


MISSION 14 - SPIRAL D

A6929

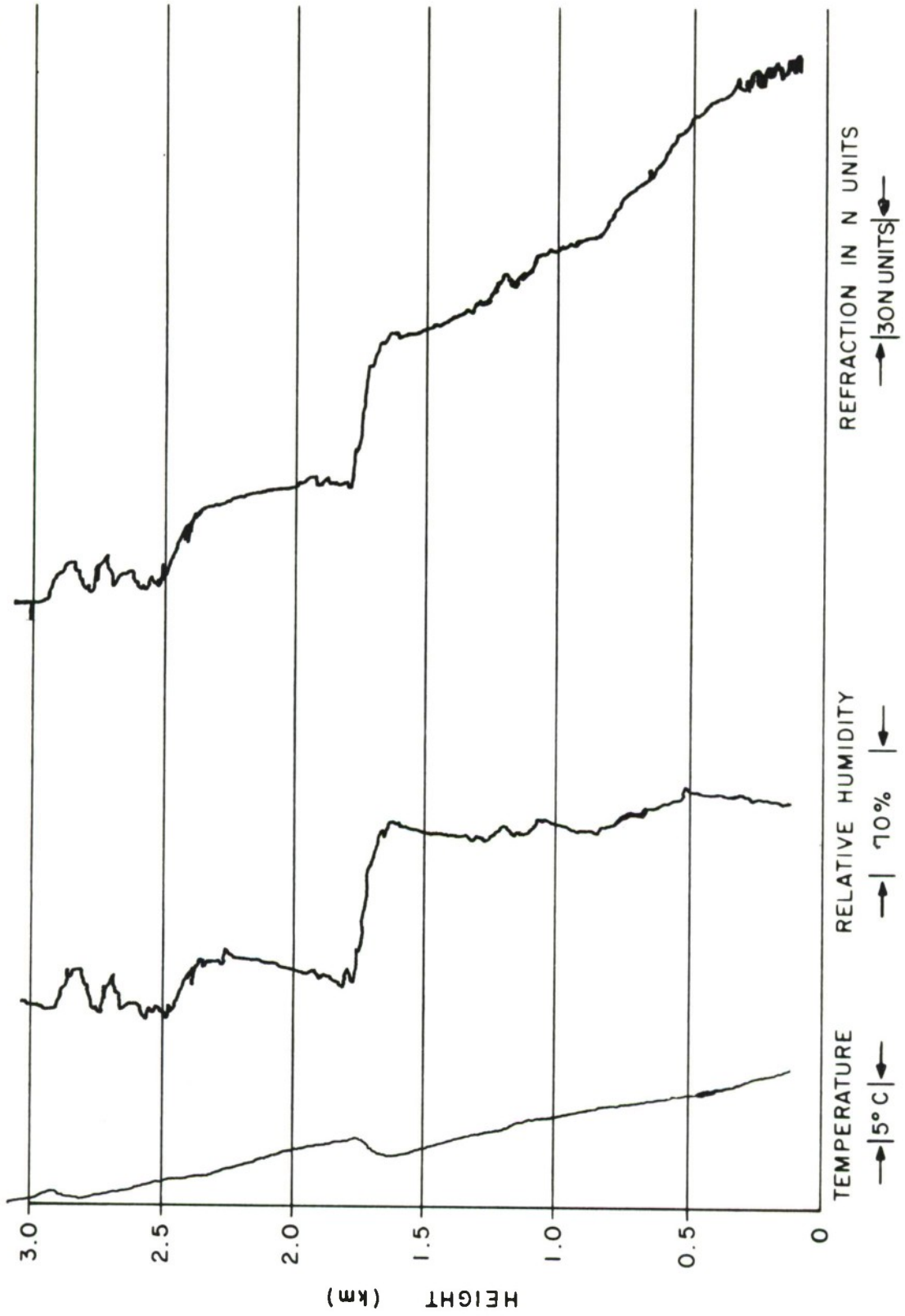


A6930



MISSION 14 - SPIRAL E

A6931



MISSION 14 - SPIRAL F

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13. ABSTRACT A series of meteorological measurements was made in the northern part of the Caribbean Sea, during the Spring of 1969, to characterize the Trade Wind Inversion and its effect on radio wave propagation. Among the measurements made were data collected from the sensors on the airborne platform of the USAF C-131 Convair (37812), which was provided for use on this contract. This report is a compendium of some of the airborne data, namely of the magnetic tape analog measurements of air temperature, relative humidity, and radio refractivity recorded during test flights. The values of these parameters herein are relative, not absolute. Also, no corrections have been applied. No interpretations or correlations with other data obtained on the contract are included.			

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radio Propagation						
Refraction						
Trade Wind Inversion						
Ducting						
Meteorology						

ESD-TR-69-366 (August 1969)

Caribbean Upper Air Measurements Technical Report 1
of Caribbean Radio Ducting Investigations

R. J. Aldrich
J. R. Herlihy
L. G. Rowlandson

ERRATUM

1. Page 10, Mission 12 (23 March) - Spiral b 24-35 N, 82-37 W
Replaces 24-35 N, 87-32 W
2. Page 116, Mission 12 (23 March) - Spiral b 24-35 N, 82-37 W
Replaces 24-35 N, 87-32 W
3. Page 117, Drawing B6902 Spirals f and g not shown.
Spiral c is in line with debf.
4. Page 133, Drawing B6902 Spiral f not shown is at Key
West (a).
Spiral c lies in line with deb.
5. Page 145, Drawing B6902 Spiral f not shown is at Key
West (a).
Spiral c lies in line with deb.