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MEASUREMENTS OF WINDS AND TEMPERATURES AT ALTITUDES UP TO 65 KILOMETERS IN THE SOUTHERN HEMISPHERE

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By James C. Manning and Lloyd W. Chamberlain

SUMMARY

Meteorological data from 27 rocketsonde and corresponding radiosonde soundings conducted during the Mobile Launch Expedition of the National Aeronautics and Space Administration in March and April 1965 off the west coast of South America are presented as plots of temperature and wind as functions of altitude. The wind data are shown in plots of west-to-east and south-to-north velocity components. Summary time and space cross sections of the data are also shown.

INTRODUCTION

As a participant in the International Year of the Quiet Sun 1964-1965 (IQSY), the National Aeronautics and Space Administration launched a series of rocket-borne experiments from a shipborne facility in the southern hemisphere between about latitude 4° N and latitude 60° S (ref. 1). The experiments were conducted during March and April 1965 and were designed to aid in providing an understanding of the changes in behavior of the solar-geophysical phenomena. The IQSY studies of this expedition coupled with other International Geophysical Year/International Geophysical Cooperation (IGY/IGC) studies should provide an understanding of the changes in behavior of the solar-geophysical phenomena through an entire solar cycle. A part of this program was the measurement of meteorological characteristics of the atmosphere (wind and temperature) between sea level and about 65 km. The experiments were conducted from a converted World War II escort carrier in the Pacific Ocean along the west coast of South America. Standard radiosonde balloon-borne instruments were used between sea level and 30 km and rocket-borne instruments were used between 20 to 65 km; therefore, about a 10-km overlap was provided.

All measurements were made during the early fall transition season of the southern hemisphere. During this period, large-scale circulation changes take place in the upper and middle stratosphere when the wintertime polar cyclone starts to form. Data are presented for 15 rocket-borne temperature observations, 25 rocket-borne wind observations, and the accompanying balloon-borne radiosondes.

The purpose of this paper is to present the meteorological data to assist in the analysis and interpretation of other geophysical data from the expedition, and to contribute to the understanding of the southern-hemisphere circulation.

OPERATIONS

The meteorological-rocket launch locations are shown in figure 1. The expedition traversed the Panama Canal and commenced meteorological launches on March 7, 1965, near latitude 4° N and completed the launchings on April 16, 1965, near latitude 60° S. Approximately one-half of the soundings were conducted near Lima, Peru, to obtain geophysical information near the magnetic equator. During the expedition, 27 meteorological rockets were launched. A balloon-borne radiosonde was released as close as feasible to each rocket launch. Table I gives locations and times of all launches and radiosonde releases.

Rocket Systems

The two types of rockets used during the expedition for meteorological soundings were the Arcas and the boosted dart (Judi dart). The Arcas rocket system is shown in figure 2 shortly after shipboard launch. This rocket is a single-stage end-burning configuration and maintains a thrust of about 5g (49 m/sec^2) for about 29 seconds. Burnout of the rocket motor occurs near 14 km and the system then coasts to approximately 60 km. Near apogee, the nose cone separates from the motor case and the rocketsonde (payload) is deployed. The data are obtained as the payload descends through the atmosphere. The telemetering payload used during the expedition consisted of an Arcasonde 1A (ref. 2) suspended from a 4.57-meter-diameter metalized parachute. The temperature data measured by the payload sensor (an aluminum-coated bead thermistor having a nominal diameter of 0.254 mm) were telemetered to the GMD-1B receiver station located on the hangar deck of the ship while the wind data were obtained by tracking the drift of the metalized parachute with the MPS-19 shipboard radar. In addition to the Arcas systems containing the Arcasonde 1A, several other Arcas systems were flown during the expedition by the U.S. Naval Ordnance Test Station, China Lake, California, to measure ozone in the atmosphere. Because the ozone payloads were also suspended from a metalized parachute, wind data were obtained during three of these experiments and are included in this paper.

The second type of rocket system, the boosted-dart configuration shown shortly after launch in figure 3, was supplied by the Sandia Corporation and was used to obtain only atmospheric winds. The boosted-dart configuration provides a thrust of about 50g (490 m/sec^2) for about 2 seconds. The dart then separates from the rocket case and coasts to about 60 km. The payloads consisted of 0.127-mm-diameter copper chaff (ref. 2) which was ejected near apogee. Atmospheric winds are obtained by radar tracking of the drift of the chaff cloud.

Radiosonde

The radiosonde (ref. 3) is a meteorograph combined with a radio transmitter and is carried aloft by a neoprene balloon with an ascent velocity of approximately 6.7 meters per second. The radiosonde transmits radio signals that can be recorded at a ground station (GMD-1B) and interpreted in terms of pressure, temperature, and humidity during the ascent. During the expedition, all radiosonde balloons were tracked by the MPS-19 radar in order to determine atmospheric winds and altitudes. The temperature-sensing element is an exposed rod thermistor 2 mm in diameter and 3.8 cm in length.

Launching and Tracking Equipment

Figure 4 shows the equipment arrangement on the flight deck and stern part of the hangar deck of the launching platform, the USNS Croatan. Arcas and Hasp meteorological-rocket launchers, which were adjusted in elevation by hand and in azimuth by turning the ship, were located on the fantail of the hangar deck near the balloon-inflation shelter as shown in figure 4. Two MPS-19 radar tracking vans were located near the forward end of the flight deck. Radar plot boards, other radar recording equipment, and a deck-mounted gyro system used for correcting radar data for the ship's motion were located on the hangar deck directly below the tracking van. Numerous antennas for communications and other experiments, as well as Nike launchers, were also located on the flight deck. A side view of the USNS Croatan (fig. 5) shows the GMD tracking-antenna enclosure. The meteorological van containing the remainder of the GMD tracking system and the payload preparation and checkout area were located on the hangar deck directly below the GMD antenna.

DISCUSSION OF RESULTS

Temperature Data

The complete temperature profiles consisting of rocketsonde and radiosonde measurements as functions of altitude are shown in figure 6. All temperature data were reduced in accordance with routine meteorological procedures (ref. 2); however, studies (refs. 4 to 7) have indicated that corrections may be needed for bead-thermistor measurements above 40 km. At an altitude of about 60 km, corrections may be as large as 10° C.

Similarly, corrections may be needed for the radiosonde data above 30 km. Because of the controversial nature of these corrections, no attempt was made to apply the corrections in this paper.

The rocketsonde and radiosonde temperature data were generally in agreement within a few degrees within the overlap region with the exception of the data shown in figure 6(e) at about 30 km and figure 6(k) at about 28 km. The differences in the temperature measurements in the overlap regions may be due in part to the time and space variations between rocketsonde and radiosonde measurements at the overlap altitude.

Several rocketsonde and supporting radiosonde temperature profiles obtained during the cruise from Lima, Peru, to latitude 59°52' S, between April 3 and April 13, are shown in figure 7. The rocketsonde and radiosonde profiles are connected at the lower end of the rocketsonde measurement. The tropopause apparently is located at an altitude of about 17 km in the low latitudes (about 14°34' S) and slopes downward to about 9 km near latitude 59°52' S. This trend was expected. The temperature profile measured at latitude 7°22' S shows the coldest tropopause recorded -83° C and a rather warm temperature of 8° C at 45-km altitude. The sounding at latitude 30°52' S shows a warm tropopause at 12 km and another leaf of the tropopause at 16 km, and an increase in temperature to just above 0° C near 50 km. The sounding conducted at latitude 47°02' S (fig. 6(j)) shows the warmest (-58° C) and the lowest (9 km) tropopause.

A composite profile of the temperature observations made between latitude 47° S and 60° S is shown in figure 8 to illustrate the deep isothermal layers commencing near the tropopause that characterize the data taken during these southernmost soundings. This deep layer is especially evident in the soundings taken near latitude 59°52' S (fig. 6(m)) where the isothermal layer extends from the tropopause to about 35 km.

Wind Data

Detailed wind plots of west-to-east and south-to-north components of wind velocity as a function of altitude are shown in figure 9. Wind-velocity values computed from the radar plot-board tracking data, containing data points every 10 seconds, were smoothed by computing means for 2-km layers. This procedure is identical to that utilized at NASA Wallops Station in smoothing rocket winds for the Meteorological Rocket Network (ref. 2).

A main source of error associated with the wind data obtained from the shipboard radar tracking was the ship's motion. A comparison of wind data taken from the MPS-19 shipboard radar and the FPS-16 radar located at NASA Wallops Station is shown in figure 10 to illustrate the radar-tracking error. This sample of data was obtained during a systems check, which was conducted off the coast of Wallops Island, Virginia, prior to the expedition to the southern hemisphere, and covers altitudes of approximately 31 to

55 km. The ship was located about 16 to 32 kilometers off the coast of Wallops Island and experienced rough seas comparable to those experienced near latitude 60° S. Because the FPS-16 radar is considered to be more accurate than the MPS-19 radar, some small differences in the quality of the tracking data would occur even if both radars were located on land. It is believed that the altitude data were not significantly affected at high altitudes and the large perturbations of the MPS-19 derived wind data shown in these plots are for the most part a result of the ship's motions. Because the data exhibit perturbations that are questionable, the wind data should be smoothed if used in further analyses.

As stated previously, all meteorological observations taken during the expedition were made during the early fall transition season of the southern hemisphere; therefore, large variations in the middle and upper stratospheric winds can take place. The maximum wind measured during the expedition, about 280 knots from the northwest, is shown in component form in figure 9(v). The wind measurement was made at about latitude 59°52' S and longitude 77°58' W on April 13, 1965.

A summary of all the wind data from latitudes 4° N to 60° S is shown in figure 11. The lengths of the bars indicate the velocity of the east and west wind components (east-to-west winds negative and west-to-east winds positive). The dashed line separates the east and west wind components. From latitudes 4° N to 13° S (off Lima, Peru) easterly components were measured at altitudes from 10 to 50 km except at 20 km near the equator where light winds from the west (westerly) were observed. Winds were consistently from the east (easterly) and about 100 knots in velocity near 30 km. At latitudes 10° S to 15° S, the easterly winds changed to westerlies at an altitude of about 45 km and increased in velocity to about 80 knots at about 50 km in altitude. South of latitude 35° S, only westerlies were present at all levels. Because the wind velocities at tropospheric jetstream levels were less than 50 knots, the southern hemisphere was still considered to be in the transition season.

Summary Charts

Thirteen meteorological rockets were launched near latitude 13° S and longitude 78° W, that is, near the geomagnetic equator. A time-height section analysis of wind and temperature data is presented in figure 12. Some data were shifted slightly in time and a few data were omitted to prevent overcrowding in figure 12. It was assumed that small departures from a fixed location (see table 1) could be neglected in the broad-scale pattern. Figure 12 shows the persistence of winds from the east (easterlies) below about 50 km in early March 1965. At higher levels, winds from the west (westerlies) dominate and they propagate downward during the 3-week period. This propagation is shown by the dashed line, the demarcation line or boundary between westerlies and easterlies, descending from 49 to 43 km. In early March 1965, the cold tropical tropopause is located near 17 km at the lower boundary of the deep easterlies, and it appears to be located during the remainder of the period as indicated by the heavy solid line. The horizontal thermal gradient dictated by the generally increasing easterly components from the tropopause to about 35 km would place colder air toward the equator.

Wind and temperature observations from latitude 12° S to 60° S, April 2 to April 15, for 13 meteorological rockets is presented in figure 13. The movement in time and space is neglected and only large-scale circulation features of both the rocketsonde and radiosonde data are considered. Again, some data were shifted slightly or omitted to prevent overcrowding. Figure 13 illustrates the cold core associated with the low-latitude tropopause and the isothermal lower stratosphere over the more poleward regions. As illustrated by the heavy solid line, the tropopause is near 17 km in the lower latitudes and slopes downward to about 9 km at latitude 60° S. Poleward of latitude 40° S and within the 26- to 46-km layer, figure 13 shows a significant decrease in temperature associated with the vertical increase in the westerly wind component. Horizontal temperature gradients in the 25- to 35-km layer apparently were weak over the low and middle latitudes. Although it is not possible to define the stratopause clearly from this limited sample of data, it appears that the stratopause is located between 45 and 50 km at the low latitudes and slopes upward toward the pole.

Some further analysis of these data is given in reference 8. In reference 8, temperature corrections were made and additional smoothing was applied to the wind profiles.

CONCLUDING REMARKS

Temperature and wind data taken in the southern hemisphere between latitudes 4° N and 60° S and longitudes 74° W and 84° W for 15 rocket-borne temperature and 25 rocket-borne wind observations are presented as a function of altitude. In most cases, corresponding radiosonde temperature and wind data are presented with the rocketsonde data. This set of observations is an effort to contribute to the understanding of the southern-hemisphere circulation and to assist in the analysis of other geophysical data obtained during the expedition.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., November 15, 1967,
607-06-00-01-23.

REFERENCES

1. Anon.: Mobile Launch Expedition: IQSY-Related NASA Shipboard Sounding-Rocket Investigations. Trans. , Am. Geophys. Union (IGY Bull. no. 94), vol. 46, no. 2, June 1965, pp. 437-441.
2. Meteorol. Working Group, ed.: The Meteorological Rocket Network. IRIG Doc. No. 111-64, Range Commanders Council, Feb. 1965. (Available from DDC as AD 464 583.)
3. Webb, Willis L.: Structure of the Stratosphere and Mesosphere. Academic Press, Inc., 1966.
4. Drews, William A.: A Thermistor Arrangement to Improve Temperature Measurements at High Altitudes. NASA CR-533, 1966.
5. Wagner, N. K.: Theoretical Accuracy of a Meteorological Rocketsonde Thermistor. J. Appl. Meteorol., vol. 3, no. 4, Aug. 1964, pp. 461-469.
6. Barr, William C.: Theoretical Considerations in the Design of Atmospheric Temperature-Sensing Elements. Tech. Rept. 2195, U.S. Army Signal Res. Develop. Lab., Apr. 1961. (Available from DDC as AD 255 896.)
7. Henry, Robert M.: Corrections for Meteorological Rocket Temperature Soundings on an Individual Basis. Paper presented at Am. Meteorol. Soc. Conf. on High-Altitude Meteorology and Space Weather (Houston, Tex.), Mar. 29-31, 1967.
8. Finger, Frederick G.; and Woolf, Harold M.: Southern Hemisphere Stratospheric Circulation as Indicated by Shipboard Meteorological Rocket Observations. NASA TM X-1346, 1967.

TABLE I.- METEOROLOGICAL OBSERVATIONS IN THE SOUTHERN HEMISPHERE

Rocket systems						Radiosondes			
Launch date	Launch location		Launch time, GMT	Vehicle type	Purpose (a)	Release date	Release location		Release time, GMT
	Latitude	Longitude					Latitude	Longitude	
3- 7-65	3°55.5' N	82°46' W	1909	Arcas[b]	W	3- 7-65	3°52' N	82°25' W	2115
3- 9-65	3°04' S	84°23' W	1903	Arcas[b]	W	3- 9-65	3°04' S	84°23' W	2130
3-10-65	7°22' S	83°45' W	2130	Arcas	T	3-10-65	7°22' S	83°35' W	1654
3-11-65	9°32' S	84°10' W	2338	Judi dart	W		No data		
3-16-65	12°55' S	78°00' W	1944	Arcas	W, T	3-16-65	13°00' W	77°57' W	2055
3-17-65	12°54' S	78°02' W	1518	Judi dart	W	3-17-65	12°38' S	78°03' W	1201
3-18-65	12°49' S	77°58' W	1952	Arcas	W, T	3-18-65	12°50' S	77°58' W	2125
3-19-65	13°06' S	78°00' W	1558	Judi dart	W	3-19-65	12°50' S	78°06' W	1200
3-21-65	12°57' S	78°03' W	1515	Arcas	W, T	3-21-65	12°57' S	78°03' W	1126
3-22-65	12°28' S	77°54' W	1944	Judi dart	W		No data		
3-24-65	11°34' S	78°23' W	1913	Arcas	W, T	3-24-65	12°26' S	78°29' W	2042
3-25-65	9°02' S	79°56' W	1743	Judi dart	W		No data		
3-27-65	14°10' S	77°59' W	1924	Arcas	W, T	3-27-65	14°18' S	77°55' W	2052
3-28-65	16°01' S	78°00' W	1953	Judi dart	W		No data		
4- 2-65	12°19' S	78°11' W	1550	Arcas	W, T	4- 2-65	12°56' S	78°04' W	1729
4- 3-65	14°34' S	77°47' W	0018	Arcas	W, T	4- 3-65	14°34' S	77°47' W	0155
4- 4-65	24°36' S	76°01' W	1800	Arcas	W		No data		
4- 5-65	30°52' S	75°00' W	2119	Arcas	W, T	4- 5-65	30°52' S	75°00' W	1830
4- 6-65	35°12' S	74°16' W	1816	Arcas[b]	W	4- 6-65	35°12' S	74°16' W	1957
4- 8-65	39°07' S	75°11' W	1530	Judi dart	W		No data		
4-10-65	47°02' S	77°45' W	1604	Arcas	W, T	4-10-65	46°22' S	77°45' W	1210
4-11-65	48°35' S	77°42' W	0011	Arcas	T	4-10-65	47°52' S	77°44' W	2034
4-11-65	52°11' S	77°49' W	1533	Arcas	W, T	4-11-65	51°17' S	77°42' W	1208
4-13-65	59°52' S	77°58' W	1956	Arcas	W, T	4-13-65	59°51' S	78°03' W	2151
4-14-65	59°46' S	77°50' W	0038	Arcas	W, T	4-13-65	59°51' S	78°03' W	2151
4-15-65	52°28' S	78°09' W	1842	Arcas	W, T	4-15-65	52°06' S	78°02' W	2051
4-16-65	51°20' S	78°05' W	0018	Arcas	W	4-15-65	52°06' S	78°02' W	2051

[a] W, wind observation; T, temperature observation.

[b] Naval Ordnance Test Station ozone payload; only wind data obtained for meteorological program.

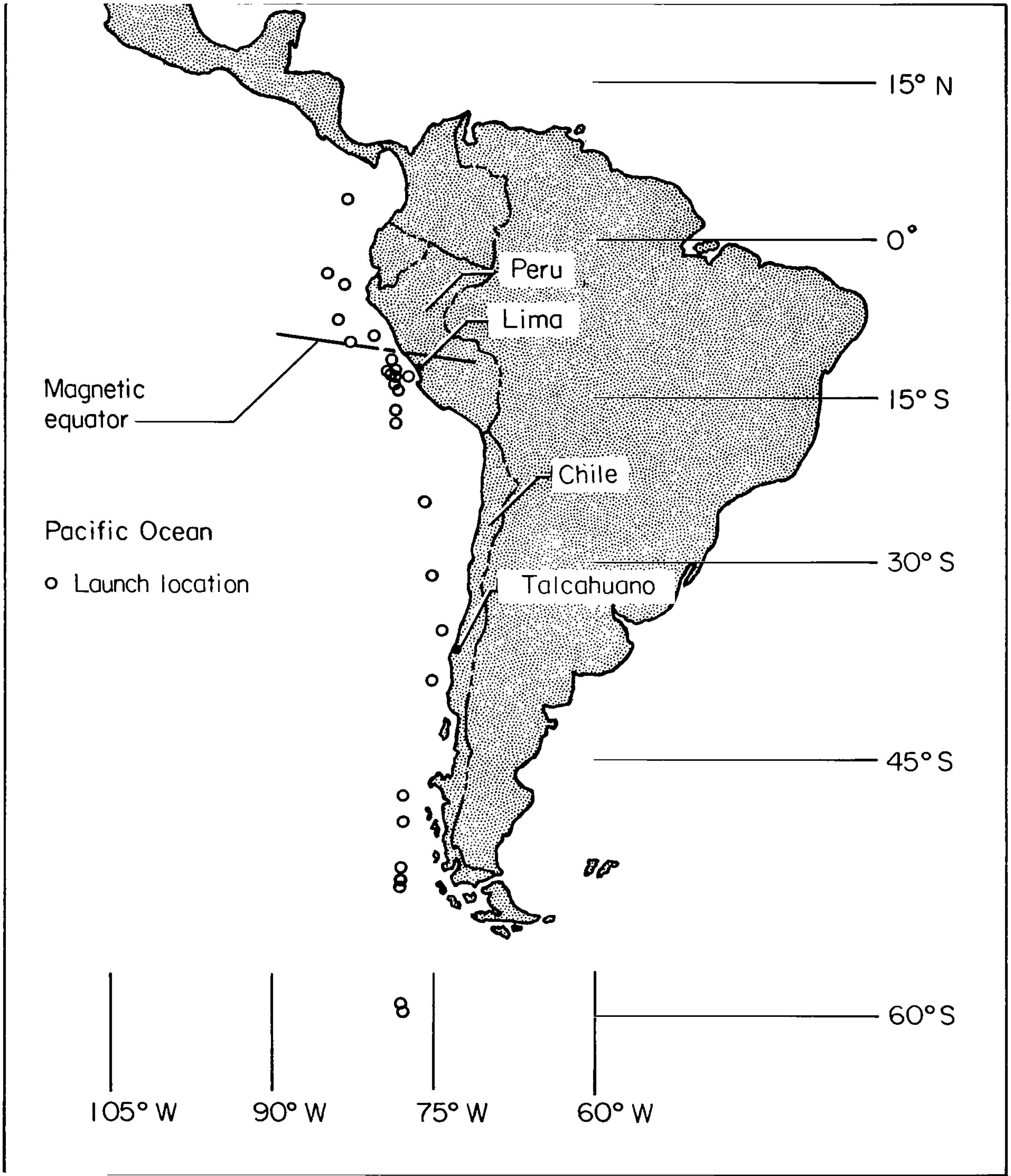


Figure 1.- Meteorological-rocket launch locations in the southern hemisphere.

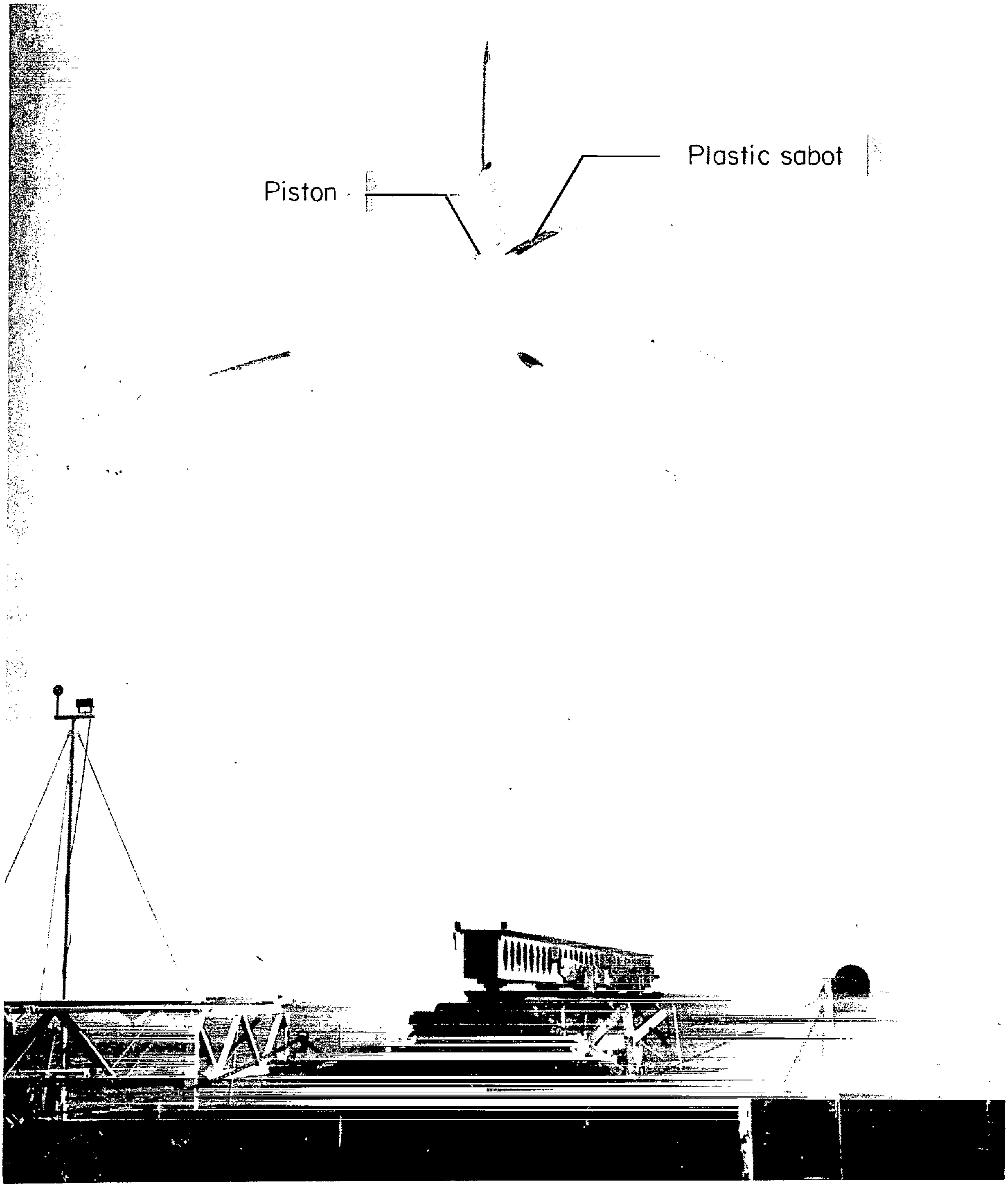


Figure 2.- Arcas shipboard launch. L-67-8722

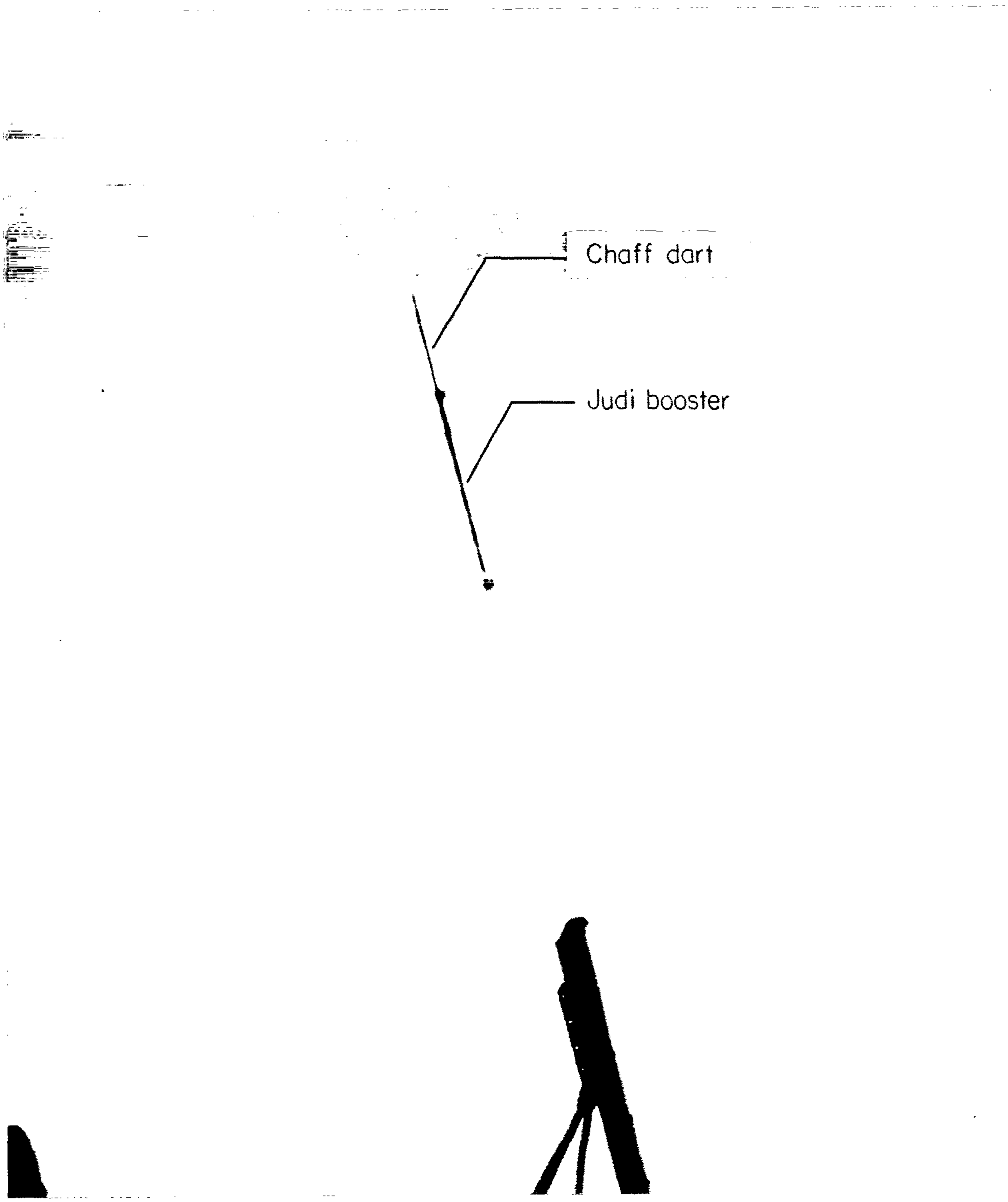


Figure 3.- Boosted-dart launch. L-67-8723

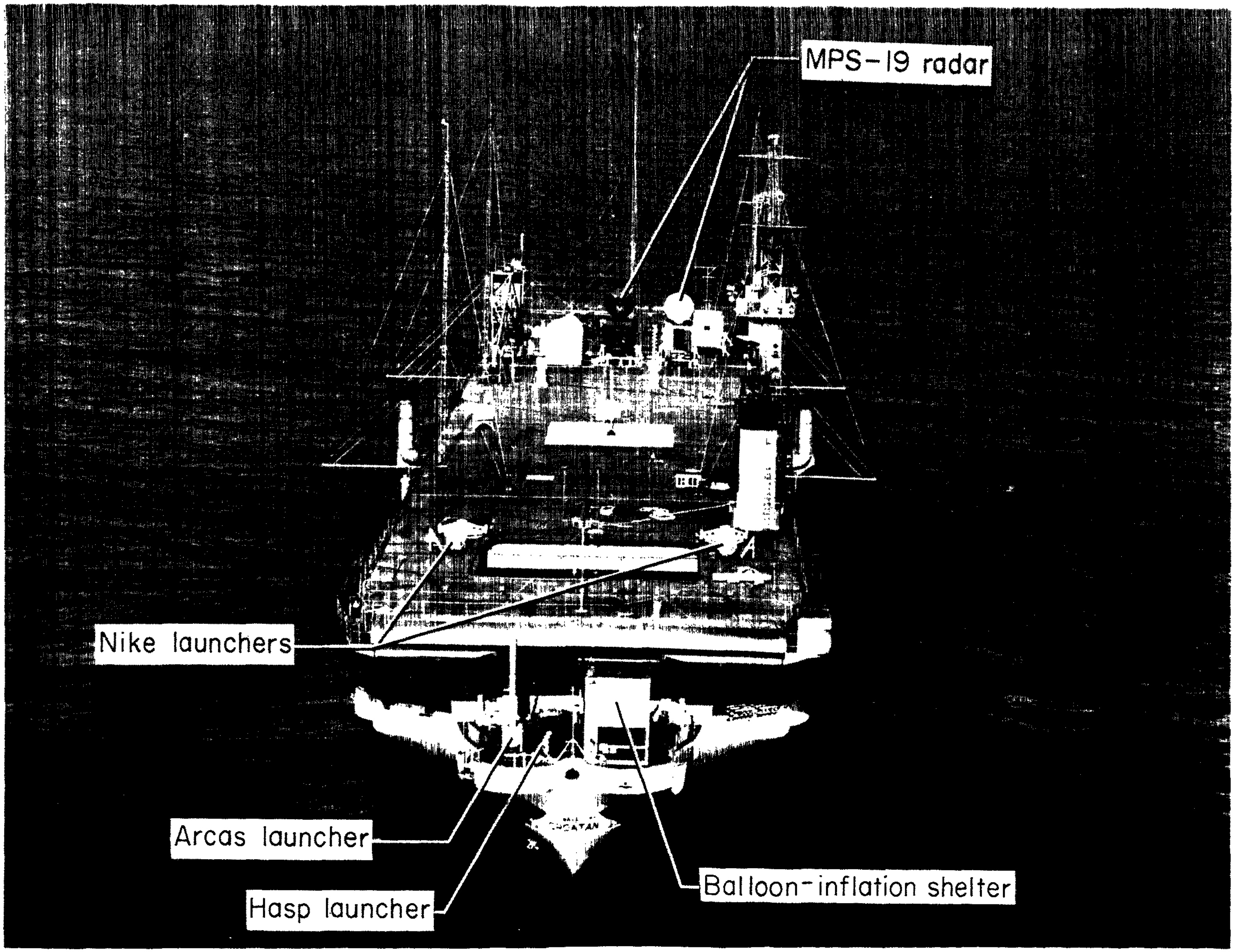


Figure 4.- Stern view of USNS Croatan. L-67-8724

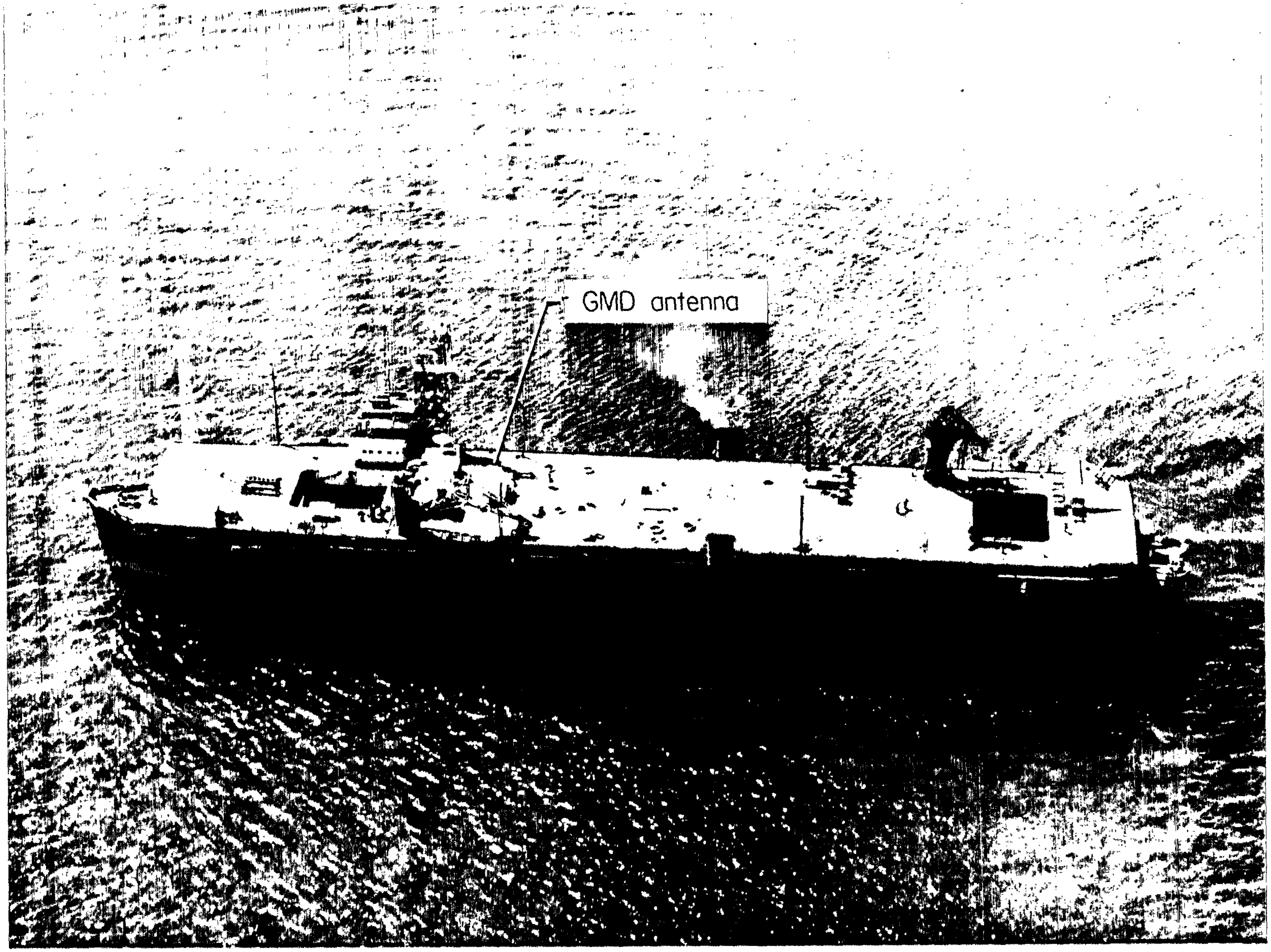
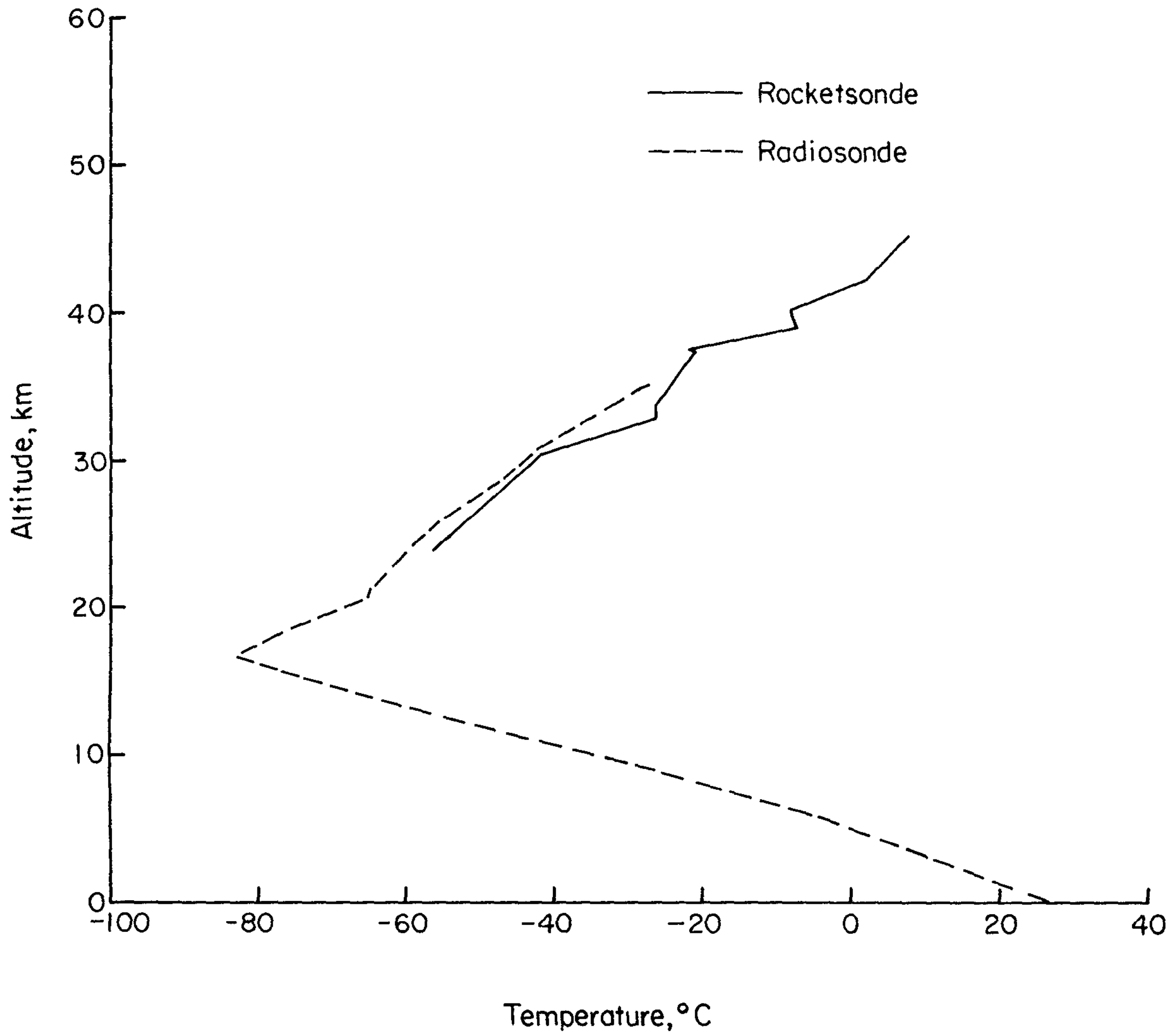


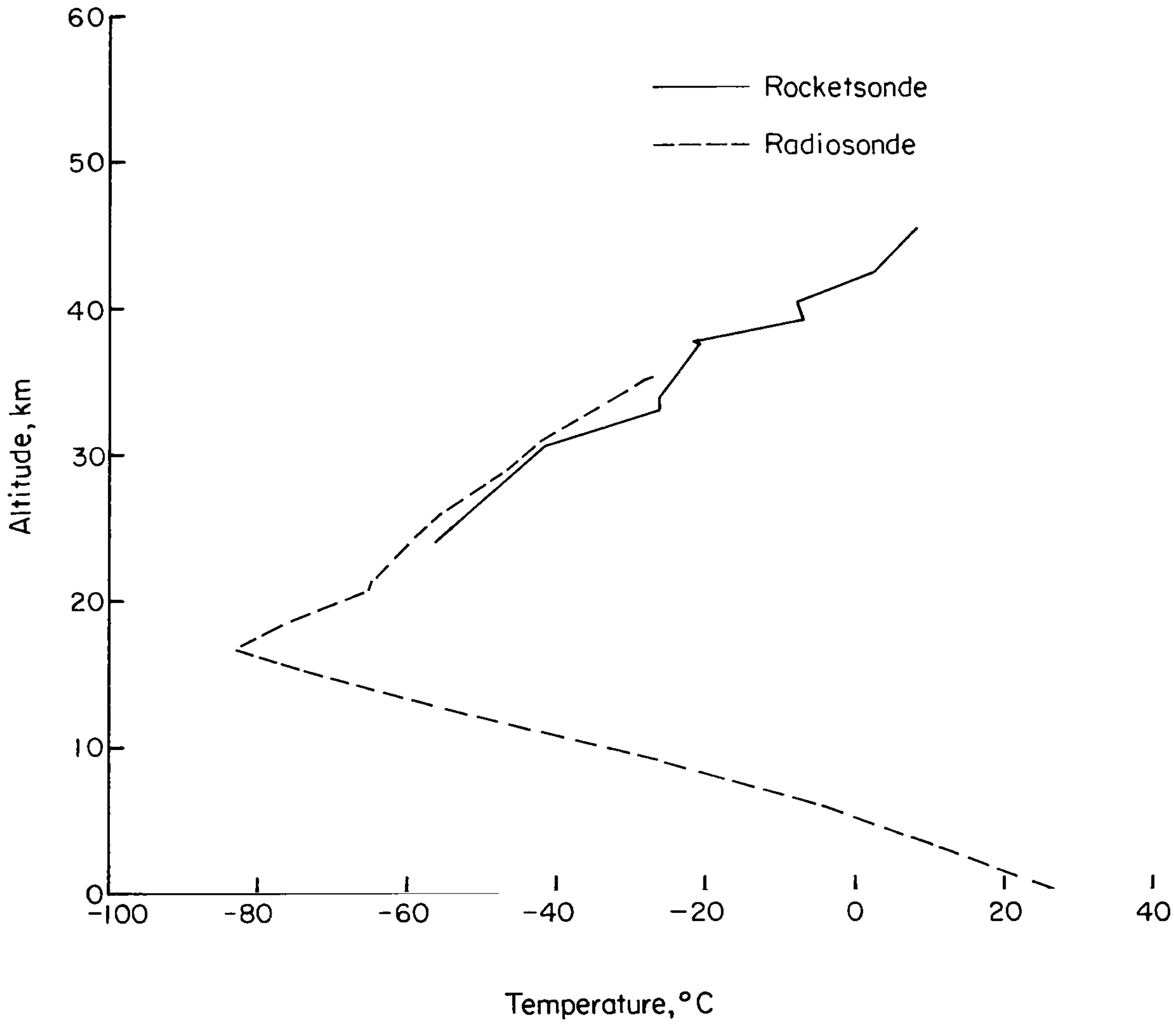
Figure 5.- Side view of USNS Croatan.

L-67-8725



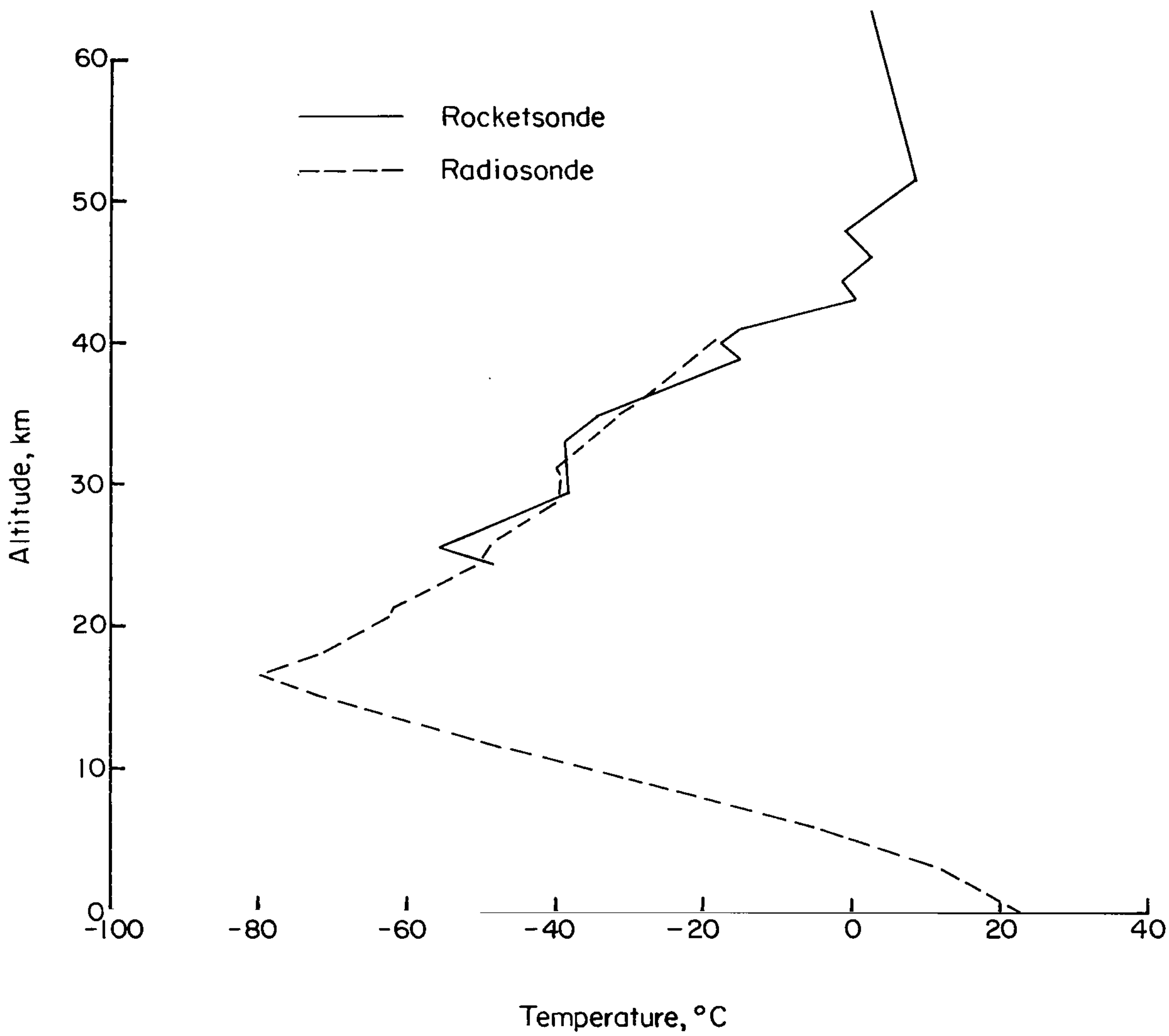
(a) March 10, 1965; latitude 7°22' S and longitude 83°45' W.

Figure 6.- Temperature profiles.



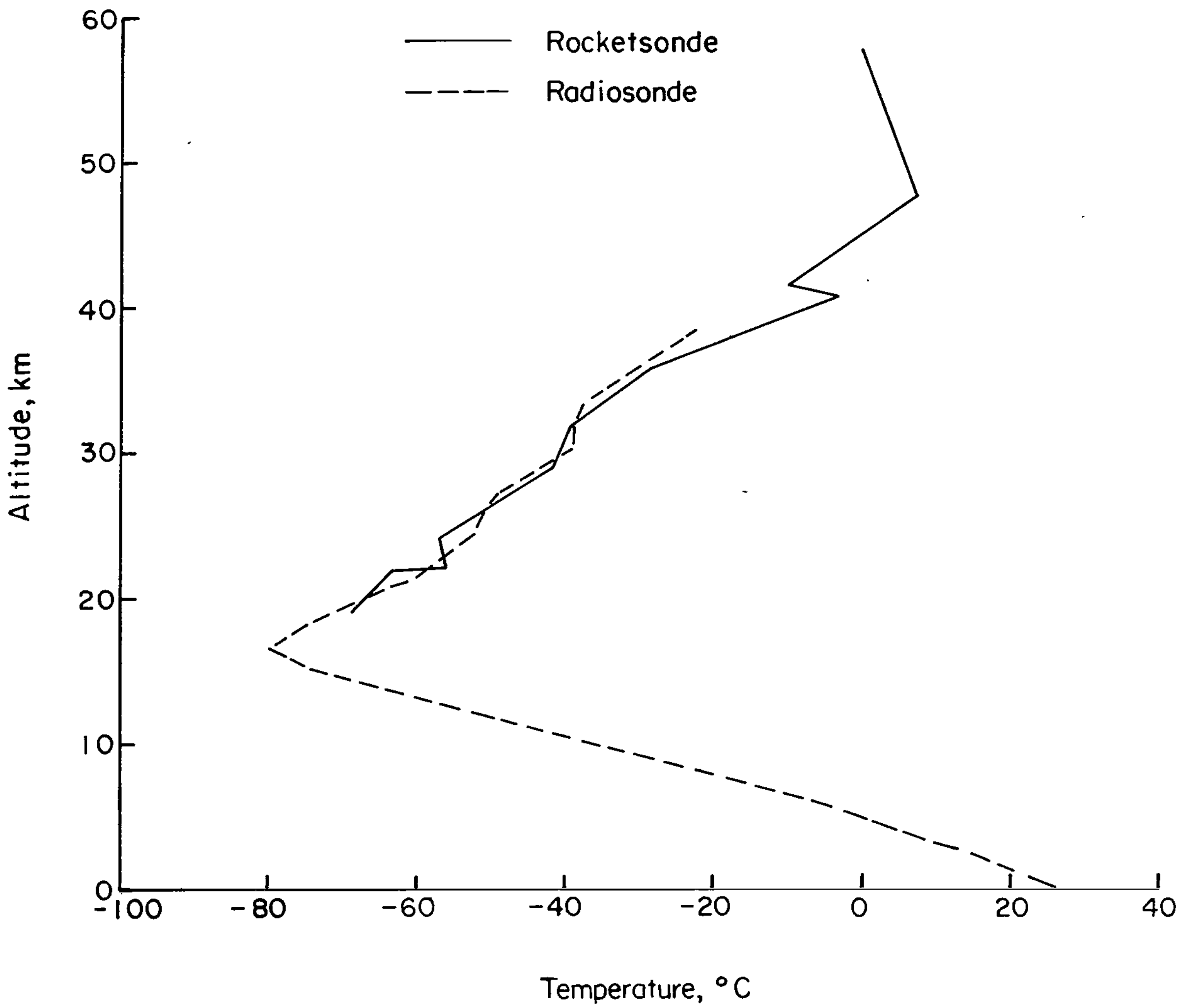
(a) March 10, 1965; latitude 7°22' S and longitude 83°45' W.

Figure 6.- Temperature profiles.



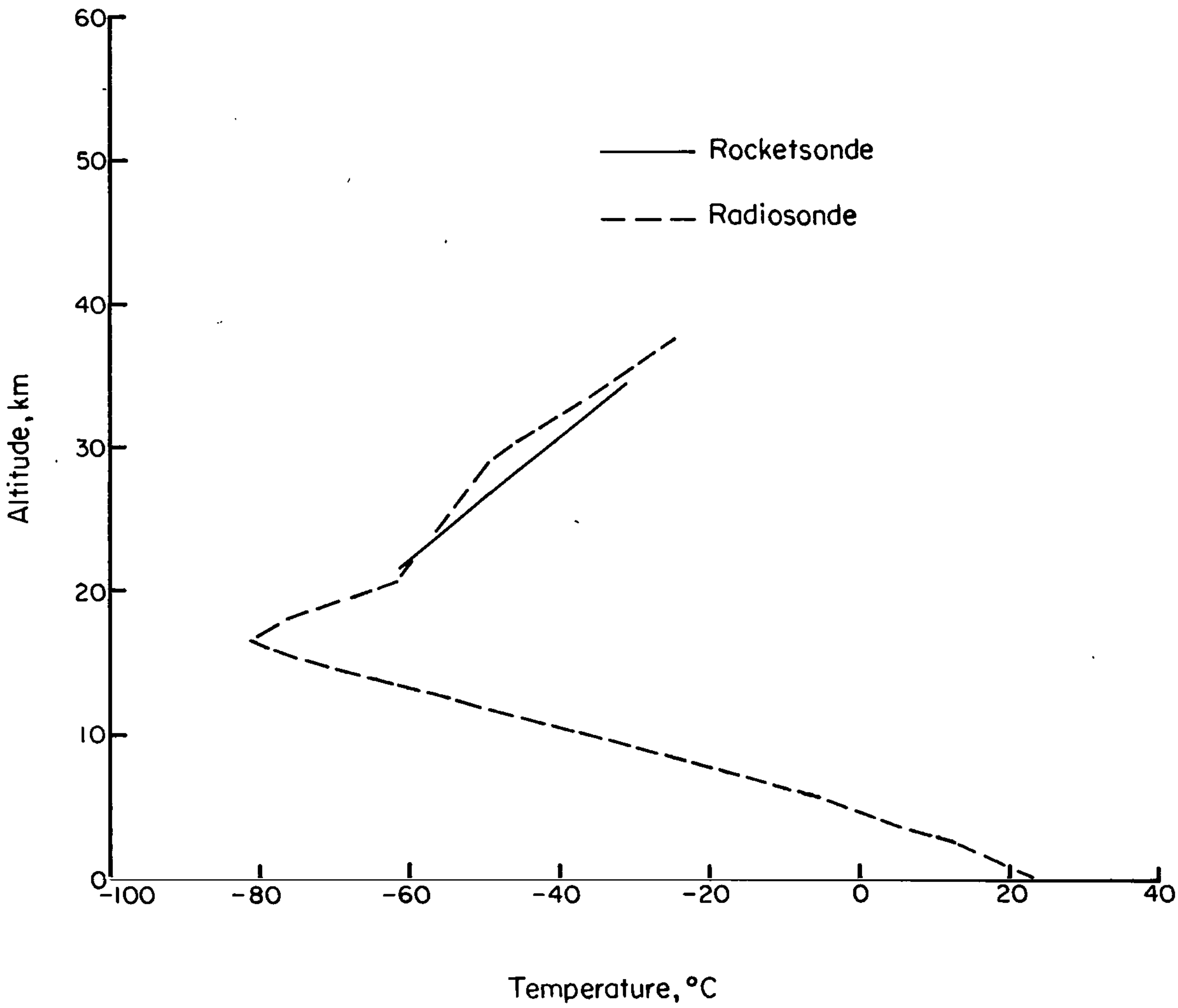
(b) March 16, 1965; latitude 12°55' S and longitude 78°00' W.

Figure 6.- Continued.



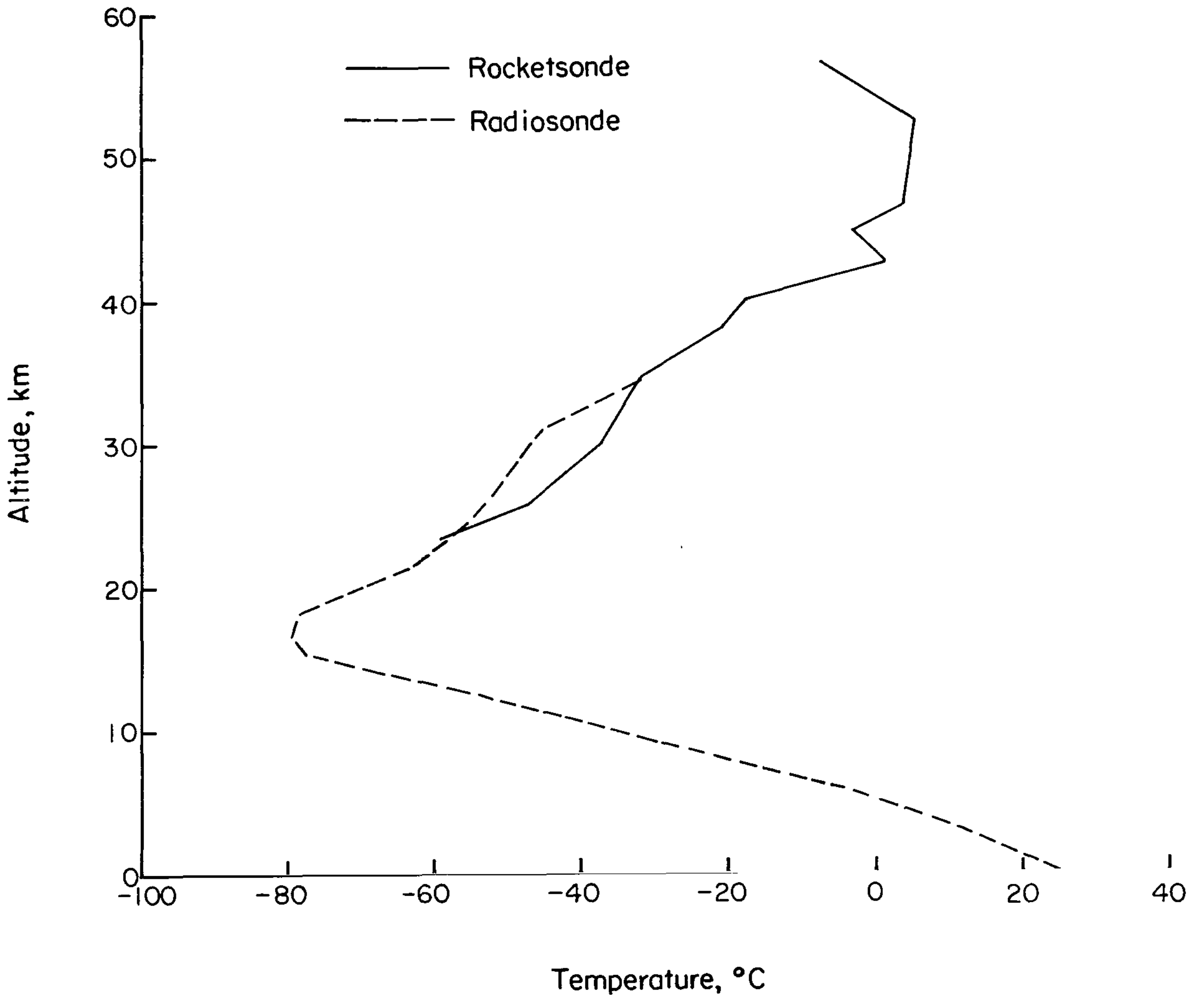
(c) March 18, 1965; latitude 12°49' S and longitude 77°58' W.

Figure 6.- Continued.



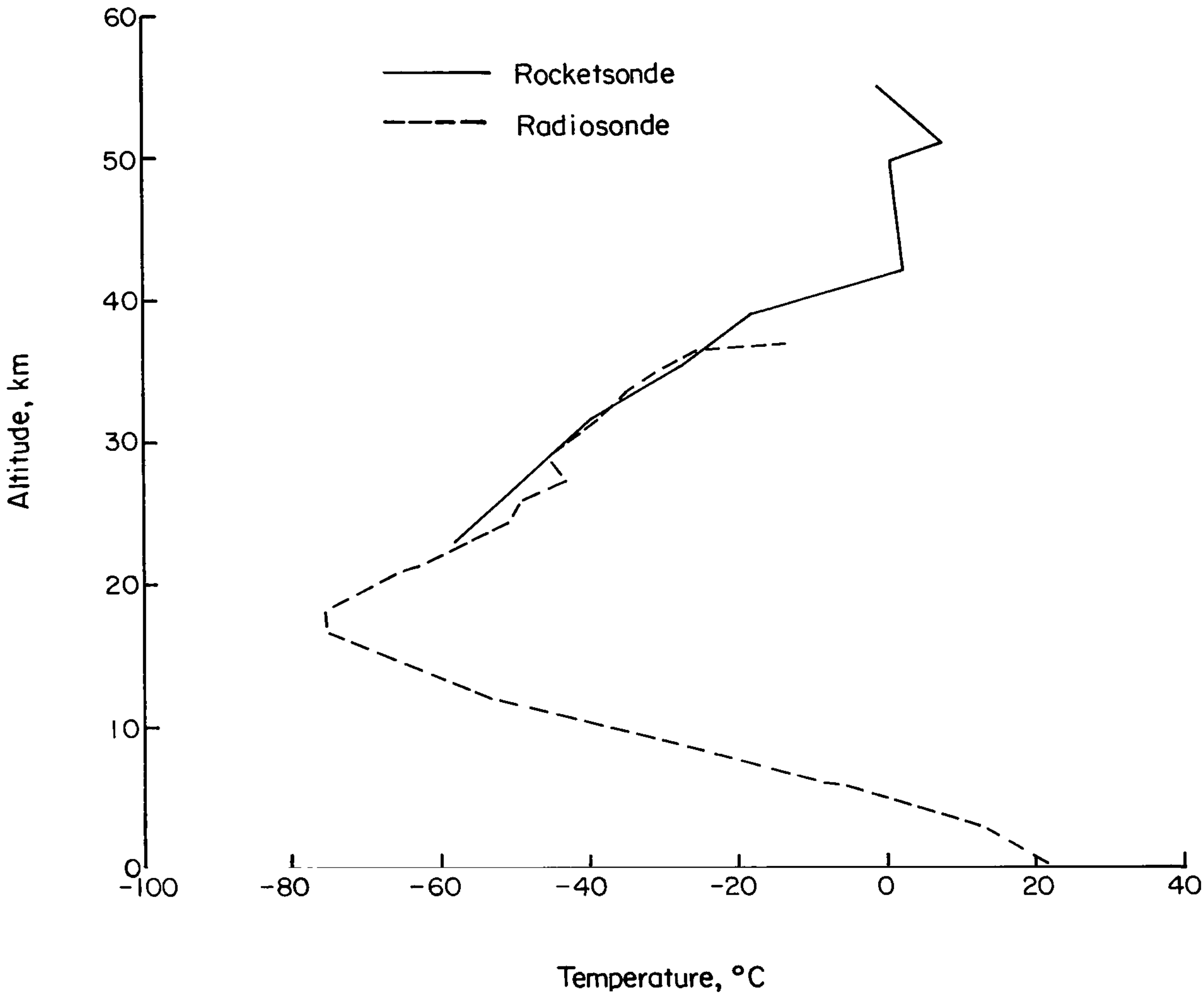
(d) March 21, 1965; latitude 12°57' S and longitude 78°03' W.

Figure 6.- Continued.



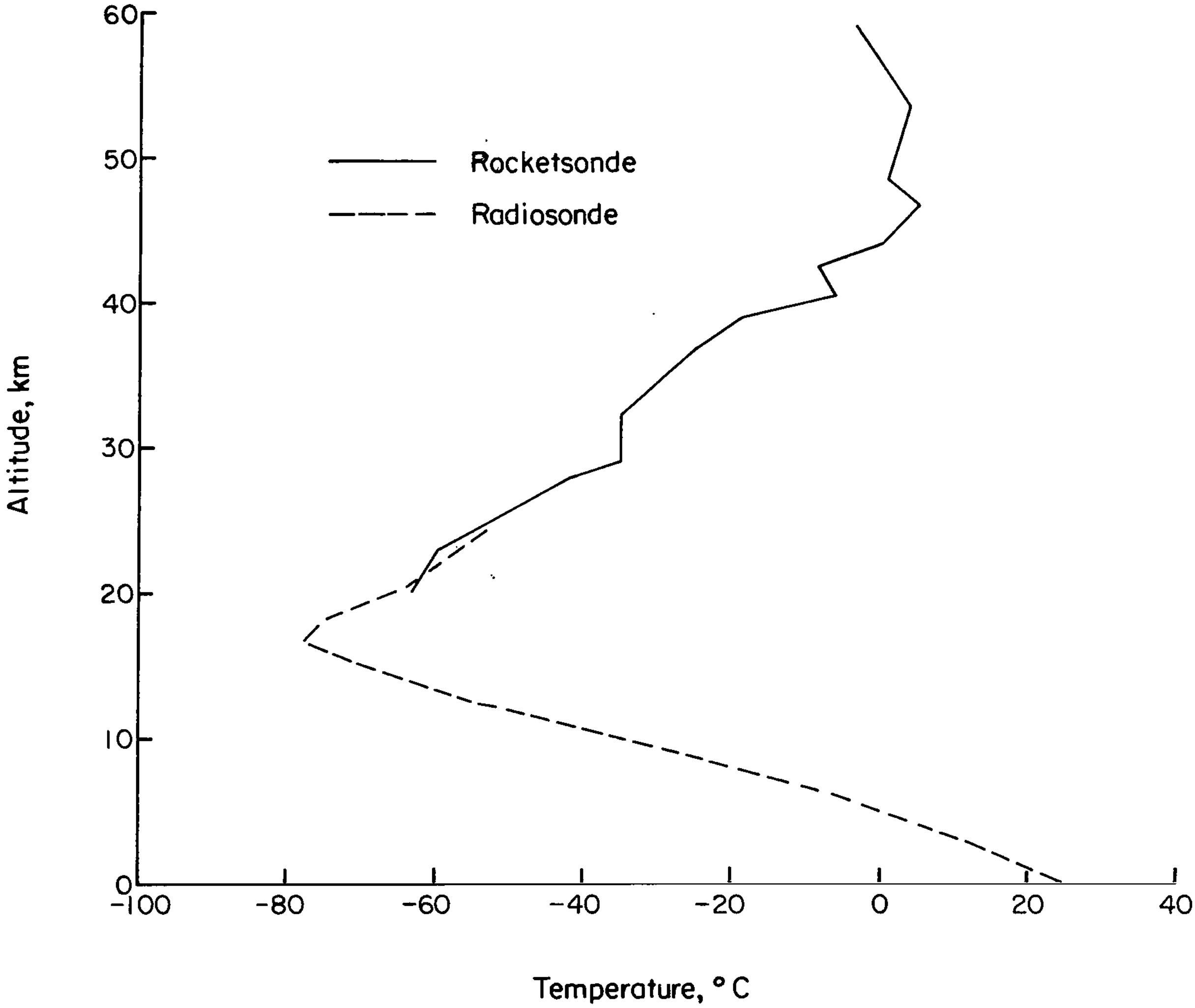
(e) March 24, 1965; latitude 11°34' S and longitude 78°23' W.

Figure 6.- Continued.



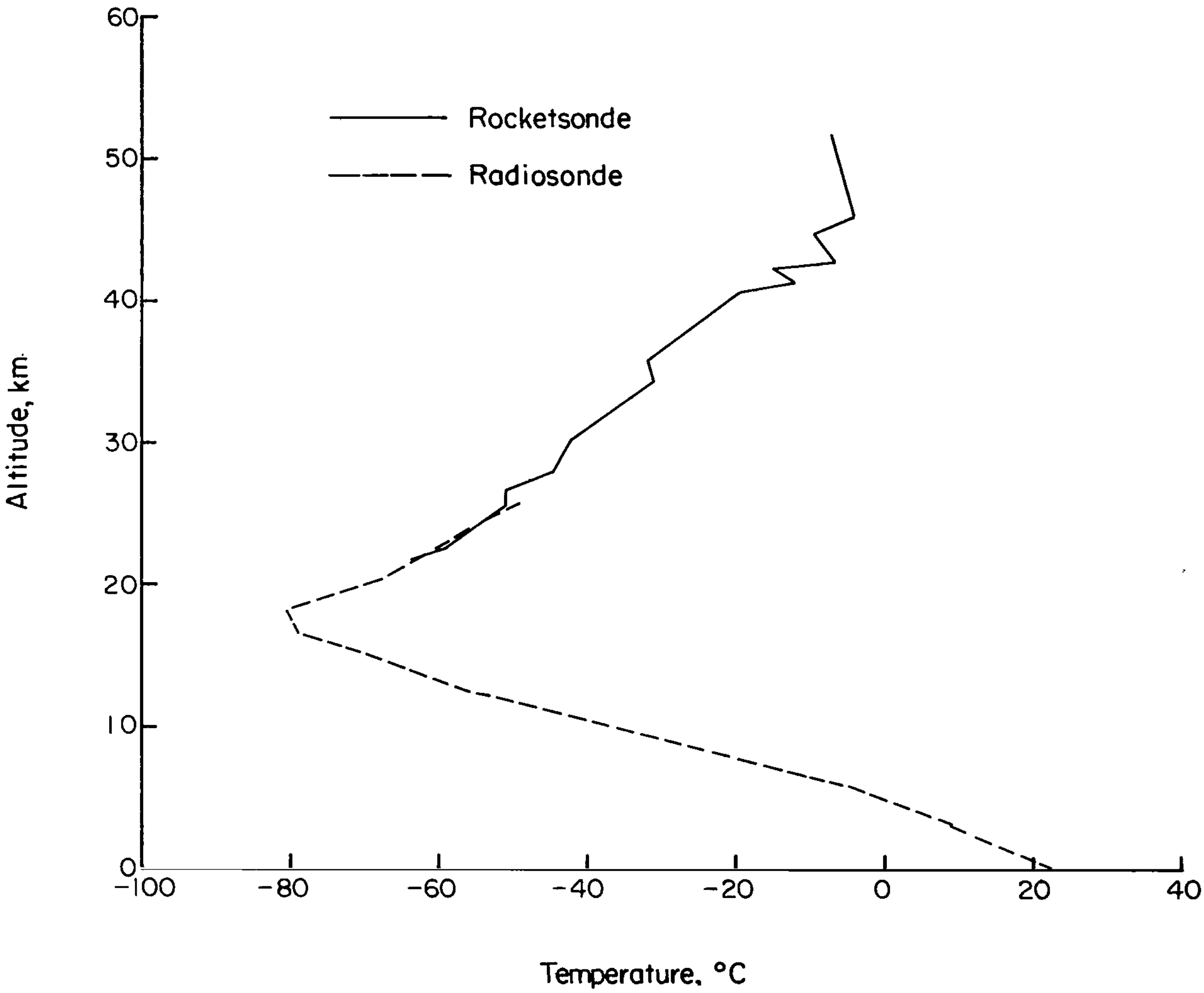
(f) March 27, 1965; latitude 14°10' S and longitude 77°59' W.

Figure 6.- Continued.



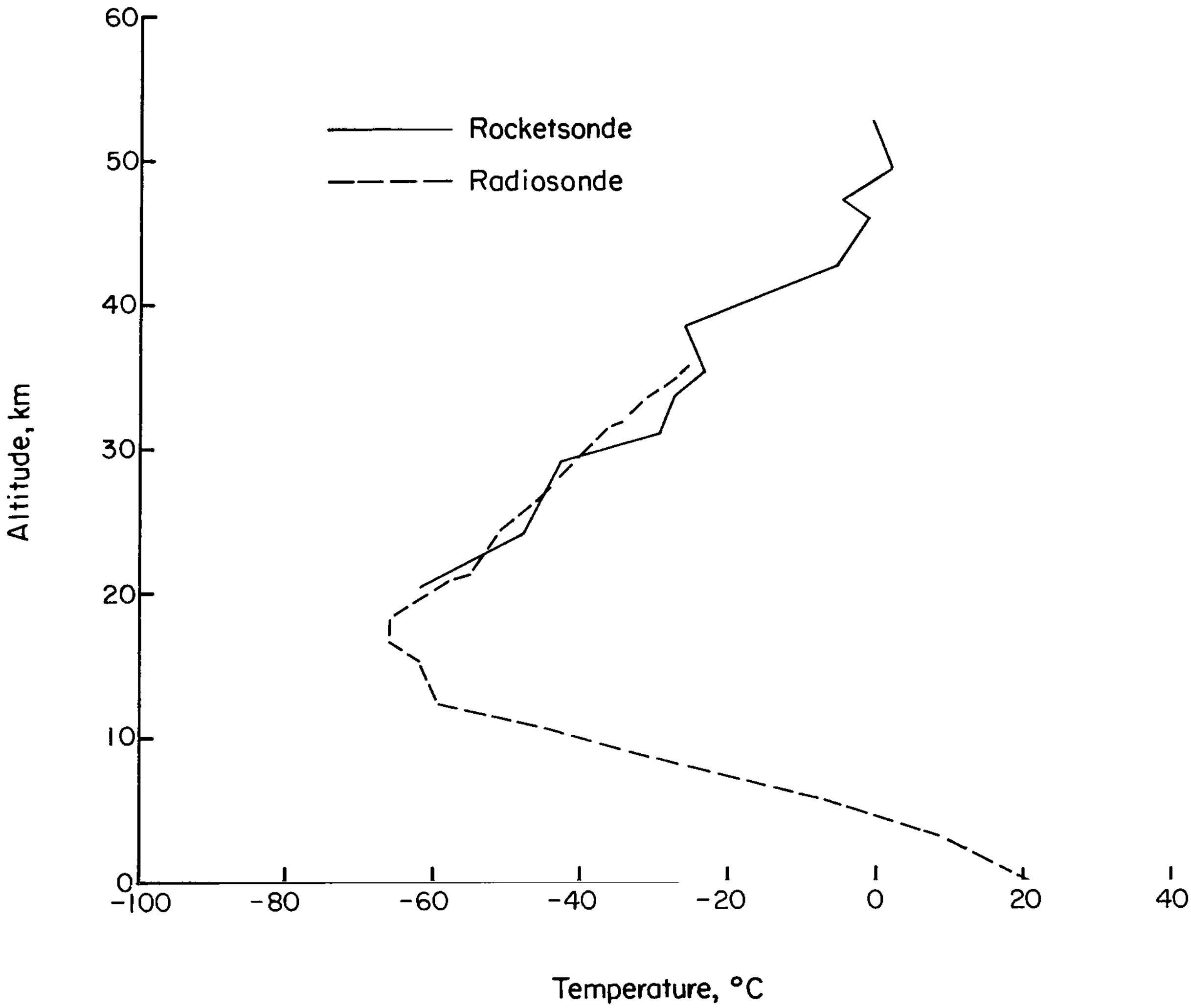
(g) April 2, 1965; latitude 12°19' S and longitude 78°11' W.

Figure 6.- Continued.



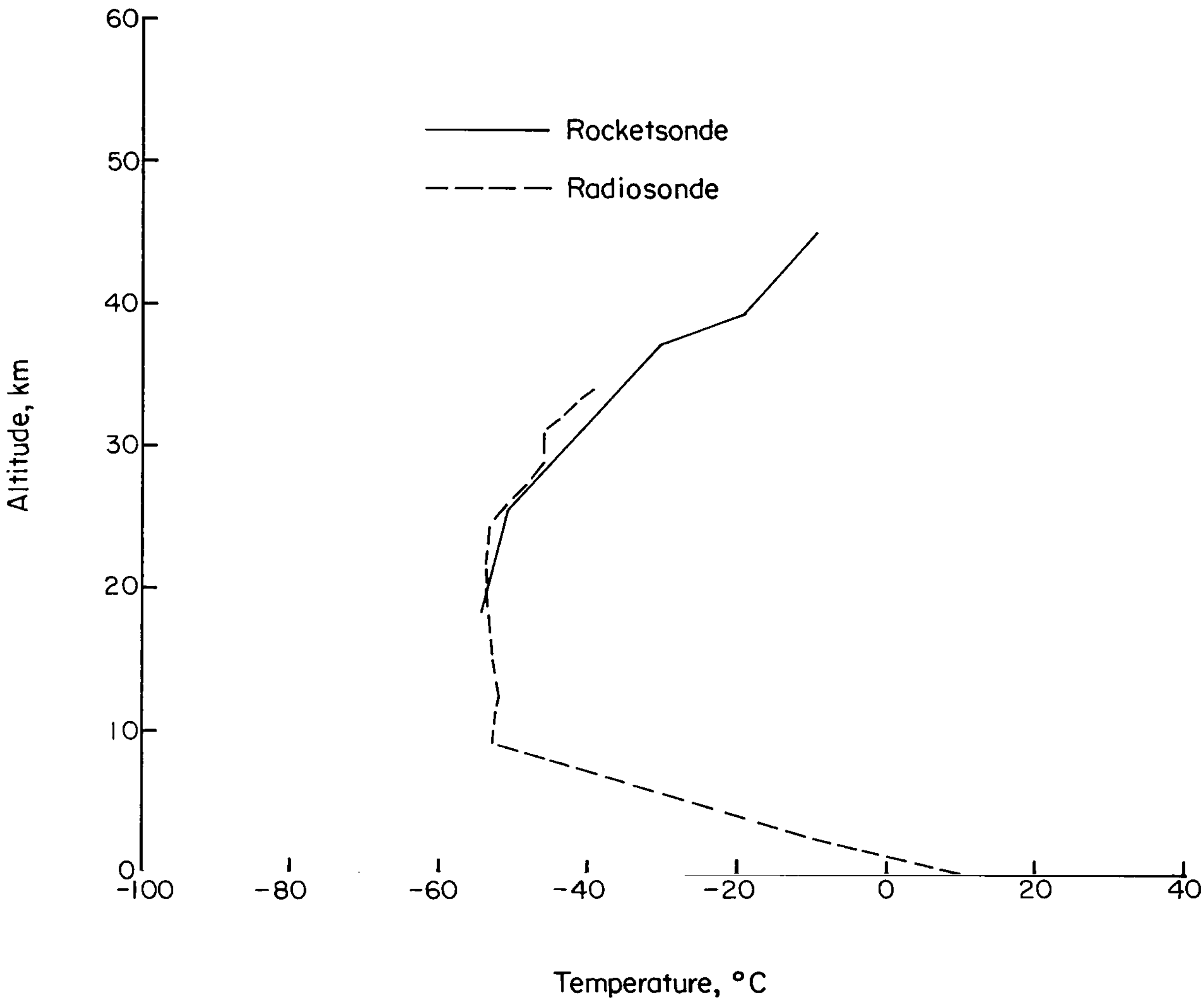
(h) April 3, 1965; latitude 14°34' S and longitude 77°47' W.

Figure 6.- Continued.



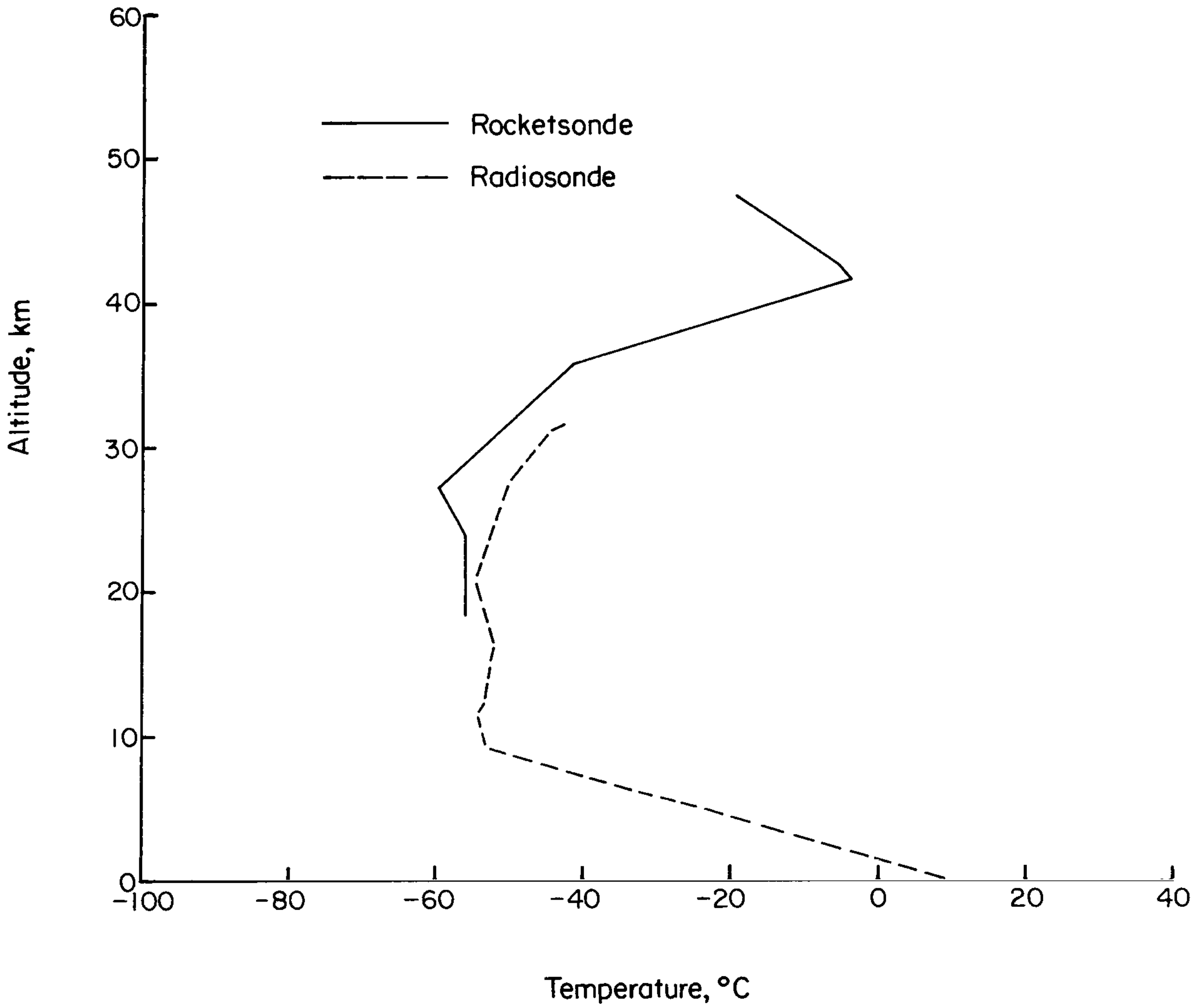
(i) April 5, 1965; latitude 30°52' S and longitude 75°00' W.

Figure 6.- Continued.



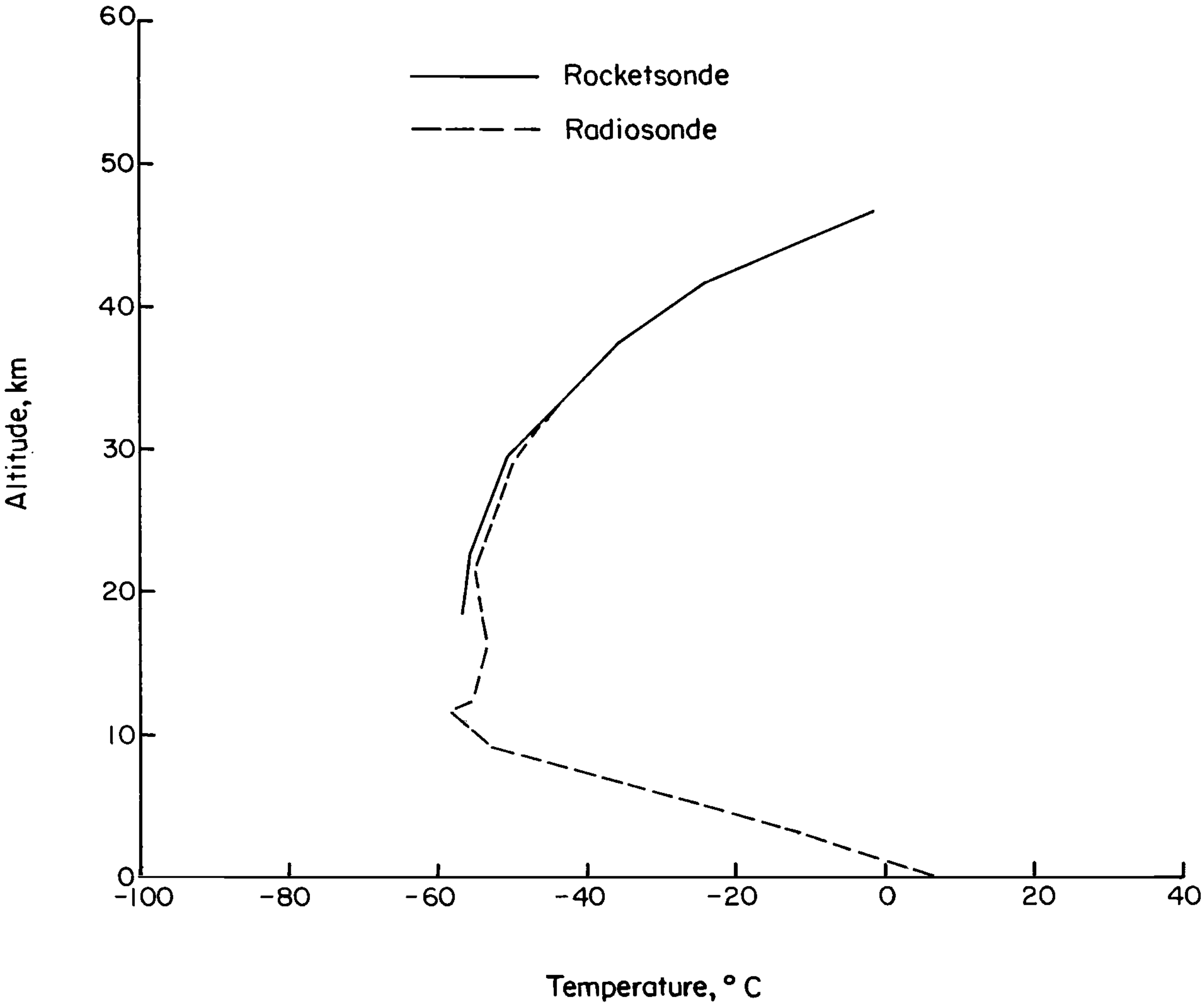
(j) April 10, 1965; latitude 47°02' S and longitude 77°45' W.

Figure 6.- Continued.



(k) April 11, 1965; latitude 48°35' S and longitude 77°42' W.

Figure 6.- Continued.



(l) April 11, 1965; latitude 52°11' S and longitude 77°49' W.

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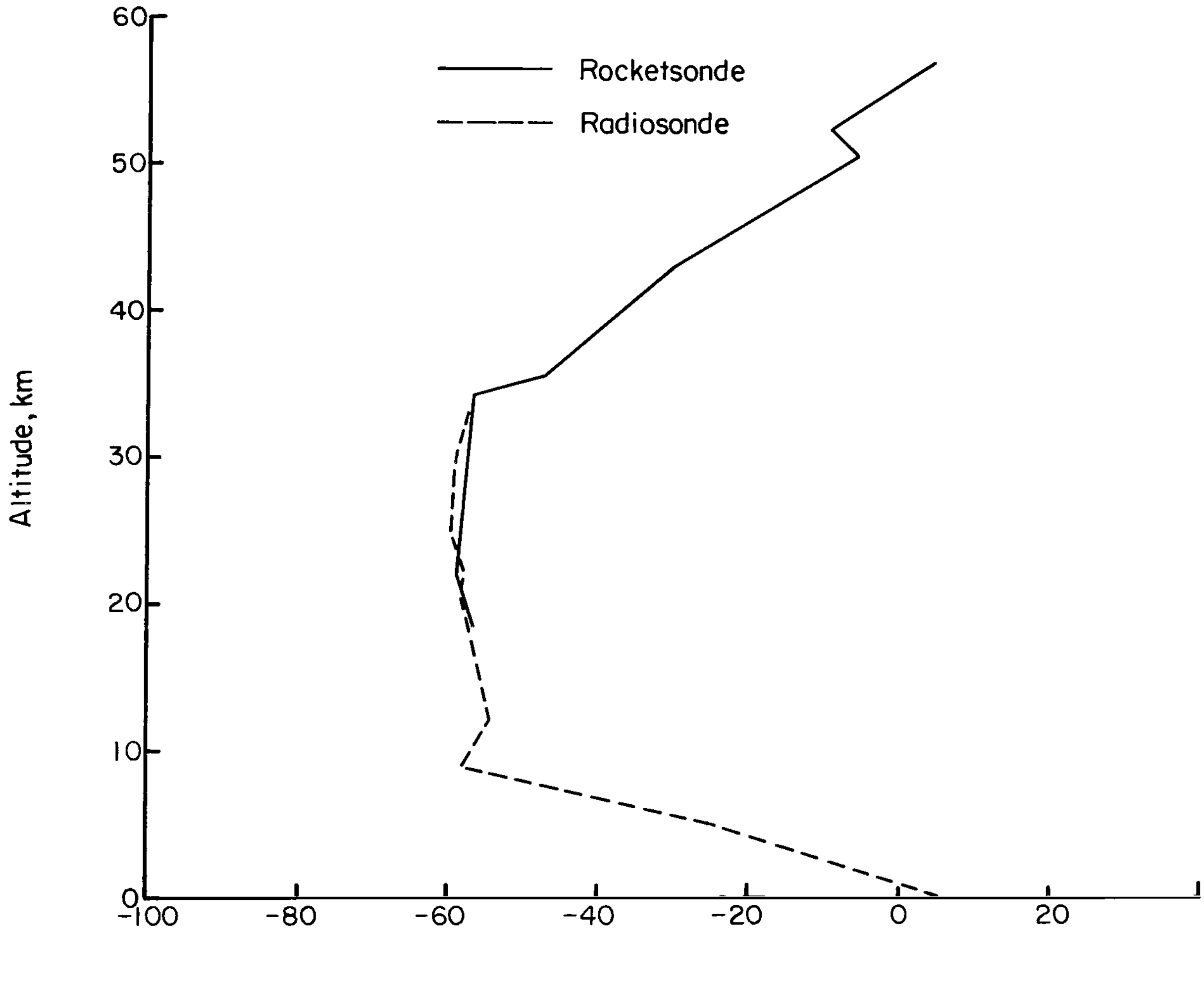
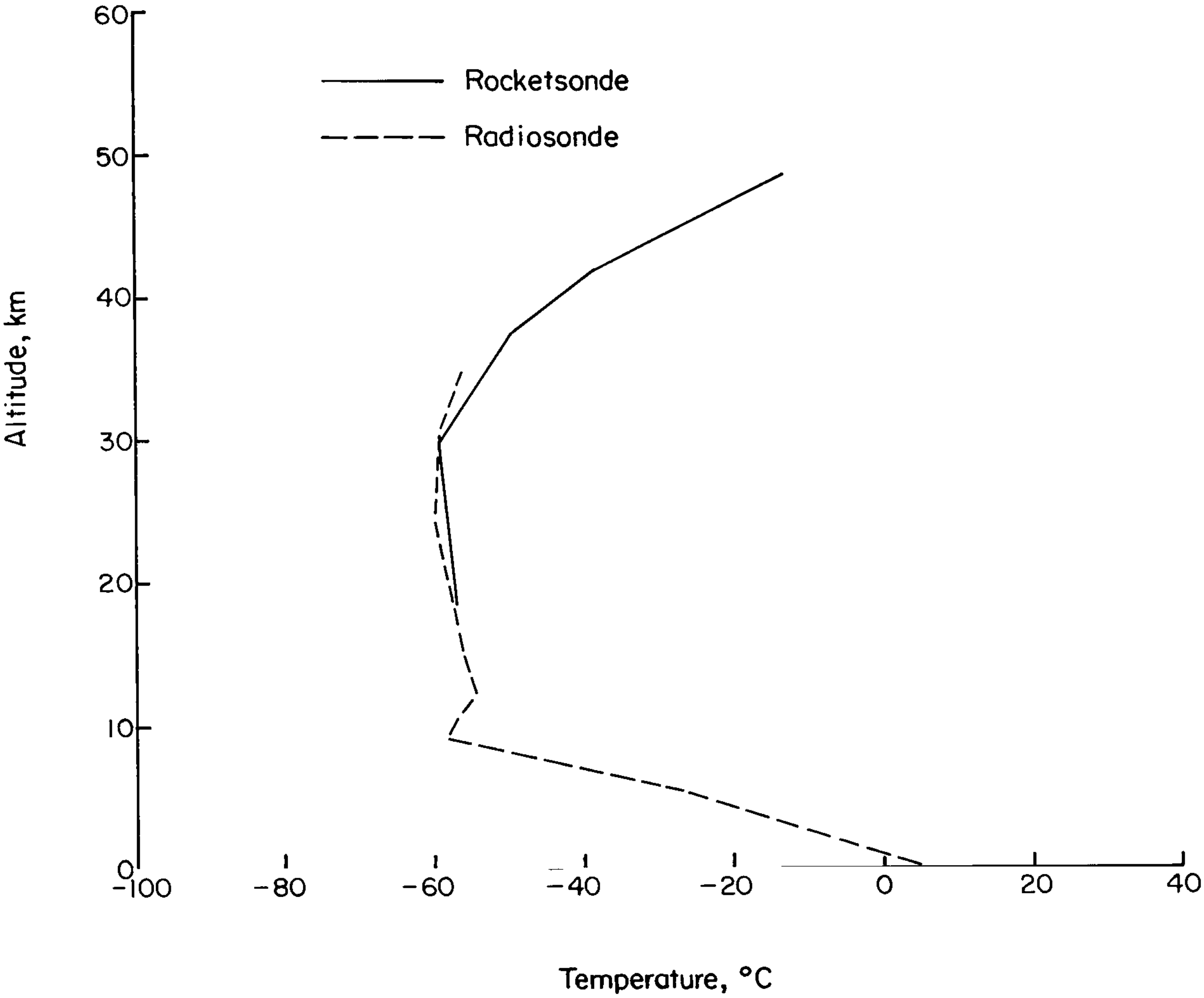


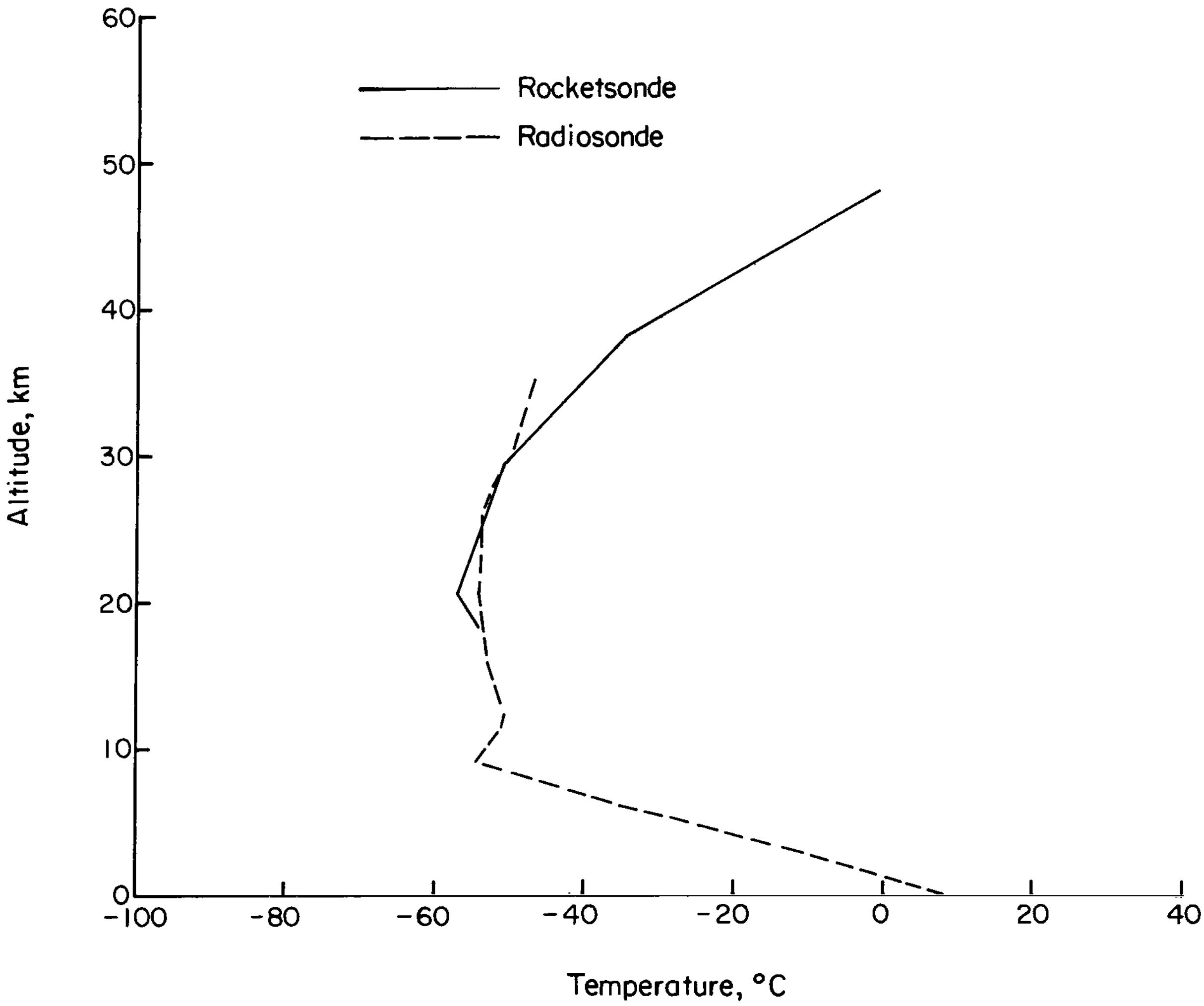
(m) April 13, 1965; latitude 59°52' S and longitude 77°58' W.

Figure 6.- Continued.



(n) April 14, 1965; latitude 59°46' S and longitude 77°50' W.

Figure 6.- Continued.



(o) April 15, 1965; latitude 52°28' S and longitude 78°09' W.

Figure 6.- Concluded.

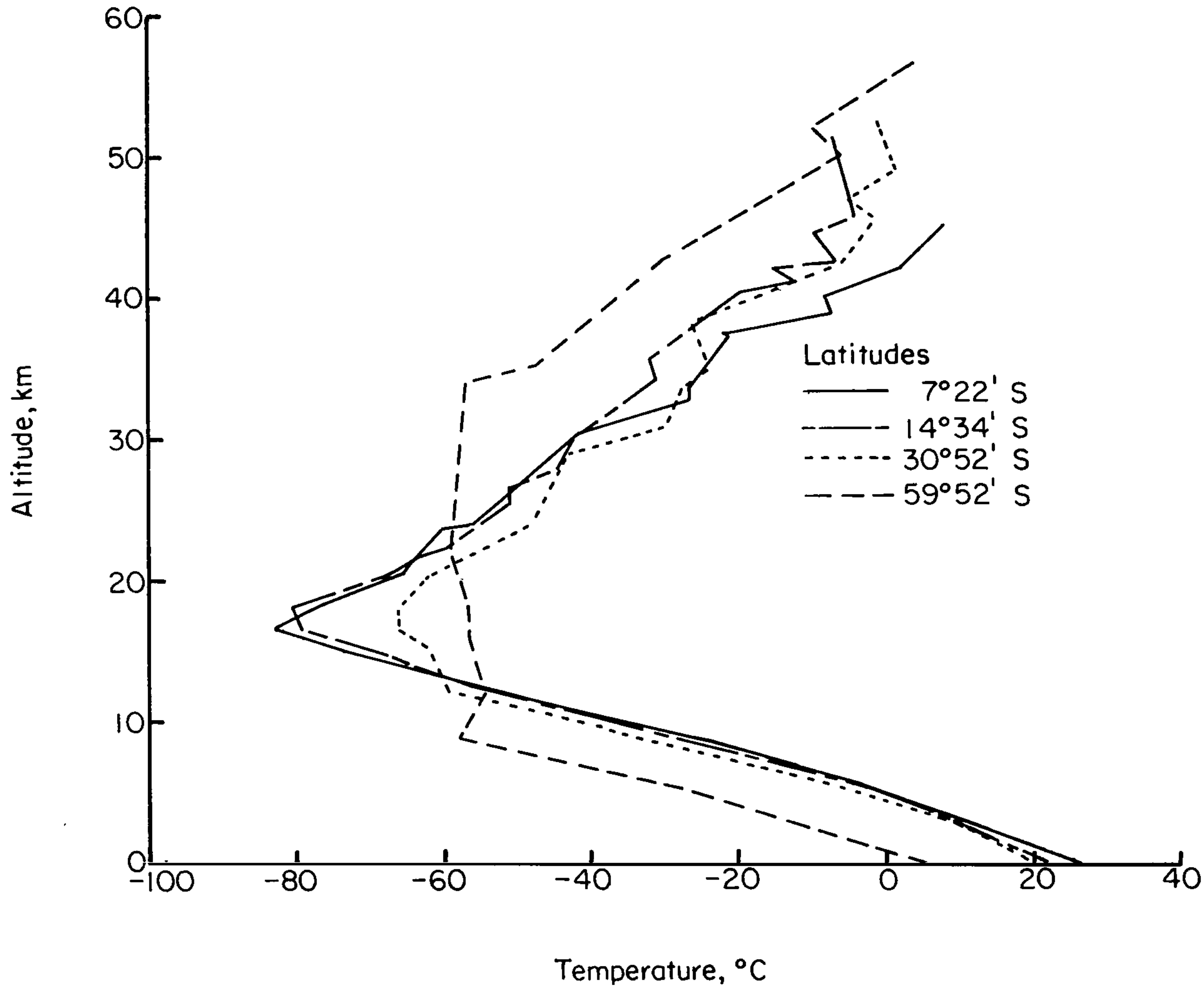


Figure 7.- Temperature profiles at several latitudes from April 3 to April 13, 1965.

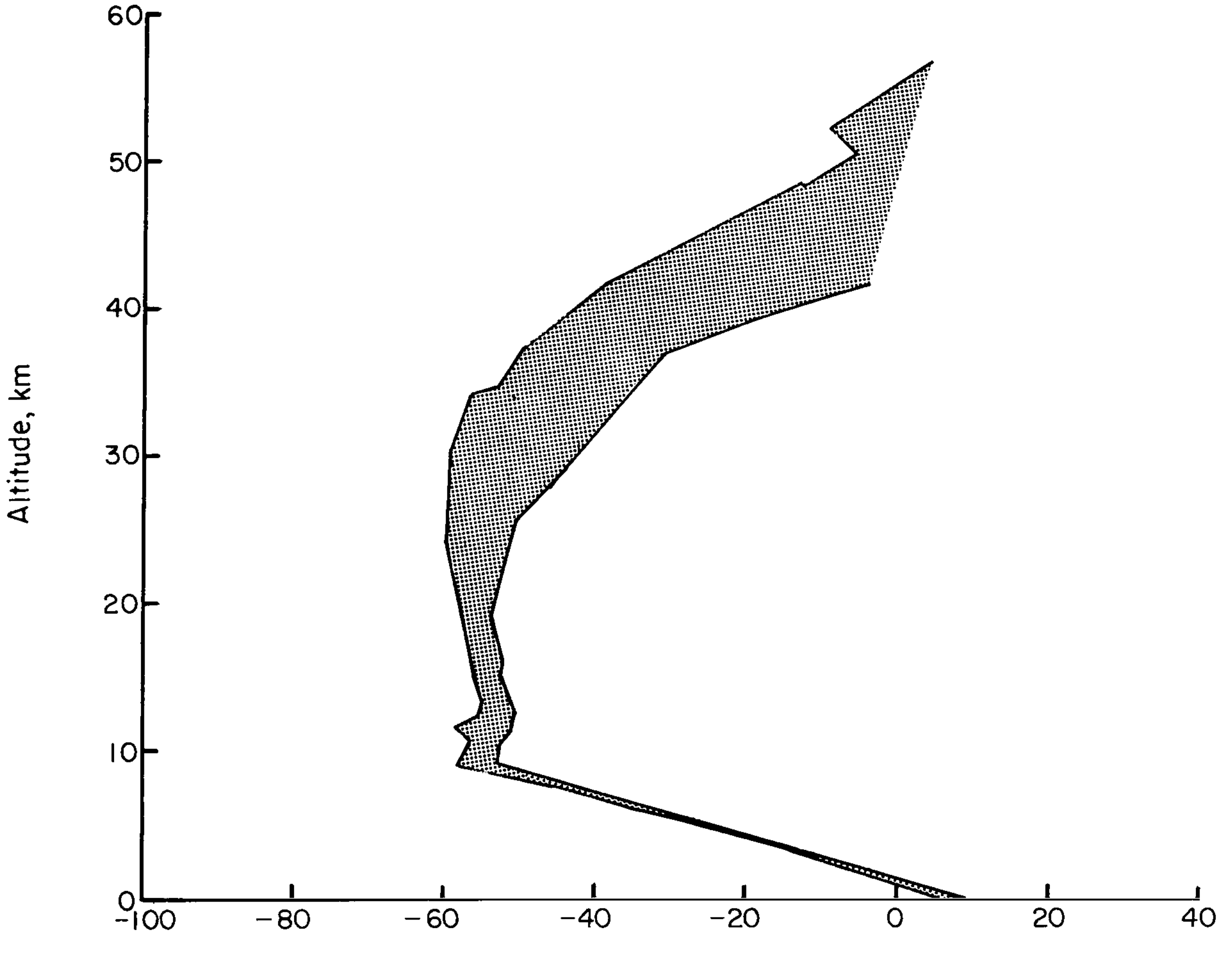
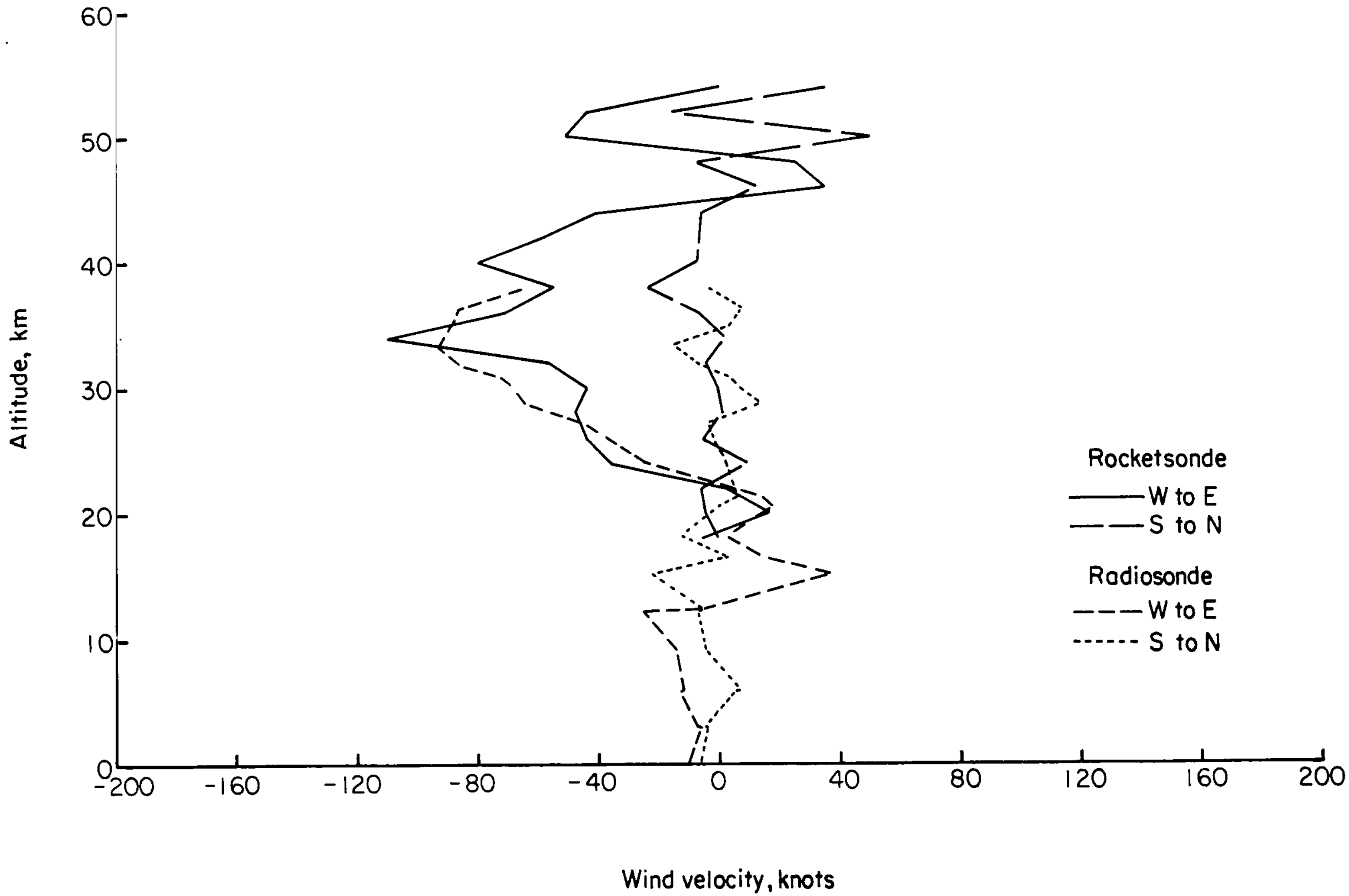
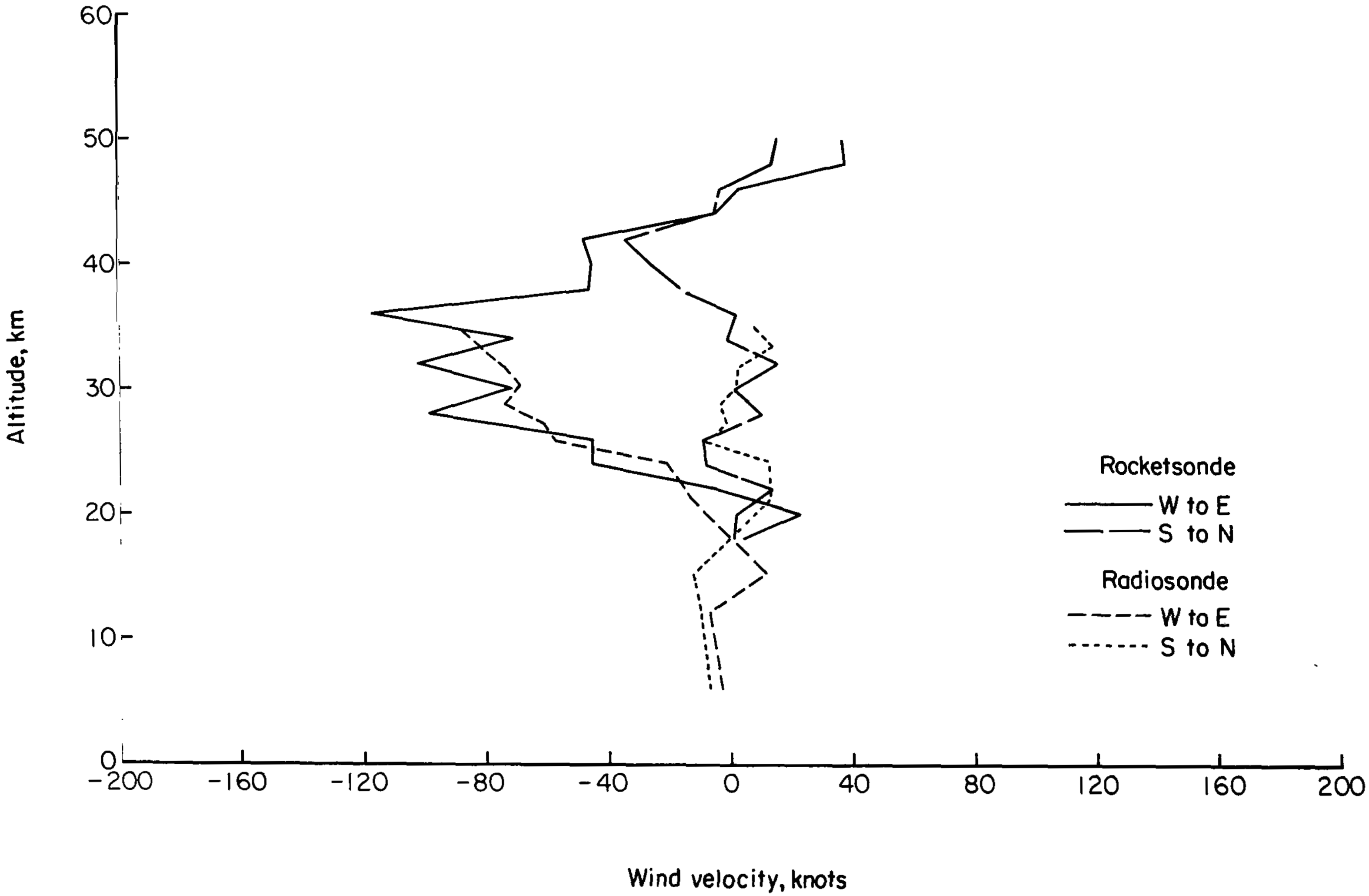


Figure 8.- Composite profile of the temperature observations made between latitudes 47° S and 60° S from April 10 to April 16, 1965.



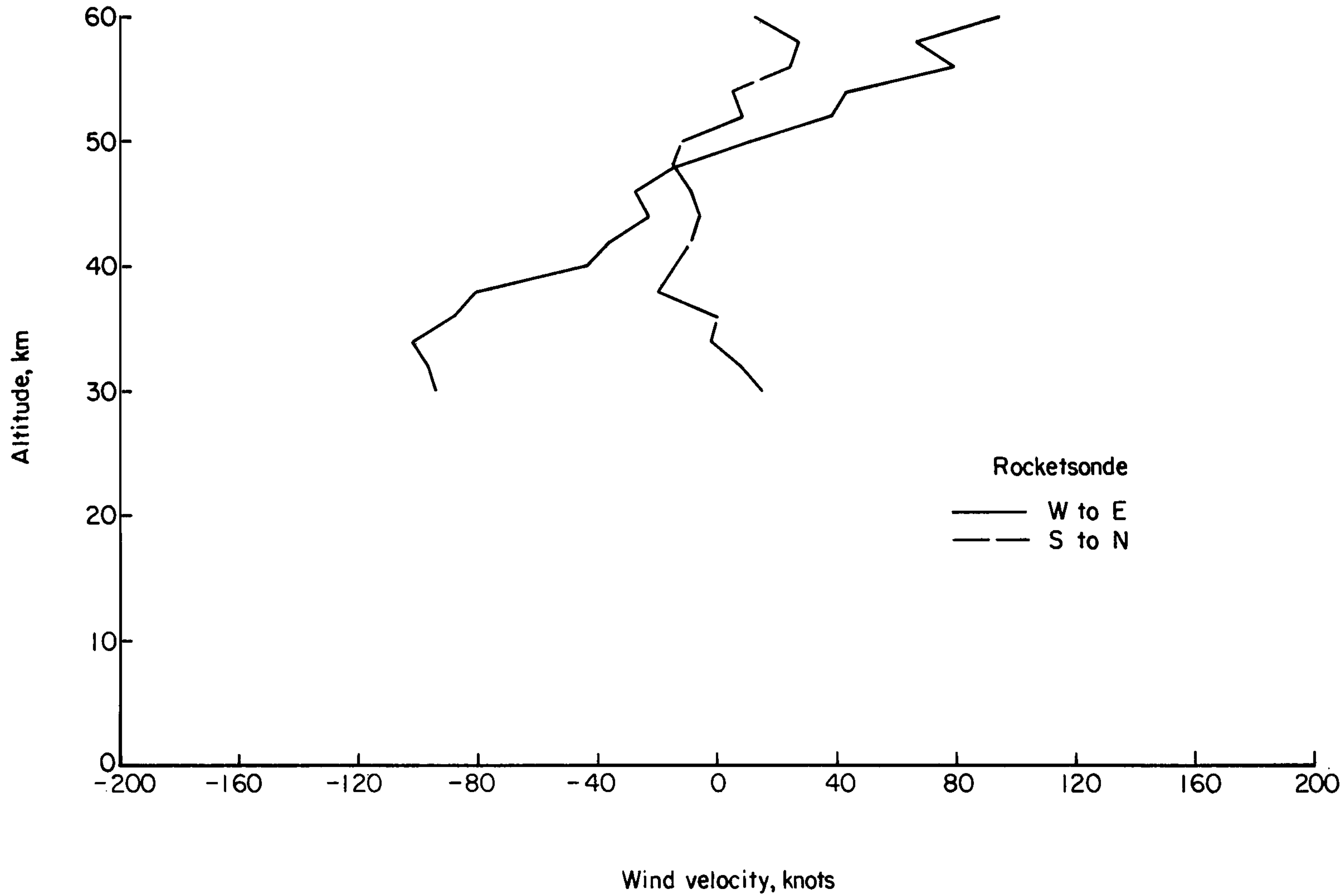
(a) March 7, 1965; latitude 3°55.5' N and longitude 82°46' W. Sensor: Parachute.

Figure 9.- Wind profiles. Positive components indicate west-to-east and south-to-north component winds.



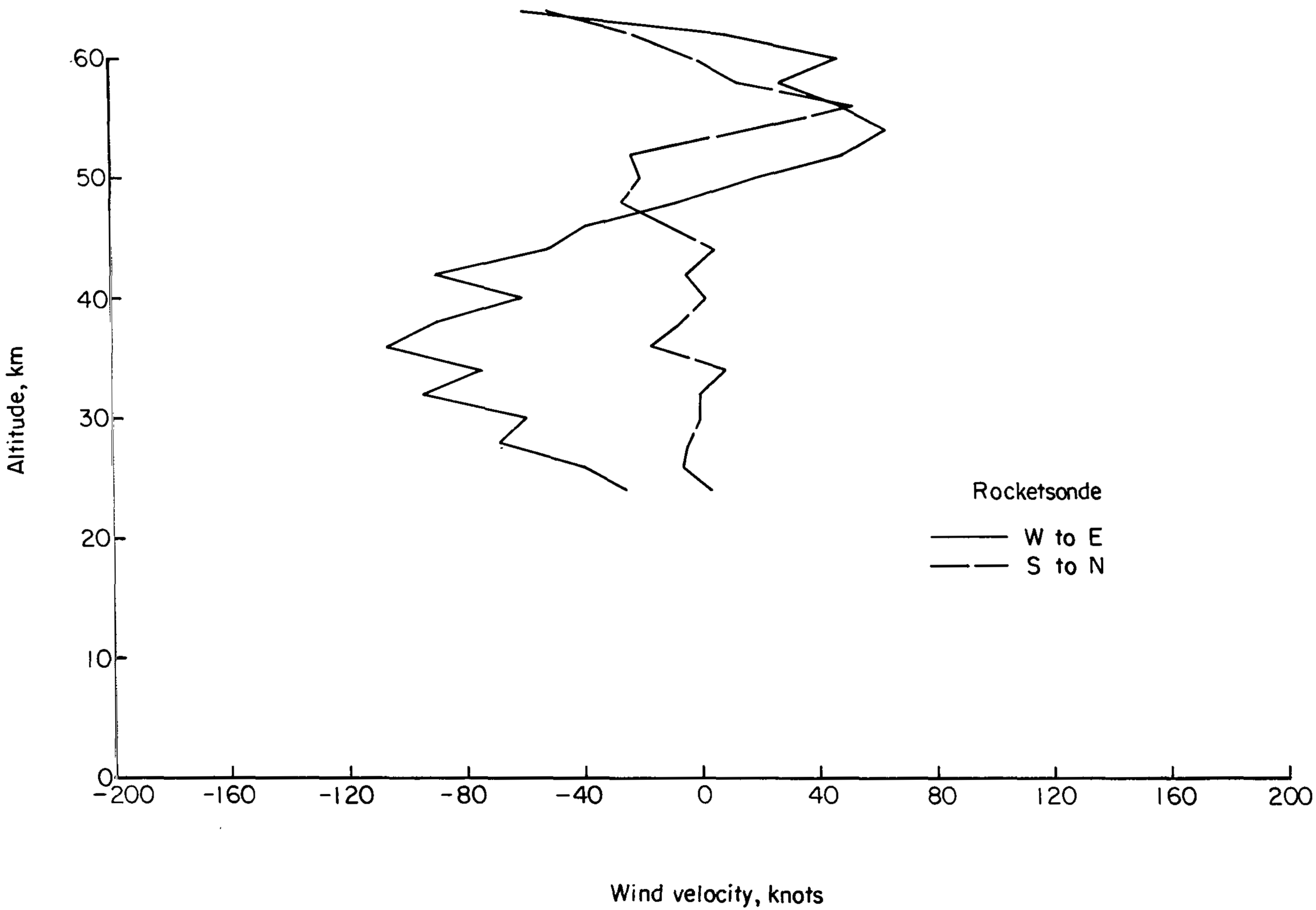
(b) March 9, 1965; latitude 3°04' S and longitude 84°23' W. Sensor: Parachute.

Figure 9.- Continued.



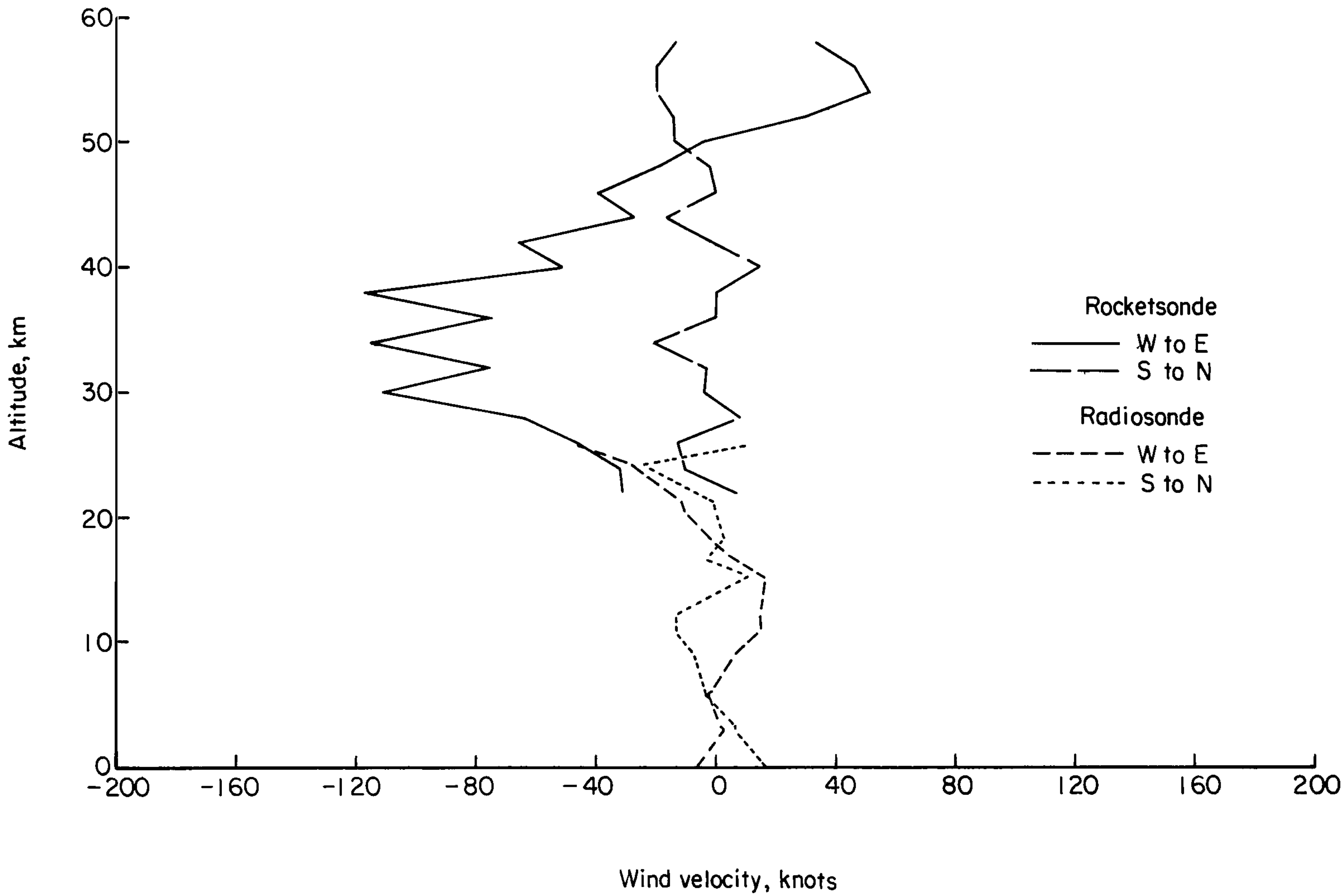
(c) March 11, 1965; latitude 9°32' S and longitude 84°10' W. Sensor; Chaff.

Figure 9.- Continued.



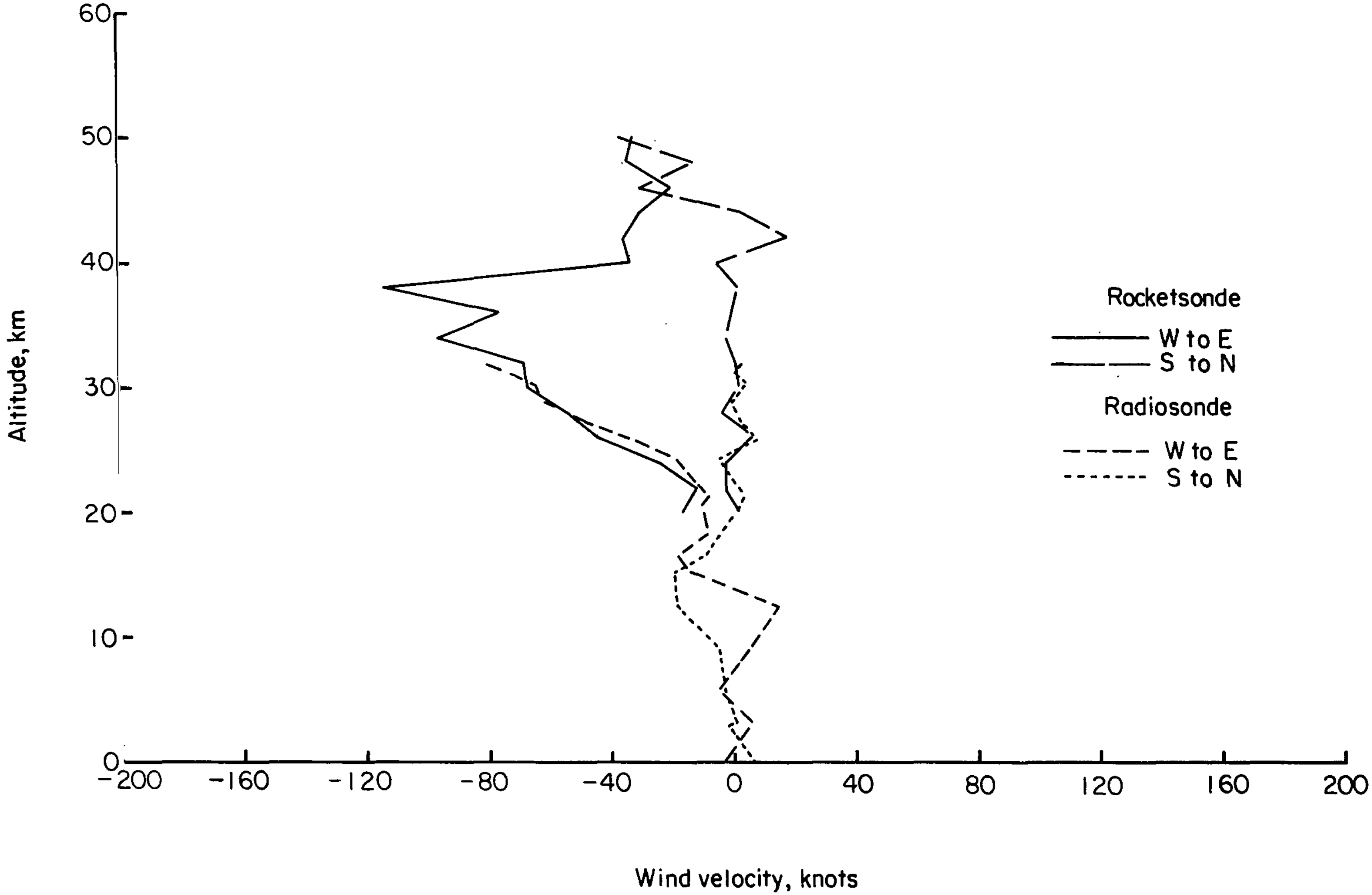
(d) March 16, 1965; latitude 12°55' S and longitude 78°00' W. Sensor: Parachute.

Figure 9.- Continued.



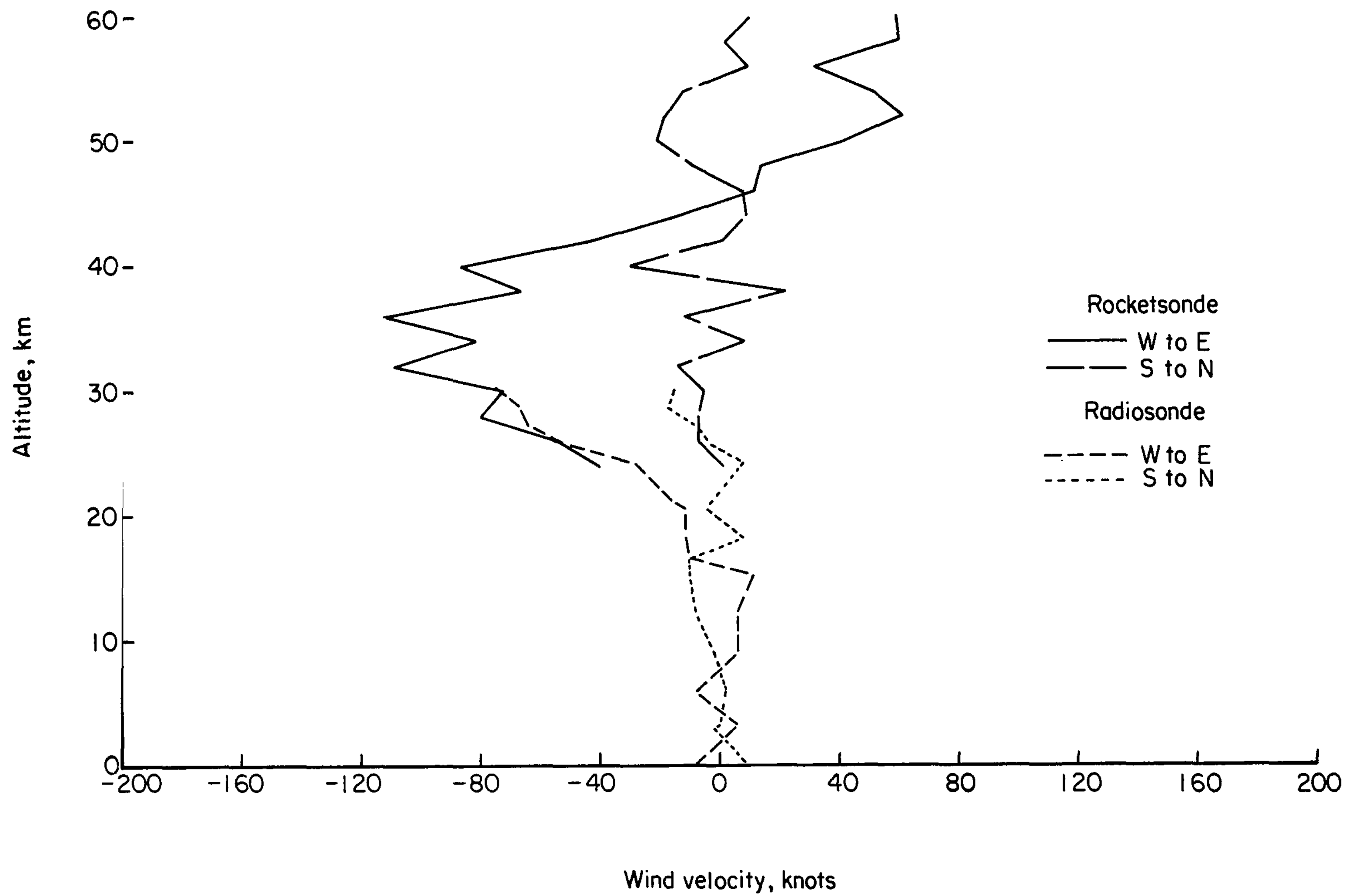
(e) March 17, 1965; latitude 12°54' S and longitude 78°02' W. Sensor: Chaff.

Figure 9.- Continued.



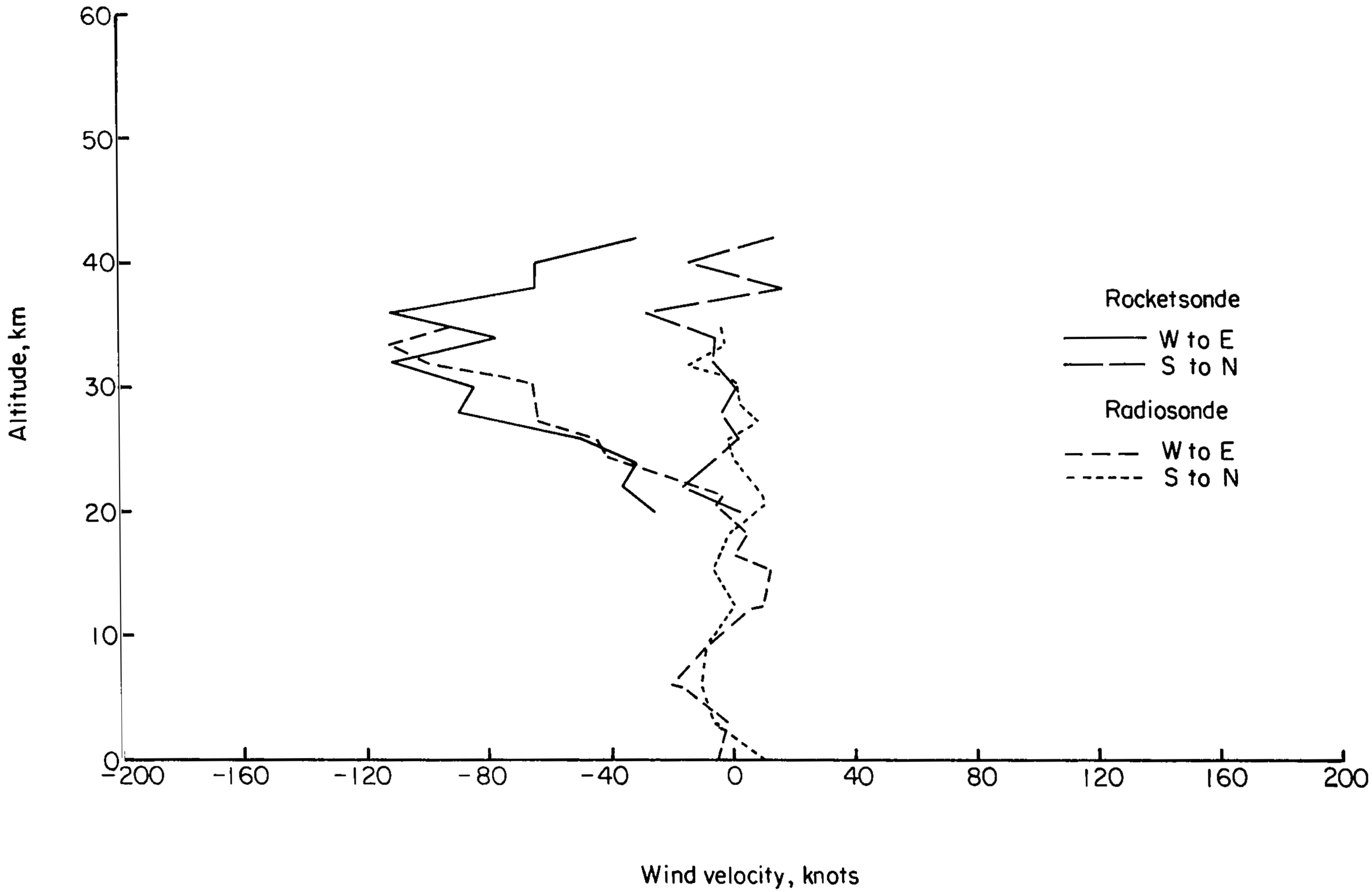
(f) March 18, 1965; latitude 12°49' S and longitude 77°58' W. Sensor: Parachute.

Figure 9.- Continued.



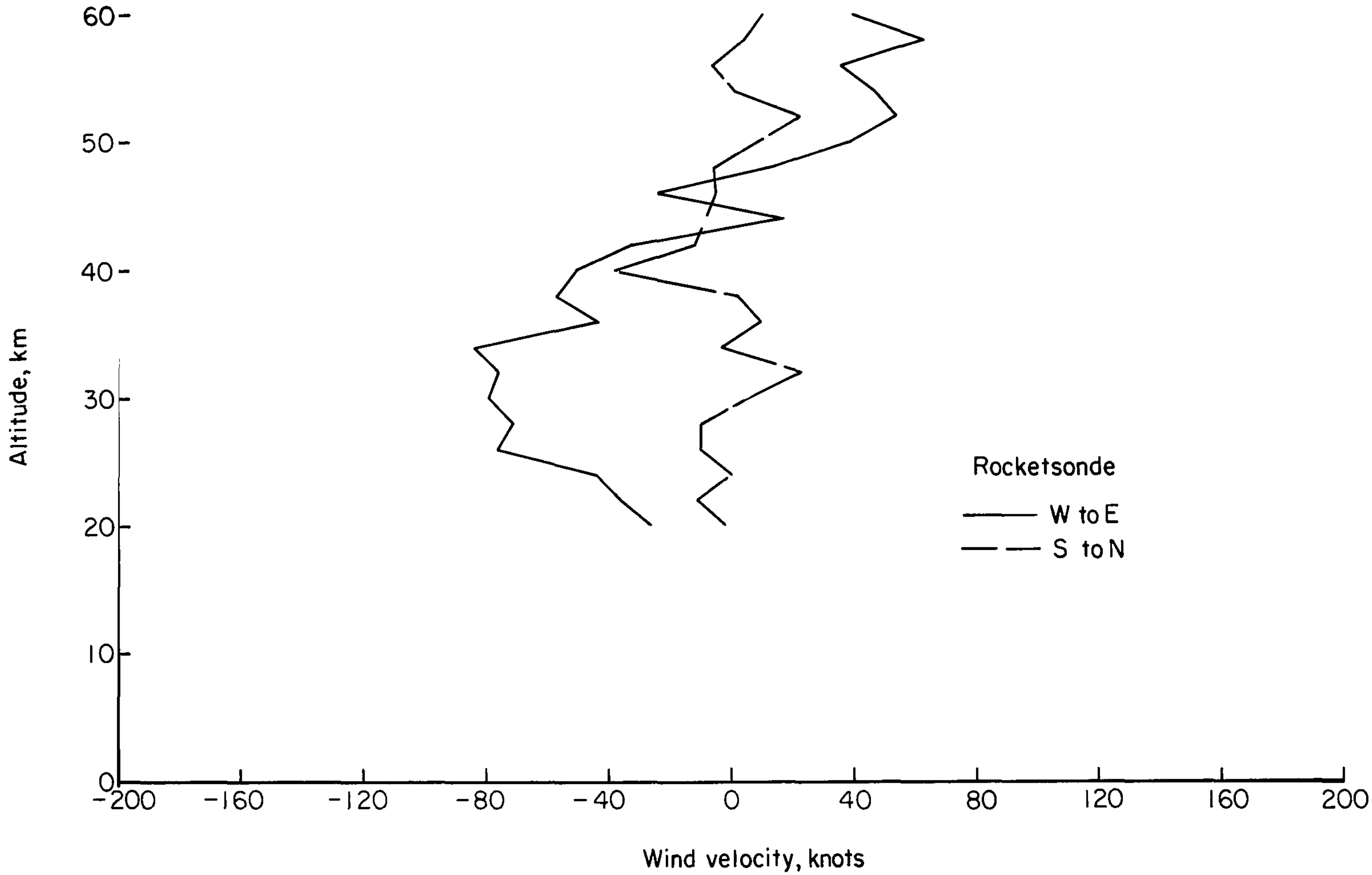
(g) March 19, 1965; latitude 13°06' S and longitude 78°00' W. Sensor: Chaff.

Figure 9.- Continued.



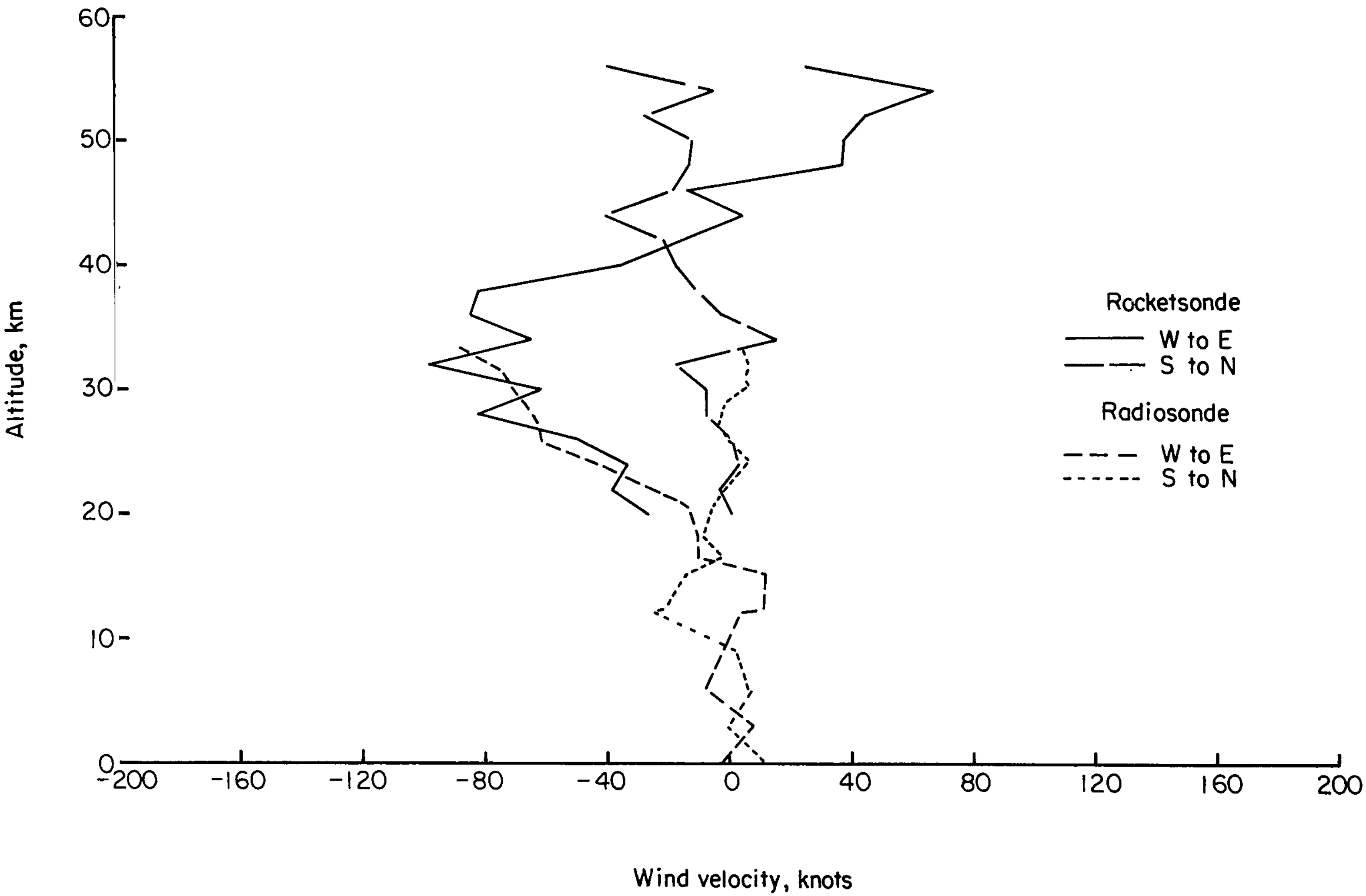
(h) March 21, 1965; latitude 12°57' S and longitude 78°03' W. Sensor: Parachute.

Figure 9.- Continued.



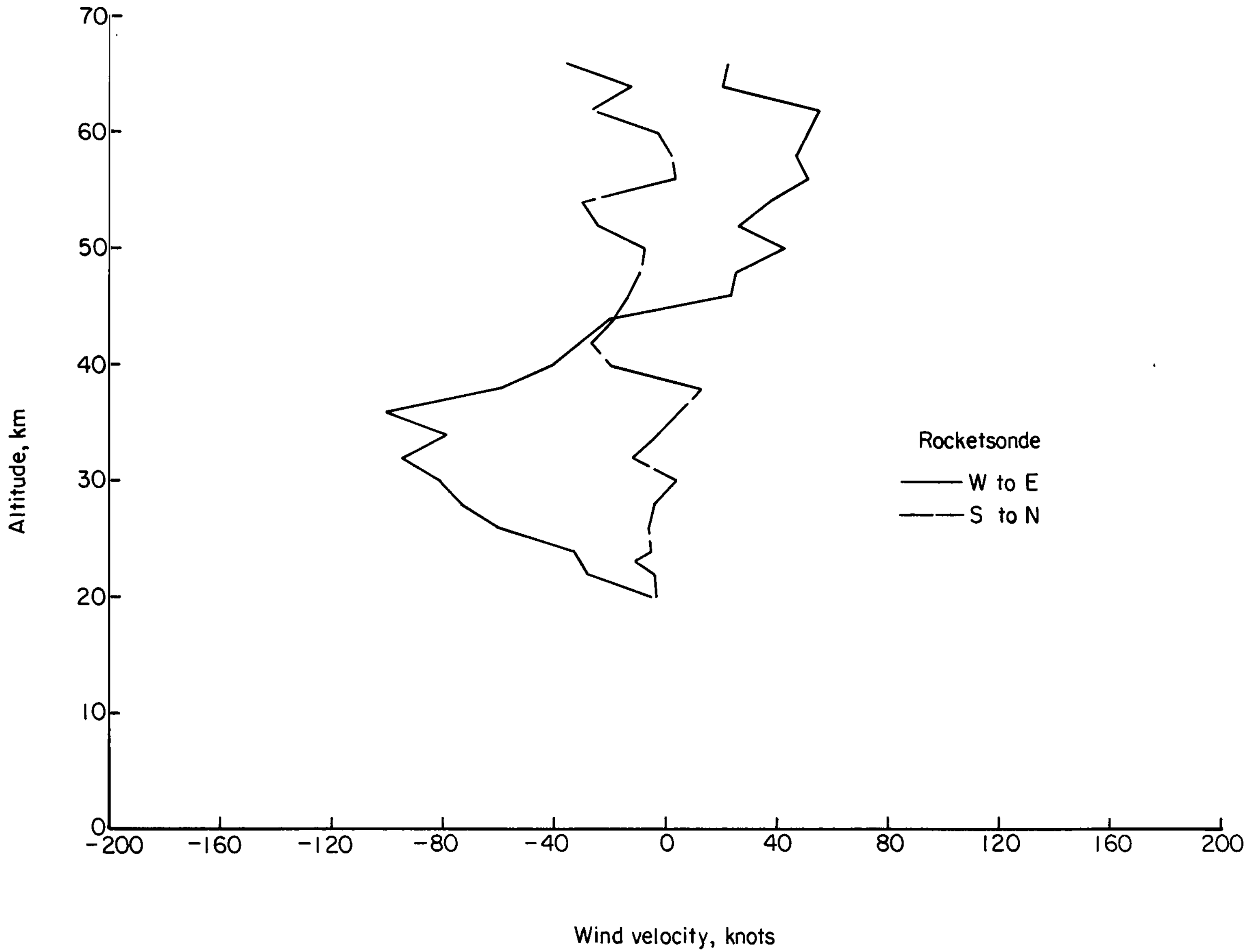
(i) March 22, 1965; latitude 12°28' S and longitude 77°54' W. Sensor: Chaff.

Figure 9.- Continued.



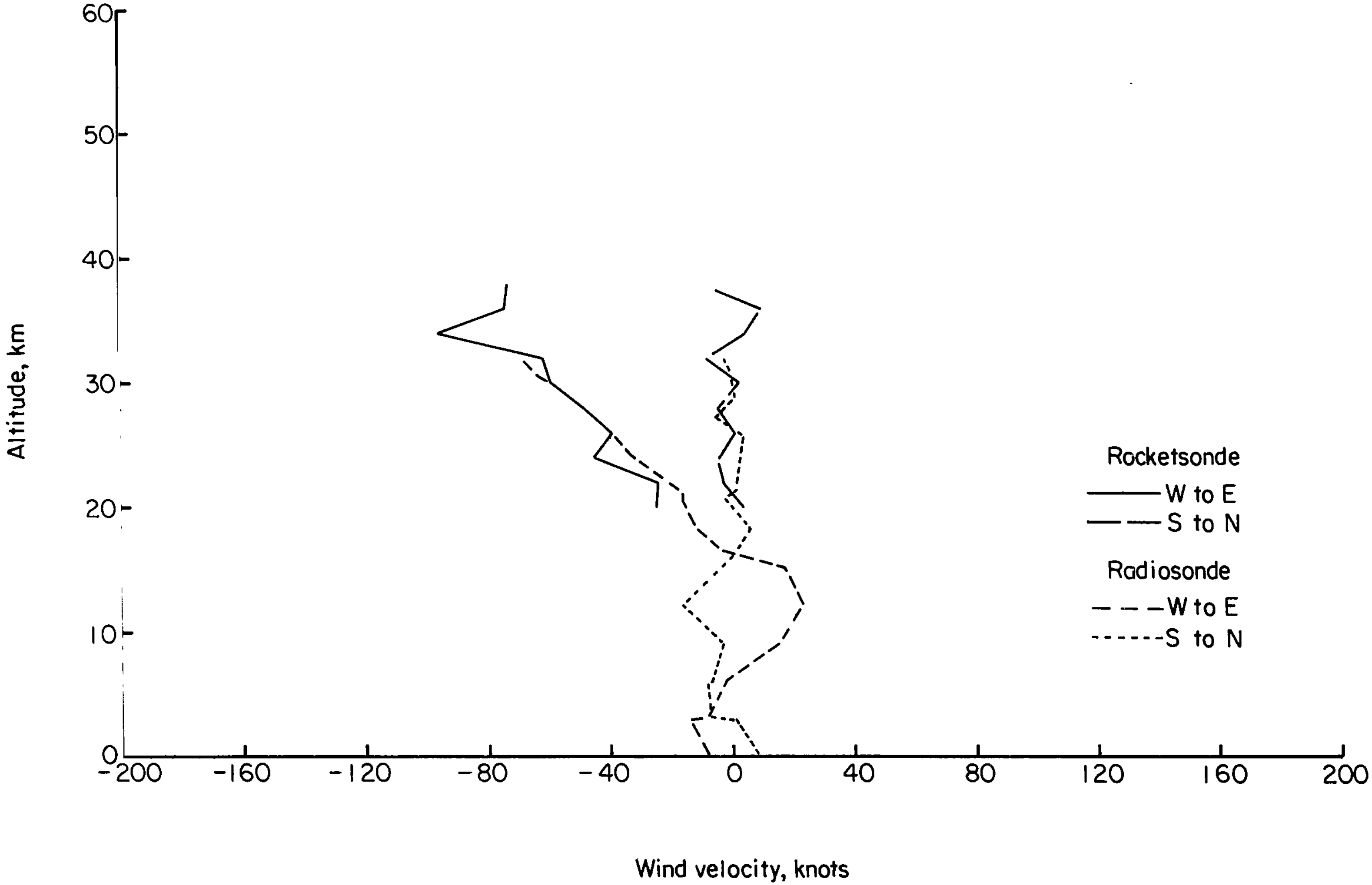
(j) March 24, 1965; latitude 11°34' S and longitude 78°23' W. Sensor: Parachute.

Figure 9.- Continued.



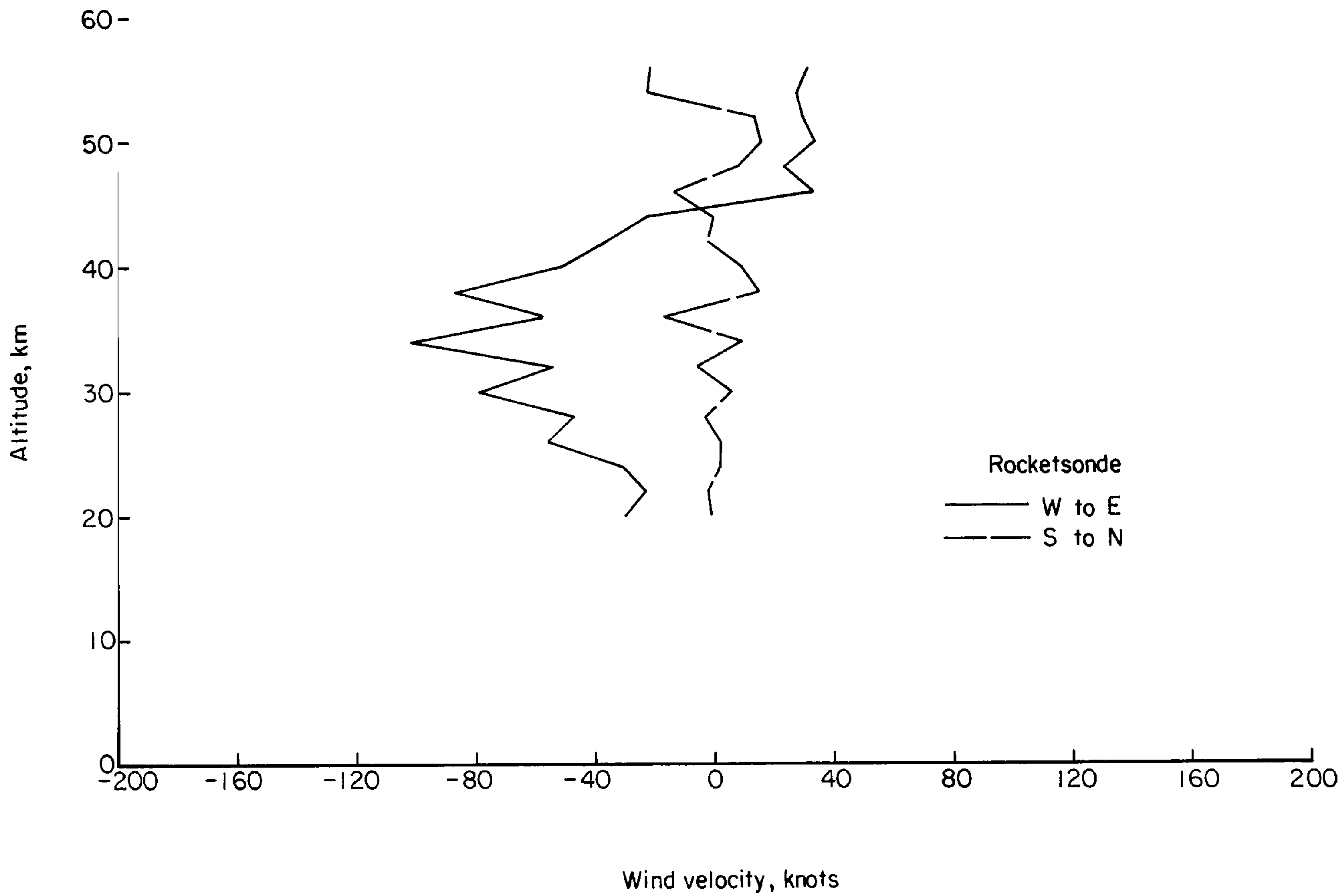
(k) March 25, 1965; latitude 9°02' S and longitude 79°56' W. Sensor: Chaff.

Figure 9.- Continued.



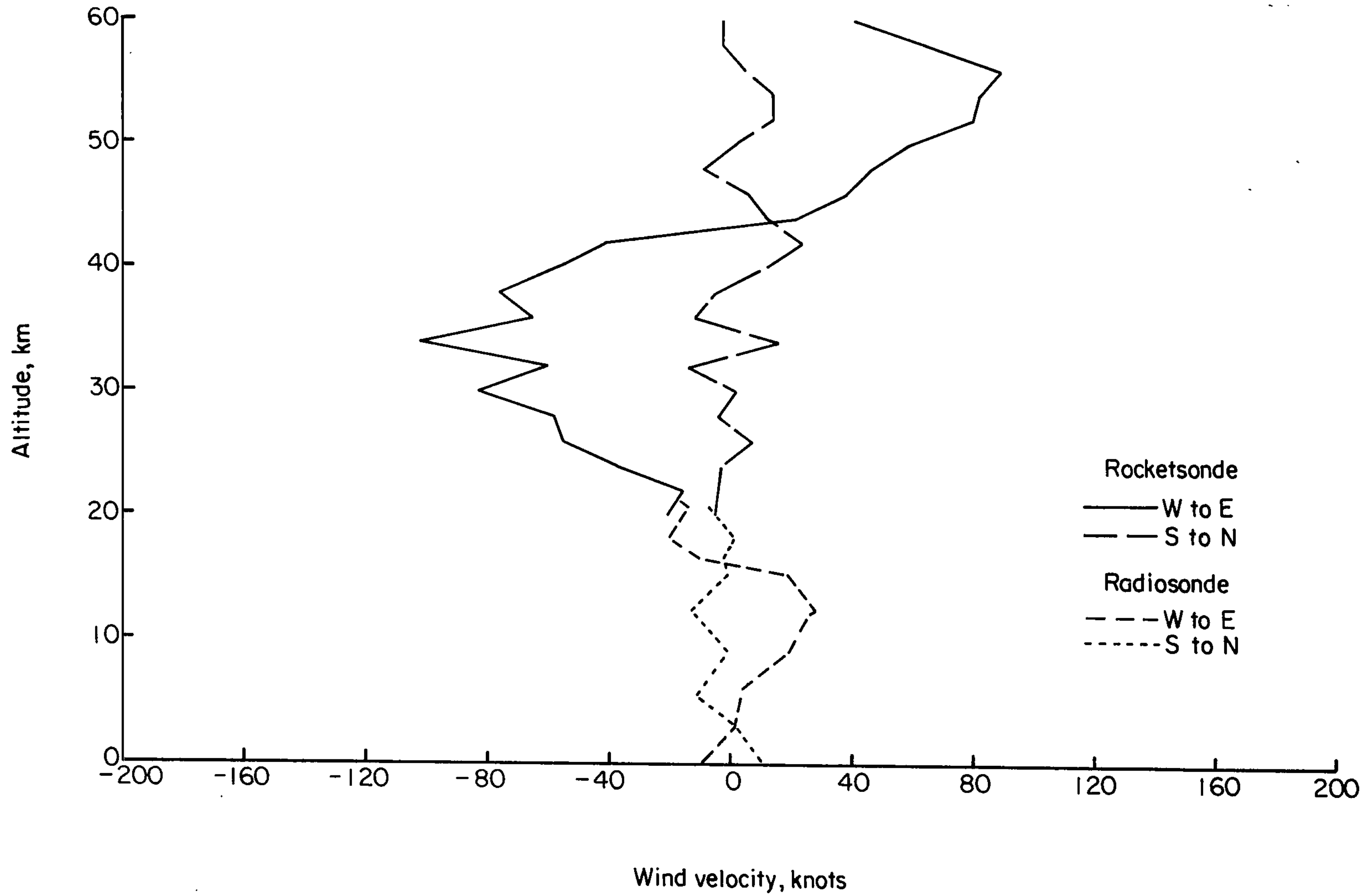
(l) March 27, 1965; latitude 14°10' S and longitude 77°59' W. Sensor: Parachute.

Figure 9.- Continued.



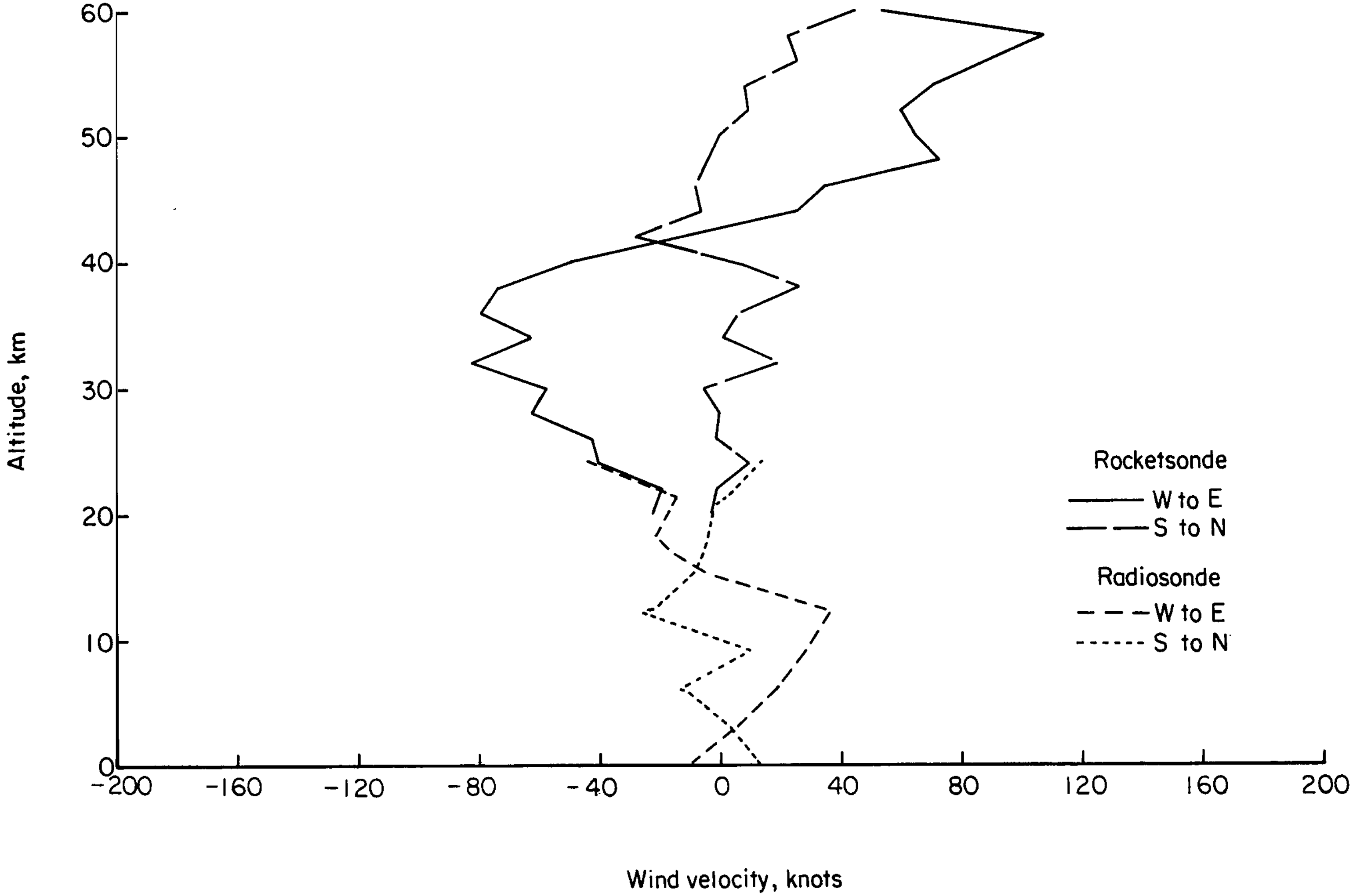
(m) March 28, 1965; latitude 16°01' S and longitude 78°00' W. Sensor: Chaff.

Figure 9.- Continued.



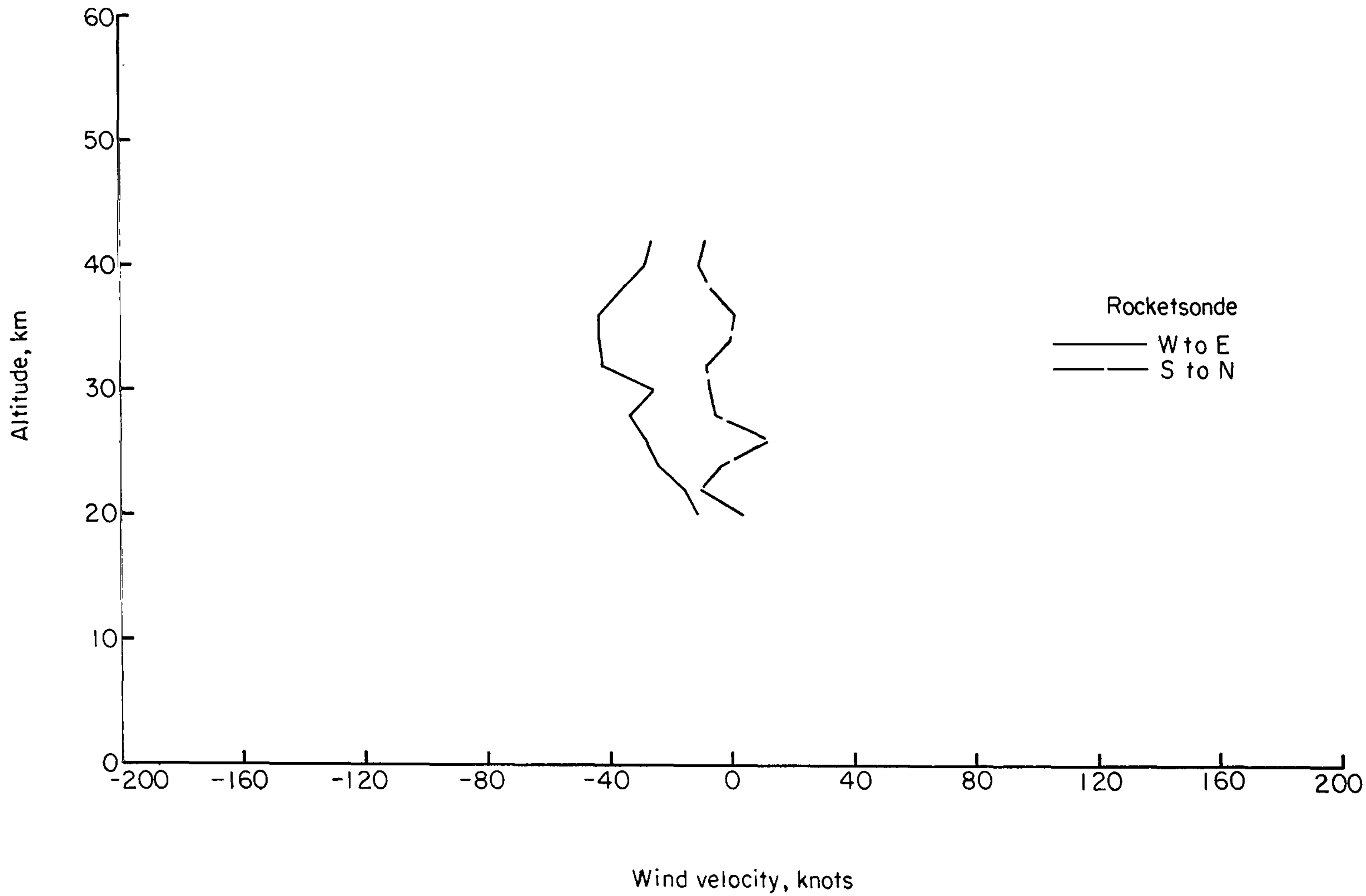
(n) April 2, 1965; latitude 12°19' S and longitude 78°11' S. Sensor: Parachute.

Figure 9.- Continued.



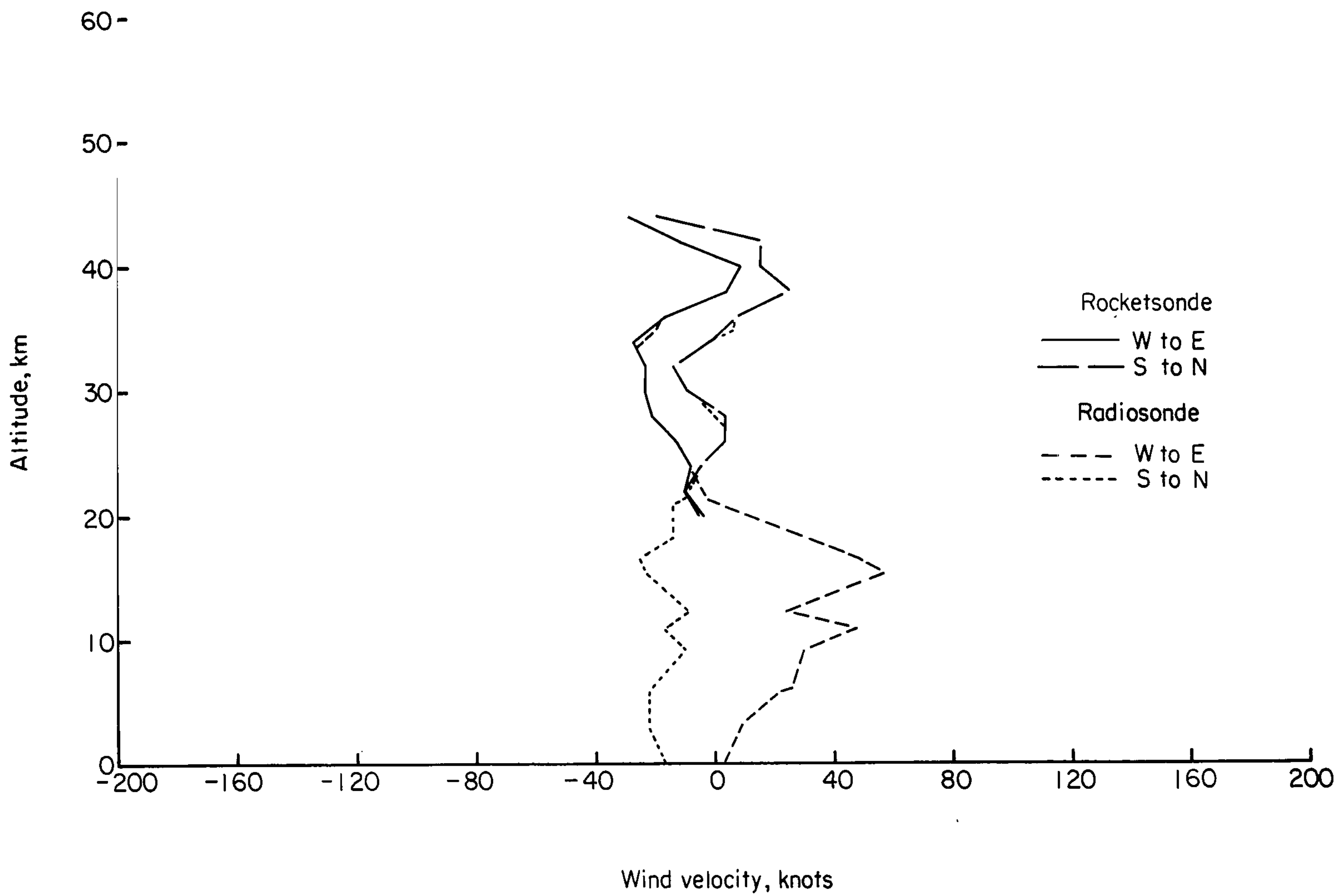
(o) April 3, 1965; latitude 14°34' S and longitude 77°47' W. Sensor: Parachute.

Figure 9.- Continued.



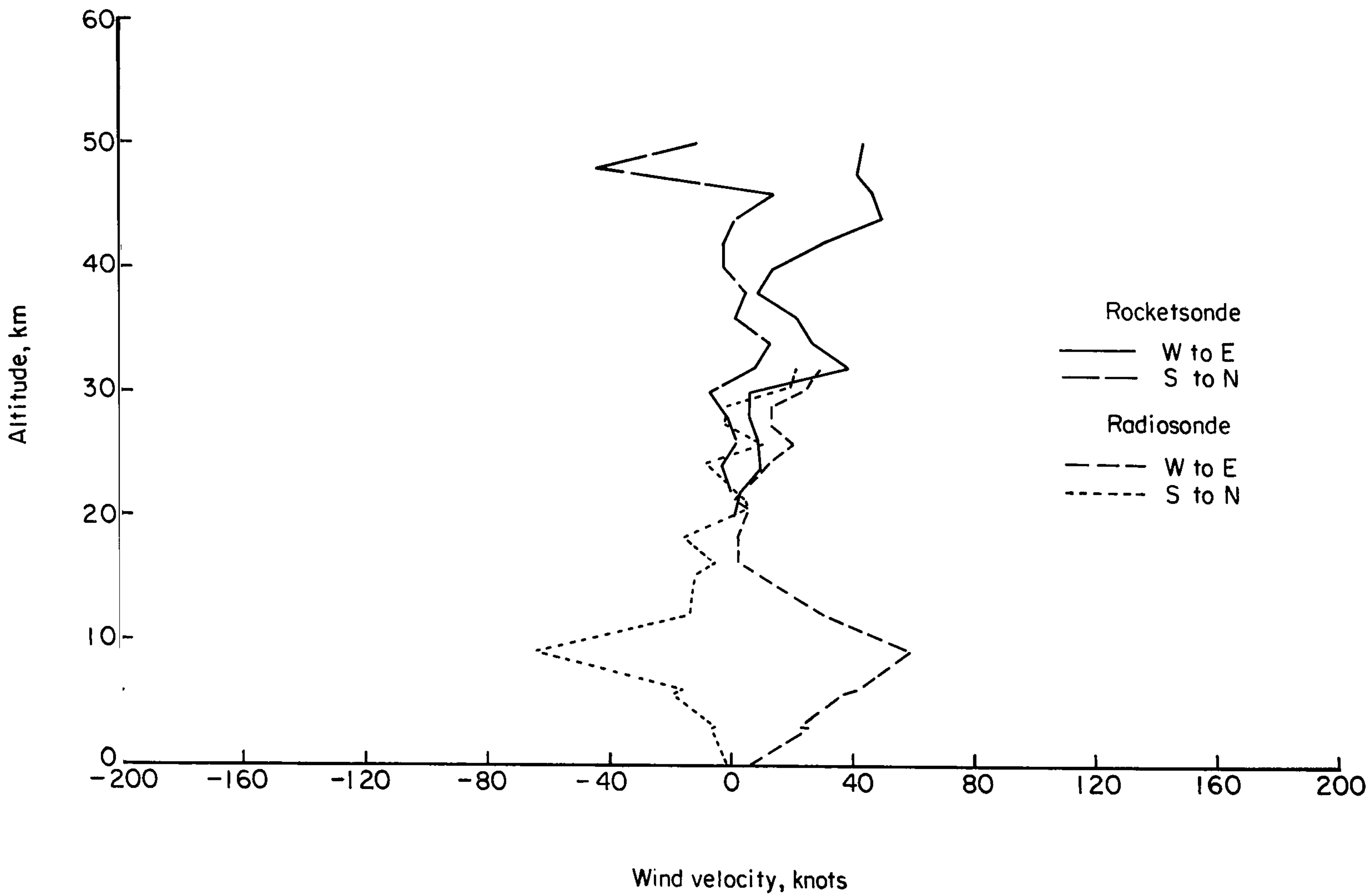
(p) April 4, 1965; latitude 24°36' S and longitude 76°01' W. Sensor: Parachute.

Figure 9.- Continued.



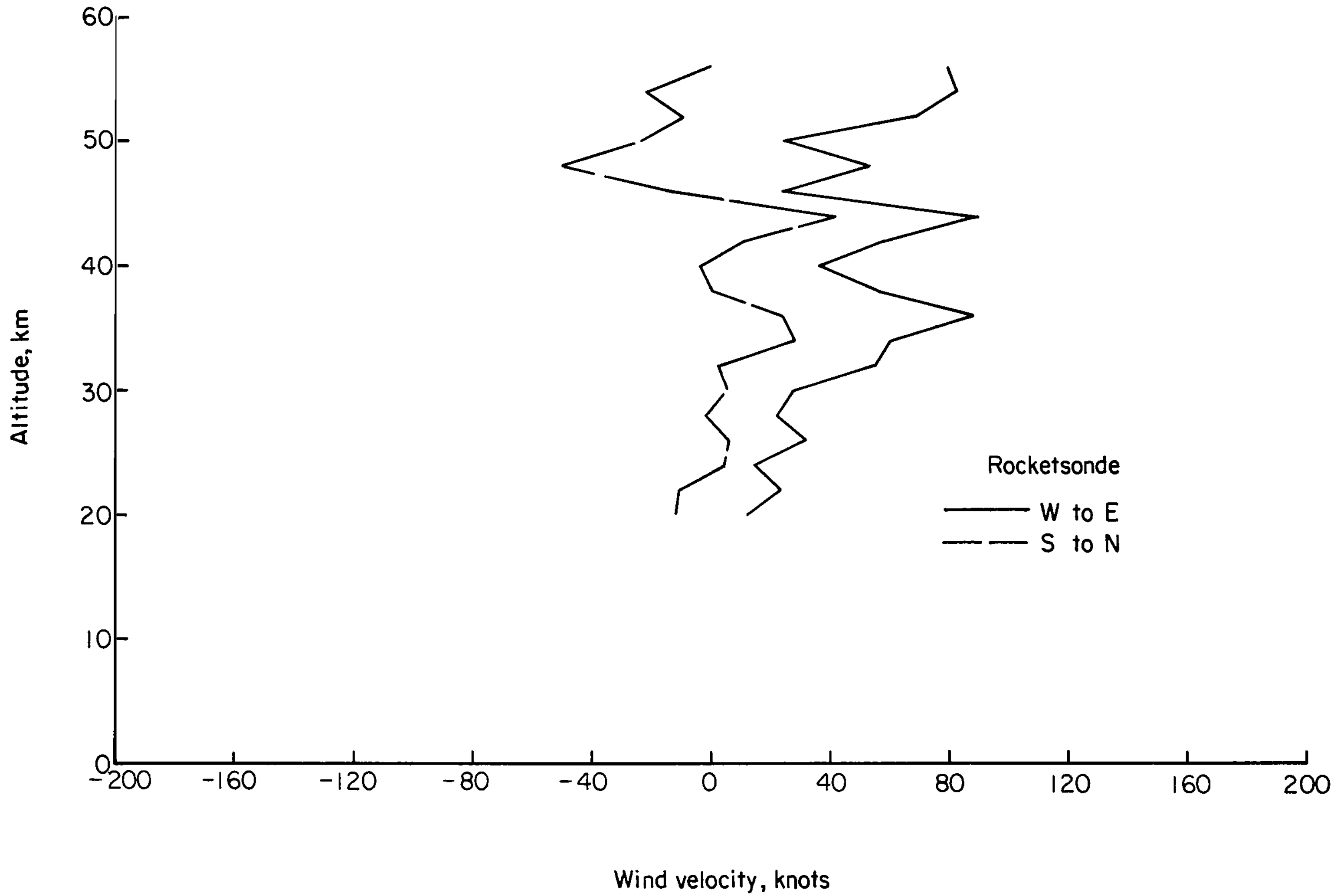
(q) April 5, 1965; latitude 30°52' S and longitude 75°00' W. Sensor: Parachute.

Figure 9.- Continued.



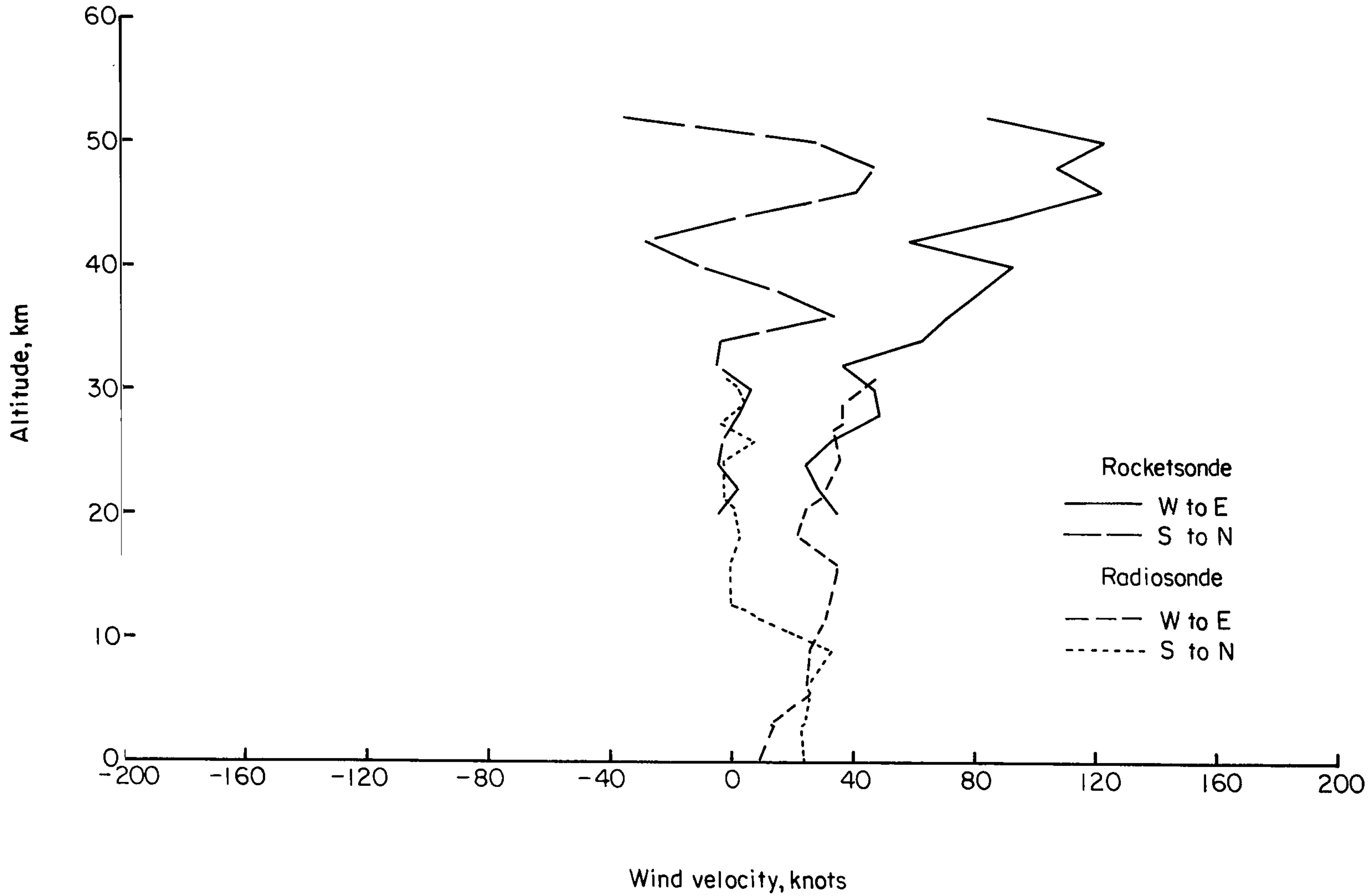
(r) April 6, 1965; latitude 35°12' S and longitude 74°16' W. Sensor: Parachute.

Figure 9.- Continued.



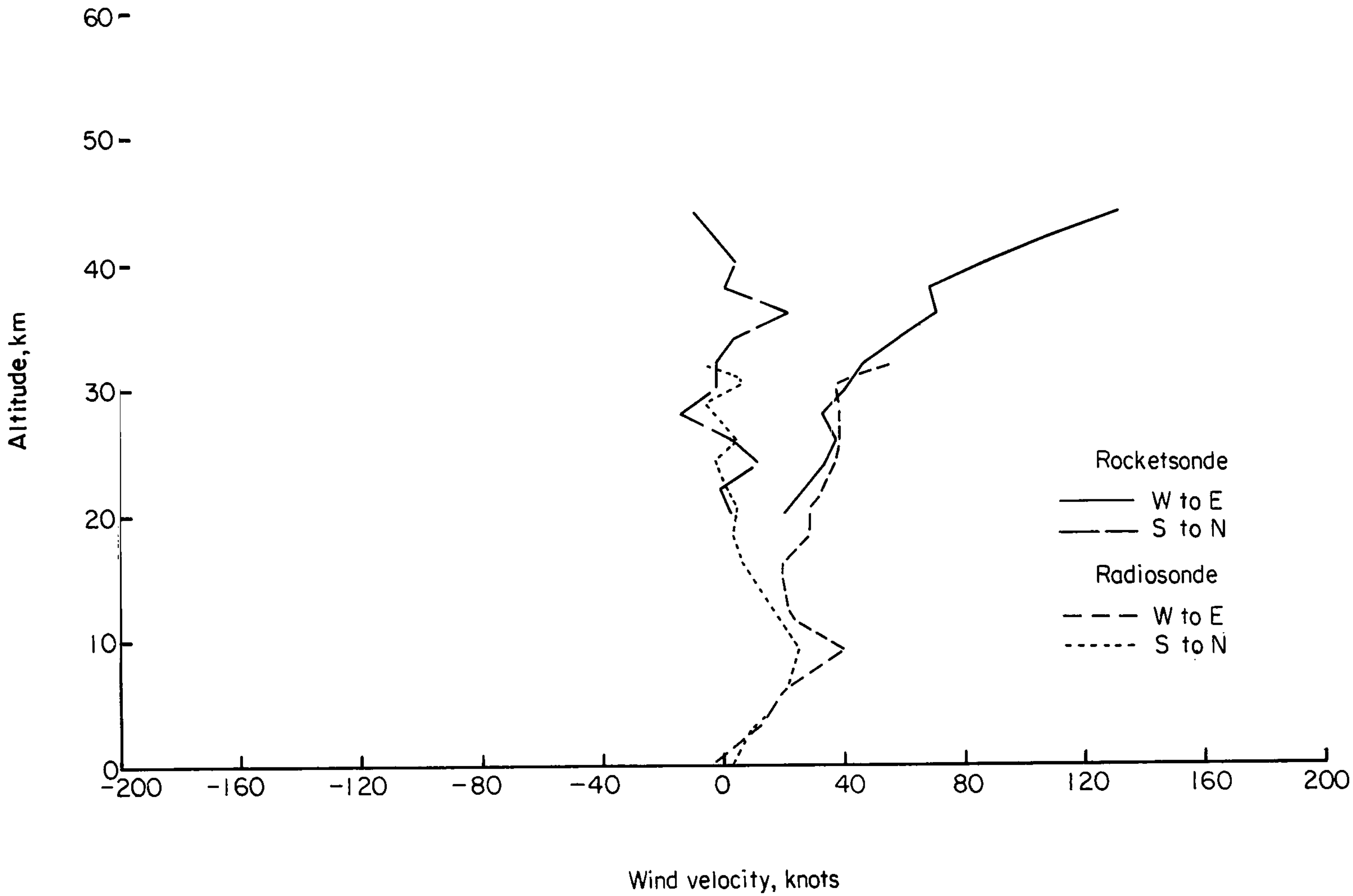
(s) April 8, 1965; latitude 39°07' S and longitude 75°11' W. Sensor: Chaff.

Figure 9.- Continued.



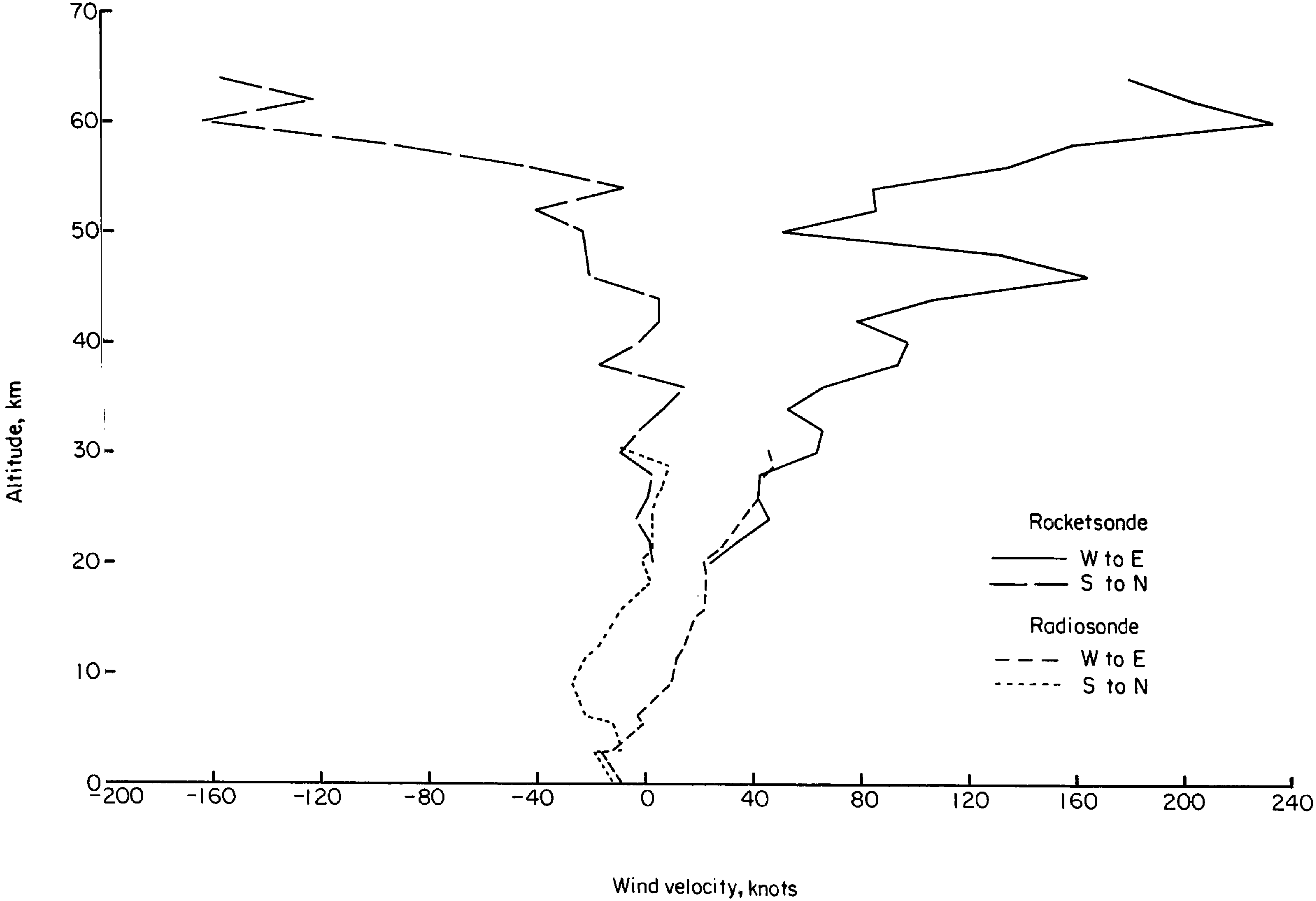
(t) April 10, 1965; latitude 47°02' S and longitude 77°45' W. Sensor: Parachute..

Figure 9.- Continued.



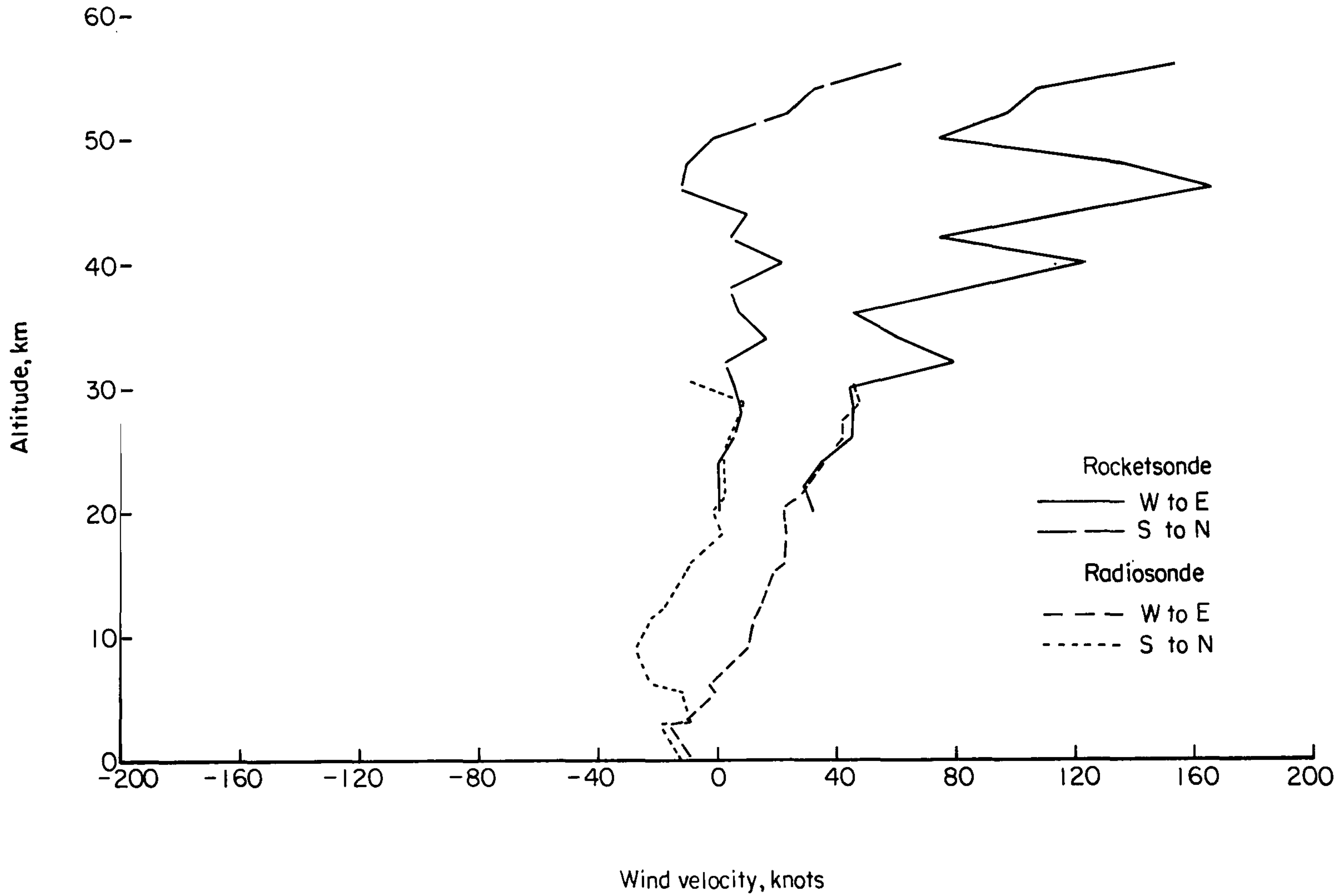
(u) April 11, 1965; latitude 52°11' S and longitude 77°49' W. Sensor: Parachute.

Figure 9.- Continued.



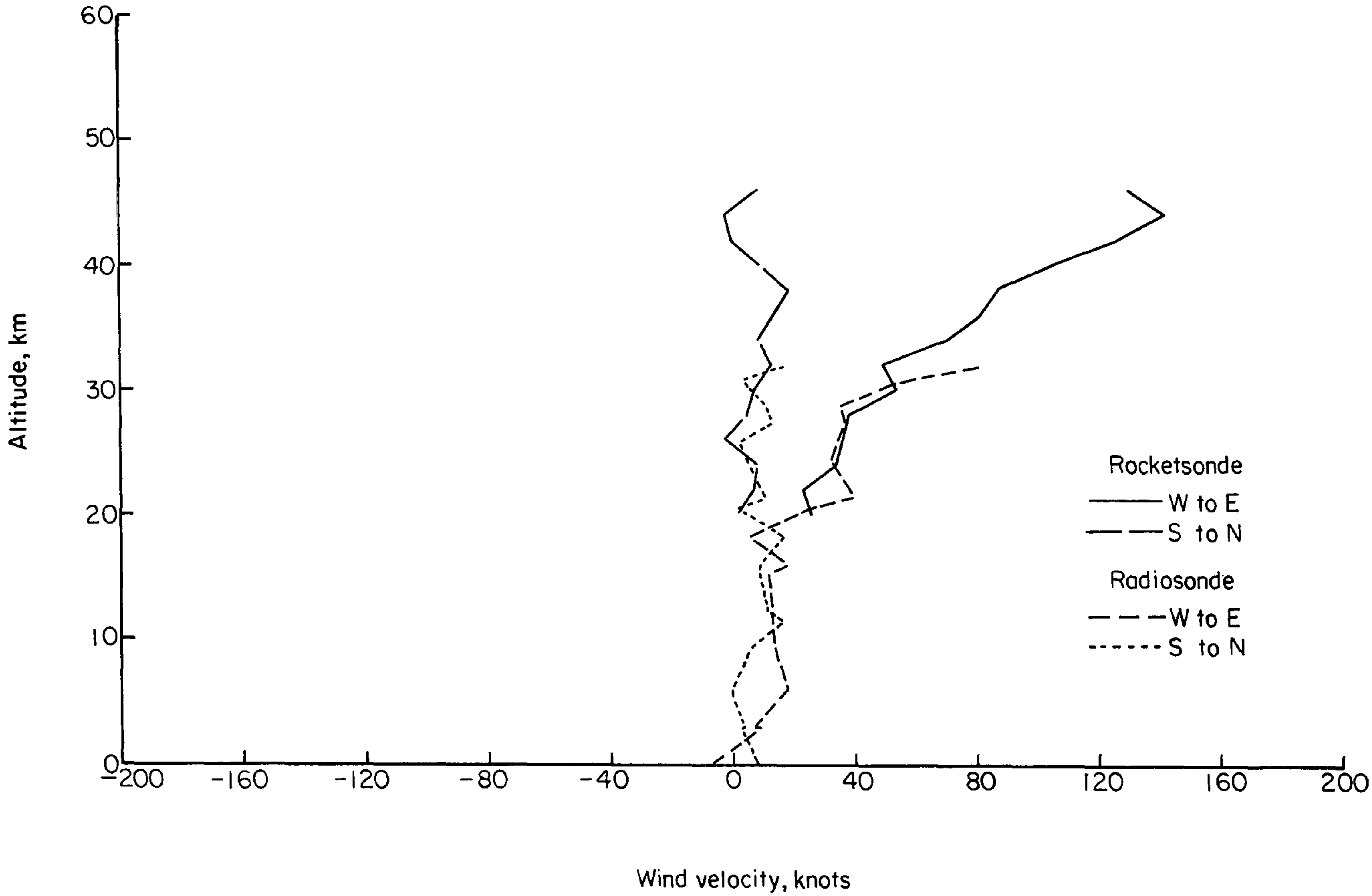
(v) April 13, 1965; latitude 59°52' S and longitude 77°58' W. Sensor: Parachute.

Figure 9.- Continued.



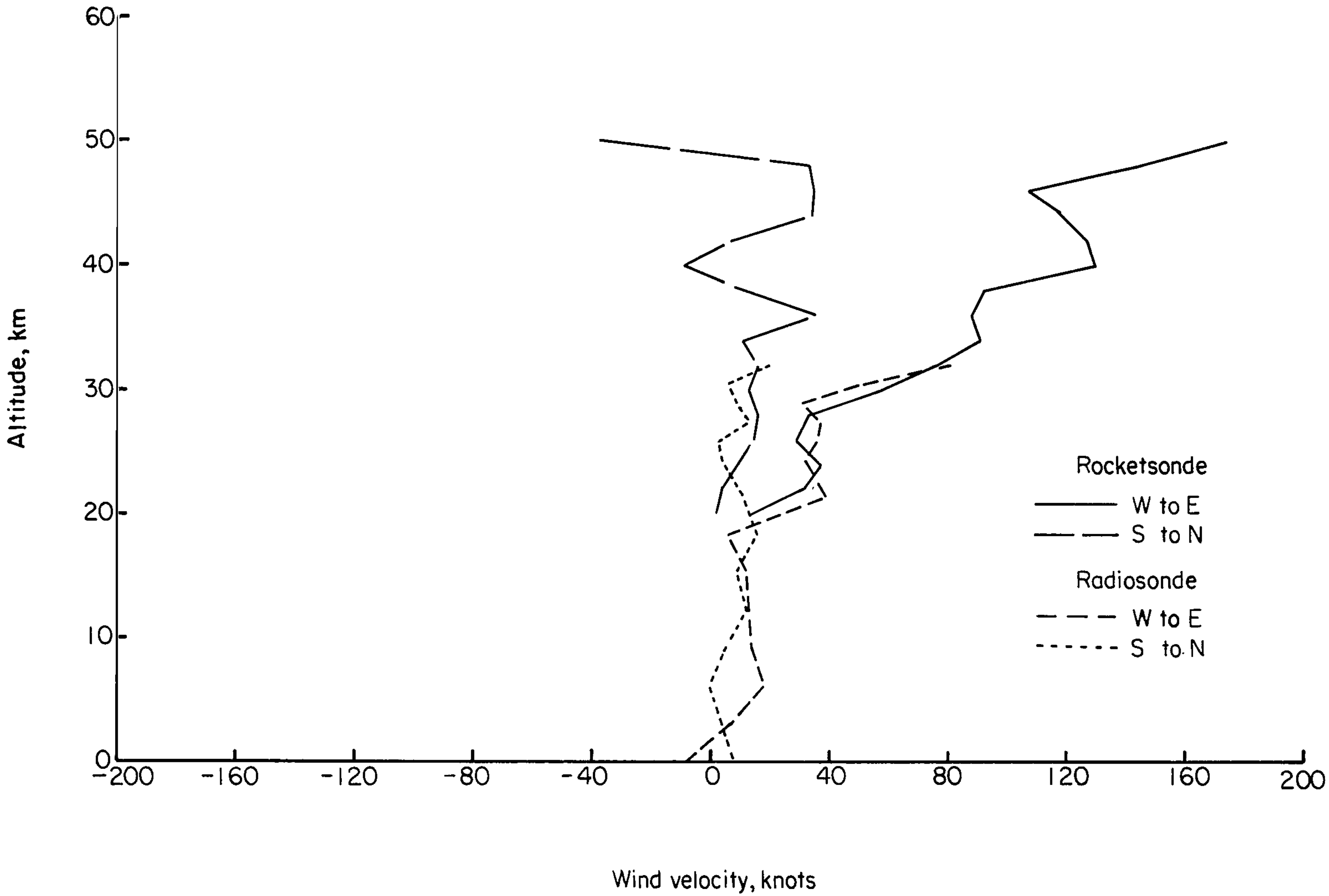
(w) April 14, 1965; latitude 59°46' S and longitude 77°50' W. Sensor: Parachute.

Figure 9.- Continued.



(x) April 15, 1965; latitude 52°28' S and longitude 78°09' W. Sensor: Parachute.

Figure 9.- Continued.



(y) April 16, 1965; latitude 51°20' S and longitude 78°05' W. Sensor: Parachute.

Figure 9.- Concluded.

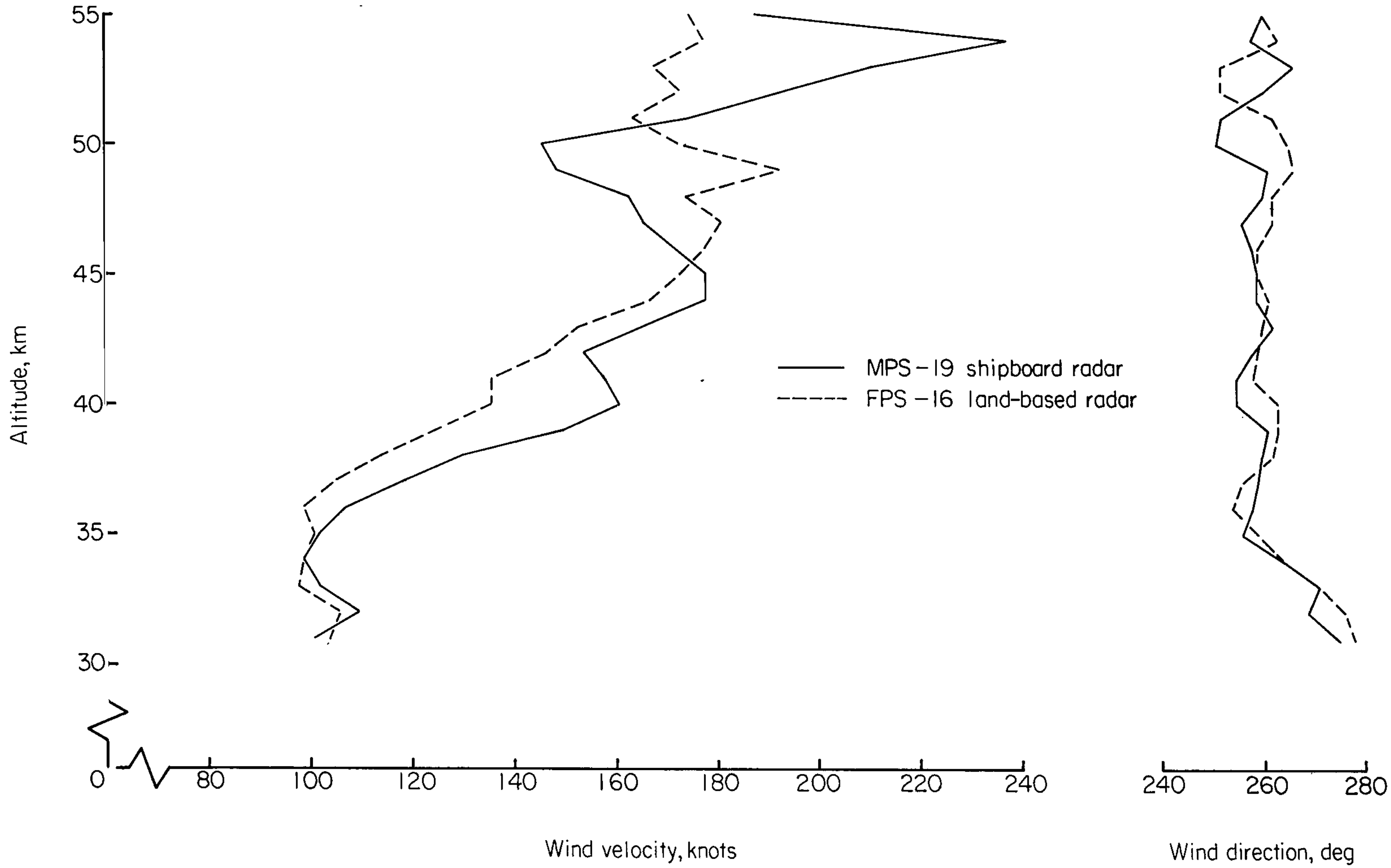


Figure 10.- A comparison of the wind data derived from the MPS-19 shipboard radar and the FPS-16 land-based radar systems.

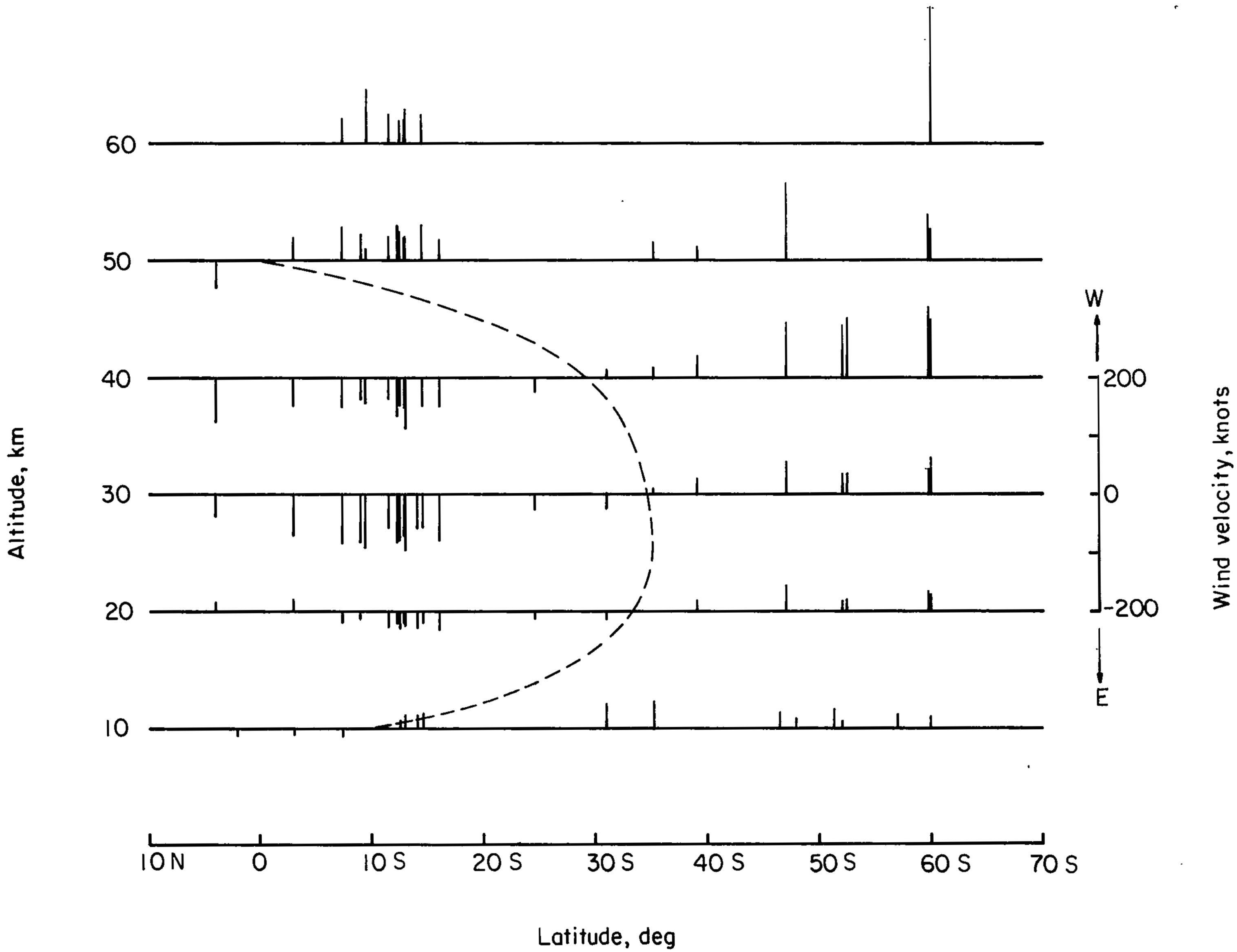


Figure 11.- Summary of wind data from latitudes 4° N to 60° S. The dashed curve is the demarcation line between easterlies and westerlies.

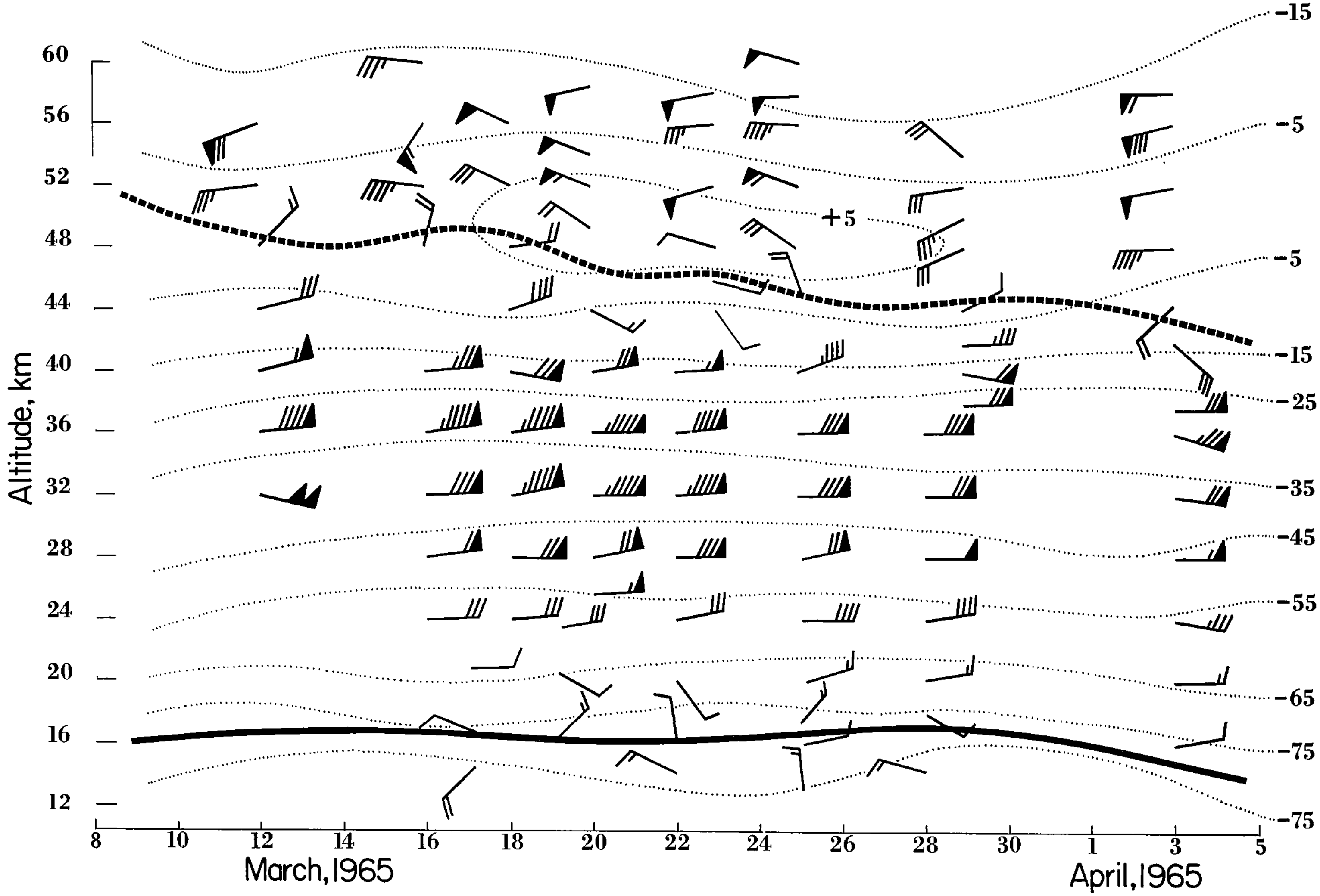


Figure 12.- Time-height section of wind and temperature data near latitude 13° S and longitude 78° W. Each flag (◢) indicates 50 knots; each full barb (/) indicates 10 knots. The direction from which the wind is blowing is indicated by the line connecting the barbs and flags. Example: ◤⁄‾‾ = 60-knot wind from west; _⁄⁄◢ = 65-knot wind from east. The heavy solid curve represents the tropopause. The heavy dashed curve is the demarcation line between easterlies and westerlies.

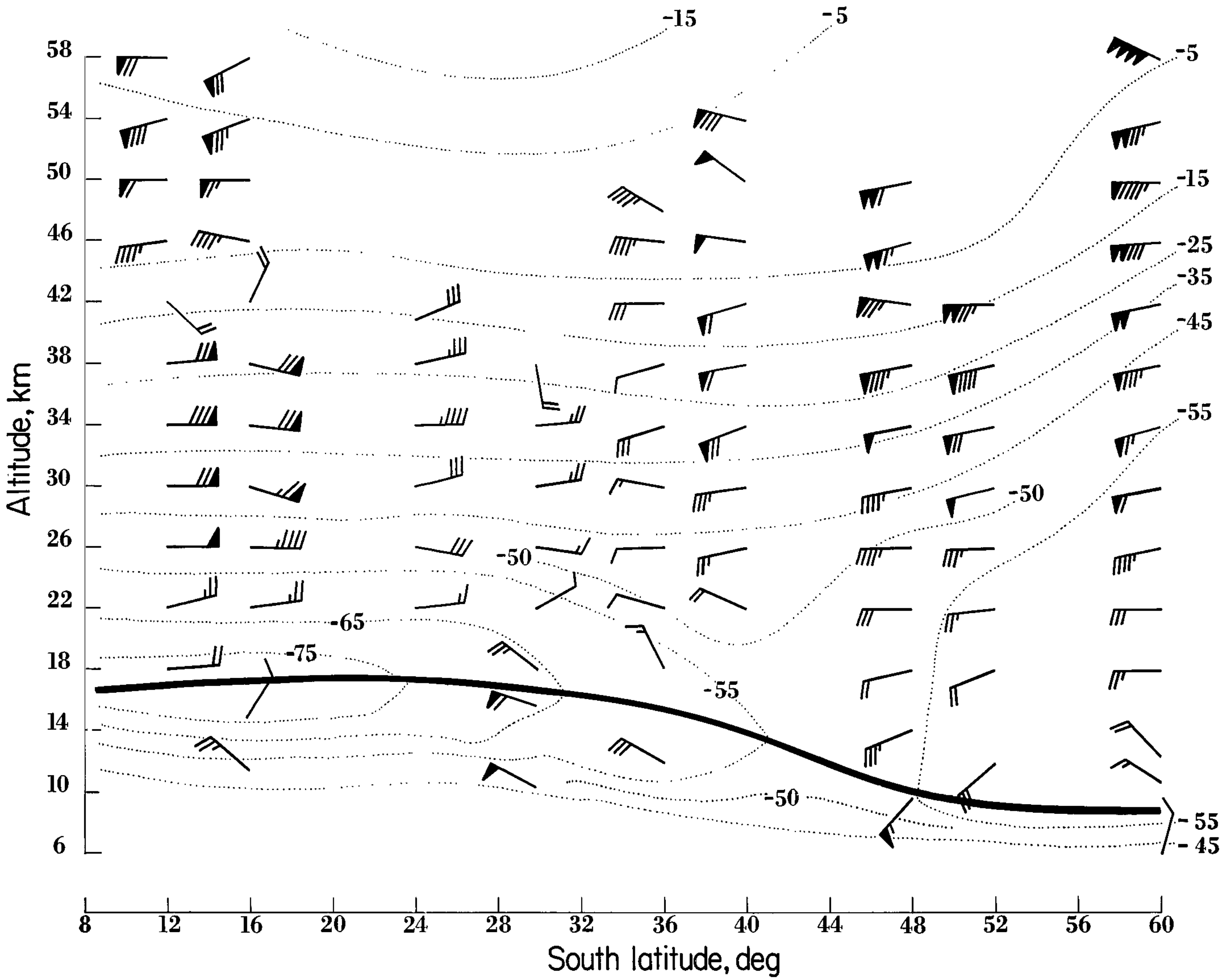


Figure 13.- Wind and temperature data observed from latitudes 12° S to 60° S along longitude 78° W from April 2 to April 15, 1965. Each flag indicates 50 knots; each full barb (/) indicates 10 knots. The direction from which the wind is blowing is indicated by the line connecting the barbs and flags. Example: = 60-knot wind from west; = 65-knot wind from east. The heavy solid curve represents the tropopause.

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