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MARINE AIR PENETRATION OF THE MONTEREY BAY COASTAL STRIP AND SALINAS VALLEY, CALIFORNIA

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ABSTRACT

The composition and circulation of marine air penetration of the Monterey Bay coastal strip and the Salinas Valley are investigated. Integration of the environmental factors of temperature, humidity and circulation of the marine air is related to potential evapotranspiration measurements made at crop levels from the coast inland. Moisture zoning is indicated and daily rates of potential evapotranspiration 40 miles inland vary from 2 to 3.5 times the coastal rate.

Surface and low level winds 800 to 900 meters above surface from the coast to 40 miles inland appear to be offshore in the morning and onshore in the afternoon, with a reverse circulation indicated above this low level flow. These conditions are present even though the synoptic situation would indicate otherwise. The marine layer appears to be well-mixed with a low level maximum wind speed found at 100 to 300 meters above the surface and capped by a turbulence inversion which may have the appearance of a strong subsidence inversion. Inversion appears to be present even with synoptically unstable conditions and may be present over this air shed a large part of the year.

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MARINE AIR PENETRATION OF THE MONTEREY BAY COASTAL STRIP AND THE SALINAS VALLEY

Introduction

Urban development often follows certain patterns because of local climate. The Los Angeles Basin, the San Francisco Bay Area, and the Salinas Valley have agreeable climates because of marine air penetration into these valleys. While the Los Angeles and San Francisco Basins have been urbanized, the Salinas Valley remains an agricultural area where some of the most intensified year-round agriculture in the world is practiced. Although the pattern of development is rapidly changing, at the present time the Salinas Valley and Monterey Bay coastal strip offer an ideal location to make a before and after study, i.e., pre-urbanization and post-urbanization.

Marine air penetration is essentially composed of two phenomena; the daily sea breeze, and the Pacific Coast monsoon. Both of these circulations are due to differential heating of the land and water masses adjacent to them, although they are much different in scale. Schroeder, et al (1967), describes the Pacific Coast monsoon as a slow steady transport of marine air inland from the Pacific anticyclone in response to the differential heating between the ocean areas and the hot interior valleys and deserts of the southwest. This begins in late spring and continues until fall with some interruptions. The sea breeze is a smaller scale circulation superimposed on the monsoon circulation and is due to a local daily coastal heating differential. The sea breeze circulation begins near the beach interface in the morning and expands landward and seaward. The expansion of the sea breeze is not symmetric about the coast line, but is greater over water (Defant, 1951). The inland penetration of the sea breeze is often dependent on terrain factors and may extend many miles inland through mountain passes and valleys (Fosberg and Schroeder, 1966). There is a discontinuity in the roughness at the beach and a non-steady state wind profile results with the sea surface being aerodynamically smooth and the earth's surface a rough aerodynamic surface (Sutton, 1953). Miller (1968) says that the momentum of the sea breeze within the marine layer does not significantly penetrate the inversion base, and his results seem to indicate a circulation within the marine layer of a relative wind

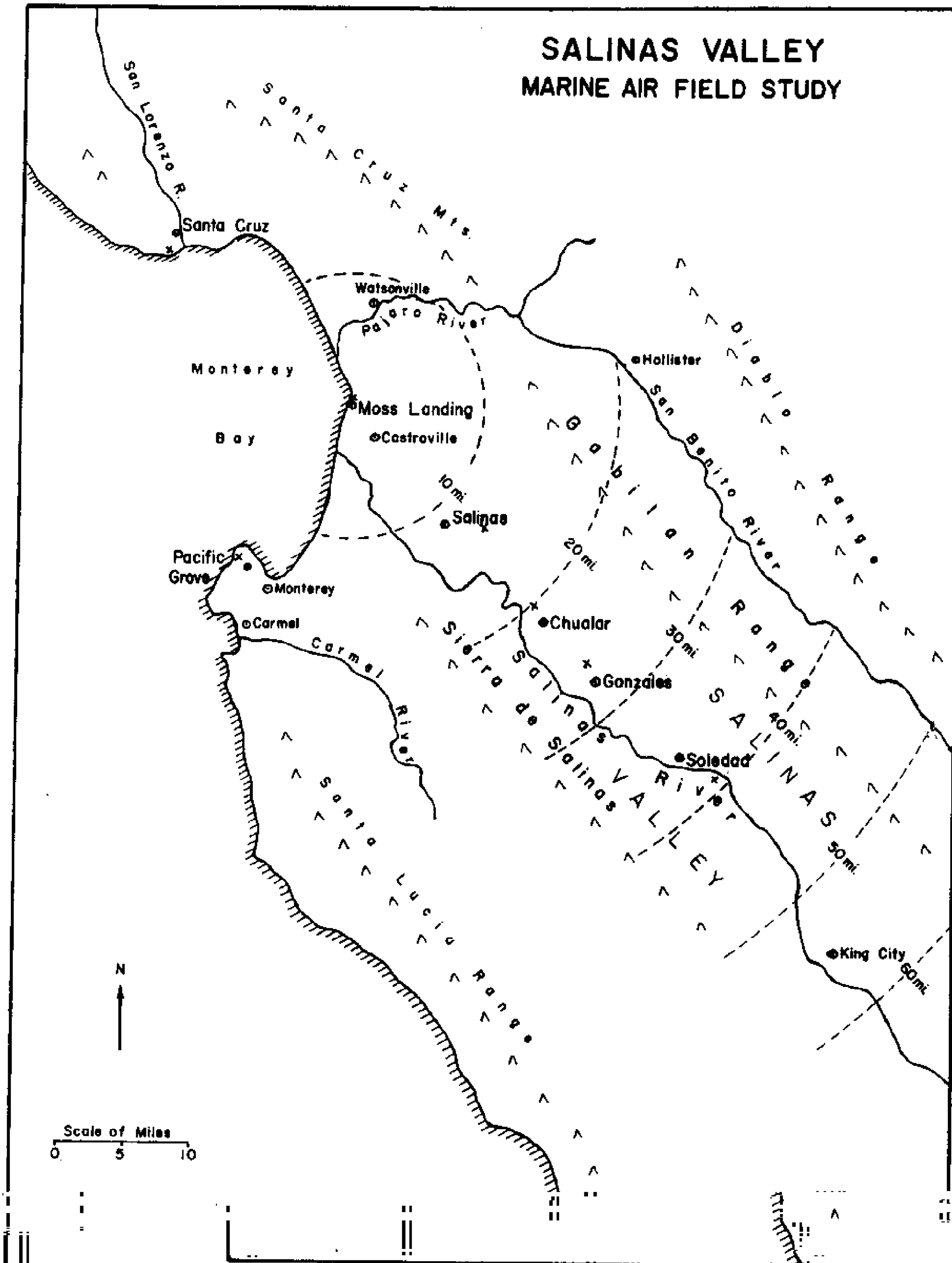


Figure 1. Map of station locations on the Monterey Bay and Salinas Valley.

maximum at about 200 meters above the surface and a wind minimum at about 350 to 400 meters. He also finds another wind maximum above the marine layer and near the top of the inversion.

The Environment

Monterey Bay is a 25-mile wide inlet in the California Coast. The coast line in this part of Central California is oriented northwest to southeast. The Salinas Valley is a narrow steep-sloped coastal valley which opens out on the Monterey Bay and extends southeastward from the bay with mountain ranges of two to three thousand feet on either side of the valley. The flat area of the valley floor at the mouth of the valley is some twenty-five miles wide, but the valley narrows down to about six miles at Soledad, forty miles inland, and to three and one-half miles at King City, which is about sixty miles from the coast.

There is a unique combination of oceanographic, atmospheric, and topographic features which determine the climate and the economy of this area. The large scale atmospheric circulation places a high pressure cell off the coast for a large part of the year with the gradient winds blowing parallel to the coast and from the northwest. Due to Ekman or frictional transport, the surface waters are caused to move to the right of the prevailing winds and away from the coast. This permits upwelling waters in the Monterey Bay coastal area to cool a shallow layer of marine air which may extend some 1000 to 3000 feet above the surface.

Strong subsidence or sinking of air in the northeast quadrant of the Pacific high pressure cell causes a temperature inversion to cap the coastal marine air and effectively sets up a temperature and moisture zoning in the vertical with cool and moist mixed air below and dry warmer air above in the inversion.

Strong daytime heating of the land areas inland from the coast establishes a horizontal temperature and moisture gradient. It is in response to this gradient of temperature that the cool, moist, and often fog laden air from the coast floods over the coastal sill and deep into the valley, thus providing a heat source in winter and a heat sink in summer. The bay surface water temperatures approximate the wet bulb temperature of the air over the bay, and surface water temperatures vary from 50 to 60 degrees Fahrenheit during the year, while air temperatures are generally warmer by 5 to 10 degrees Fahrenheit. These conditions are conducive to fog formation and the typical low level weather situation shows a fog bank lying off the coast most of the year, although during the winter months this often disappears. A large amount of the incoming short wave solar radiation is absorbed at the earth's surface. Before this energy can be utilized by the atmosphere, it must be transferred across the earth-atmosphere interface. Malkus (1962, 1965), and Garstang (1965), say the most important transfer process at the earth-atmosphere interface is evaporation which provides about 50 to 75 percent of the atmosphere's energy source in the form of latent heat. It is probable in the Monterey Bay Area and in the seaward extent of the Salinas Valley that some 75 percent of the incoming and diffuse solar radiation is utilized in evaporation of sea water and fog present in the air, evapotranspiration, and movement of air in and out of this air shed.

As a result of this movement of marine air into the valley with its heat and moisture regulation, natural integration of the climatic factors of wind, temperature, and humidity have been accomplished by the plants that grow here. This is perhaps the most fertile valley in the world for the production of cold weather vegetables. The dominant factor here is the marine air. The soil is not particularly good and must be heavily fertilized. The floor of the valley only receives about 14 inches of rain per year, and must be heavily irrigated.

A moisture-temperature zoning seems to be set up where in the coastal strip artichokes, cabbages, broccoli and cauliflower grow year-round. In the next zone inland, year-round crops of lettuce, celery, carrots and other common truck garden vegetables grow. The next zone inland permits summer crops of tomatoes and beans with winter crops of broccoli, onions and garlic.

The purpose of this study is to examine the marine air composition and circulation which dominate the climate and economy. To do this adequately would take several years of data collection and evaluation so that rigorous statistical analyses could be made. Although a long-range data collection is in progress, the approach here is to collect adequate amounts of data through several days of field study, to display these data meaningfully, and to examine analyses for obvious trends.

Examination of the composition of the marine air and its penetration into the valley at crop levels leads to an investigation of the potential evapotranspiration at this level. Since so large a portion of the solar and diffuse radiation is transformed into latent heat, an understanding of this process should go a long way in the determination of the climate. Potential evapotranspiration or potential evaporative power is defined as the time rate of evaporation from wet surfaces under existing atmospheric conditions with an unlimited water supply (Read, 1968). Evaporation is a function of the physical characteristics of the evaporating surface and such other environmental characteristics as air temperature, humidity and flow over the evaporating surface. Any space-time correlation of evaporation rates must eventually depend upon space-time correlations of these environmental and physical characteristics.

The variation in evaporation rates due to the physical characteristics of the evaporating surface were reduced to a minimum in that the same type evaporating surface was placed at each observation station.

Air moisture content or humidity varies with distance inland. It is also a function of time of the day and the strength of the marine air flow into the valley. Air temperature in general would be expected to increase with time of the day up to a maximum in the afternoon and then decrease toward nightfall. It is also dependent on distance and air flow from the coast, cloud cover and fog.

The two variables of air temperature and humidity may be combined into a parameter called the Saturation Vapor Pressure Deficit (D) which is a measure of the drying power of the air. Evaporation has often been examined as an empirical relationship called Dalton's Law in the form:

$$E = f(u)D$$

E = evaporation in units of volume/time

$f(u)$ = function of the dependence of evaporation speed on wind velocity u

D = $e_s - e$

e_s = saturation vapor pressure at air temperature

e = saturation vapor pressure at the temperature of the dew point.

When examined on this basis, time and space correlations of air temperature and moisture are taken into account.

The air flow over the evaporating surface varies with space and time in that surface wind speed and direction vary as the thermal contrast between the bay and land surface builds up. Wind speeds may also increase as the valley narrows down.

The vertical and horizontal extent of the marine layer was also examined using pilot balloon observations and temperature and dew point temperature soundings of the first 2000 meters above the surface.

In the analysis of the surface data, some smoothing has been carried out so that obvious trends could be more readily displayed. Smoothing of upper air data is discussed later. Out of these observations and analyses some preliminary estimates of the moisture zoning are found and some quite surprising circulation patterns are presented.

Instruments and Observations

Surface potential evapotranspiration observations were made using Livingston porous porcelain black and white spherical evaporimeters. These instruments are approximately 5 cm in diameter and are fed by a constant supply of distilled water. The evaporimeters were located about one meter above the ground, and insofar as possible, were all placed in fallow fields. The surface winds were also measured at the one meter level with fan-type hand-held anemometers. Wet and dry bulb temperature readings were taken simultaneously with the wind and evaporation measurements. During the period of field study, the surface observations were made hourly throughout the daylight hours from 0700 to 1800. Evaporation measurements were in milliliters/hour, temperature measurements in degrees Fahrenheit, and wind speeds in meters/second. Surface measurements were taken at Moss Landing, Santa Cruz, Pacific Grove, Salinas, Chular, Gonzales, and Soledad (see Figure 1 for locations). Pilot balloon observations were taken at Moss Landing, Salinas and Soledad. These observations were made using 30 gram balloons and taking measurements every 30 seconds of ascent. The observations were made hourly from 0700 to 1800 during the field studies. In addition to these measurements, we were able to get temperature and relative humidity soundings through 3000 feet above the ground for two days. These measurements were made by a specially instrumented helicopter, which was provided by the U.S. Naval Post Graduate School, Department of Meteorology. These observations were made 5 miles northwest of Moss Landing out over the bay, at Moss Landing, Salinas, Soledad and King City. All wind directions are true and units of wind speed are meters/second. During the period of field studies, wet and dry bulb readings were also taken by a roaming observer who took observations every two miles along the highway from Moss Landing to Soledad.

Field studies were made during the period 17-18 May 1969, 7-8 November 1970, April 6, 1971, and 1-2 May 1971. During the May 1969 period, the synoptic situation was favorable for a sea breeze circulation and marine air penetration into the valley. During the November 1970 period, the first rain of the season occurred on 7 November. During the April 6, 1971 field study, rain occurred late in the afternoon, and there was a 500 mb trough passage. During the May 1971 study, there was a deep 500 mb low situated off the coast with strong southerly gradient winds indicated for the whole period. Low clouds and afternoon rain on 2 May made it difficult to take pilot balloon observations. Thus, only the May 1969 field study was really indicative of a strong marine air flow into the valley.

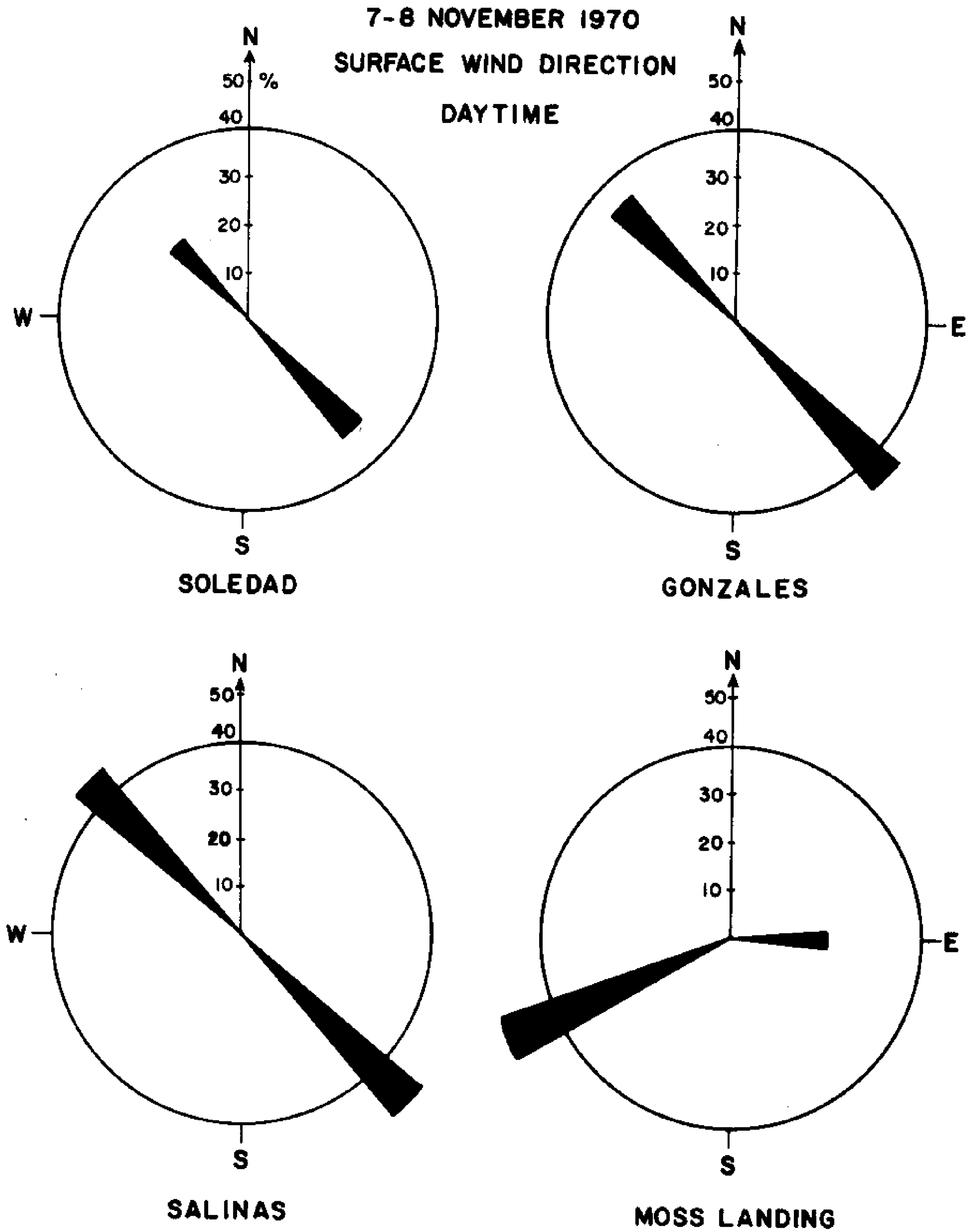


Figure 2. Daytime surface wind directions, 7-8 November 1970.

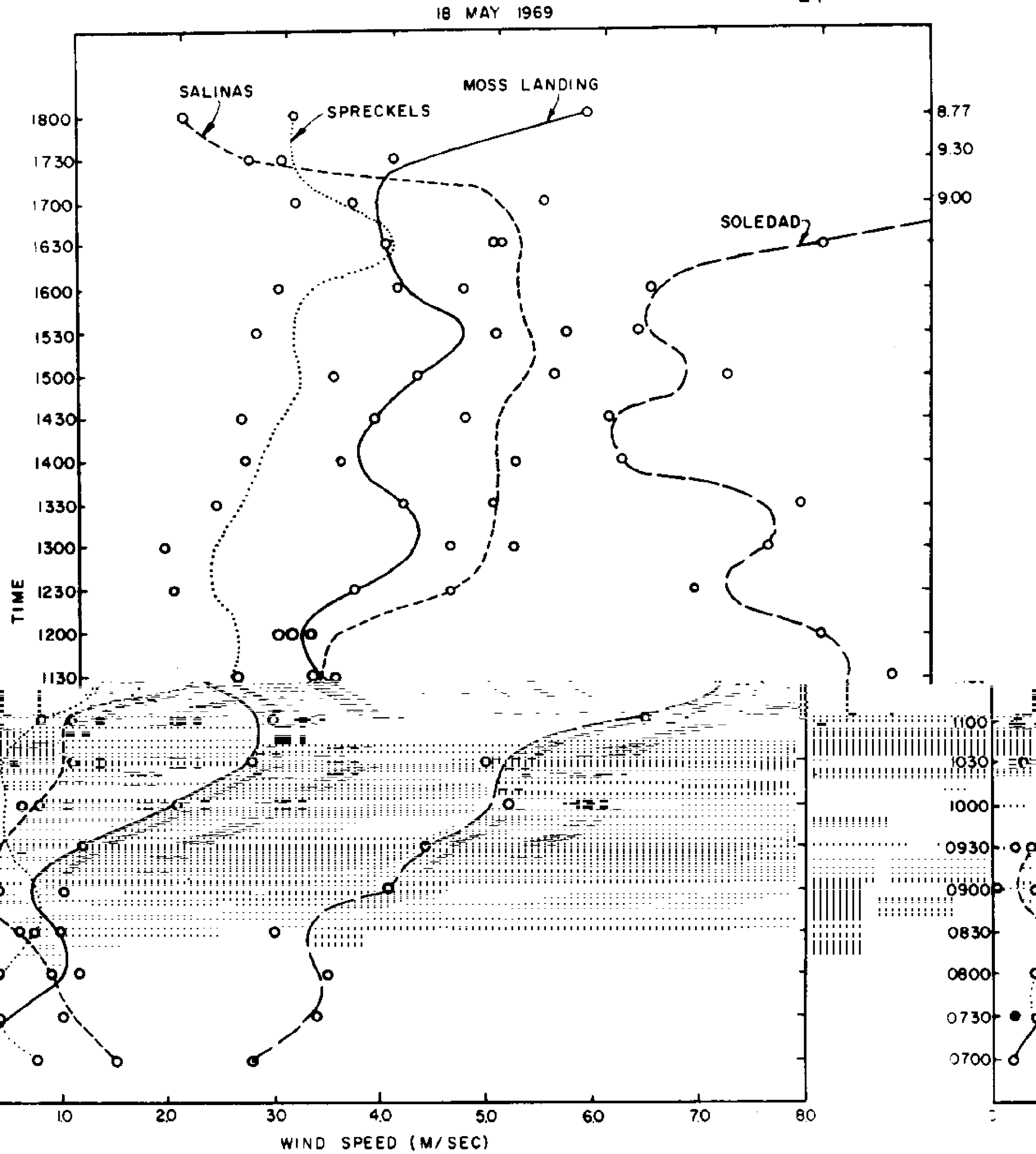


Figure 3. Surface wind speed profiles for Moss Landing,
inas, Soledad, 18 May 1969. Sal

Table 1

Surface Maximum Winds and the Times of Occurrence.

Date	Moss Landing	Salinas	Soledad
5/17/69	1230 SW 4.5 m/sec	1430 NW 4.9 m/sec	1600 SW 9.9 m/sec
5/18/69	1430 W 3.9 m/sec	1530 NW 3.1 m/sec	1630 SW 9.3 m/sec
11/7/70	1200 SW 3.0 m/sec	1300 W 2.5 m/sec	1600 NW 5.8 m/sec
11/8/70	1400 W 2.4 m/sec	1400 WNW 2.6 m/sec	1700 NW 4.3 m/sec
5/1/71	1600 SW 6.7 m/sec	1600 NW 4.1 m/sec	1500 SE 6.3 m/sec

Discussion

The surface wind directions appear to have a bimodal distribution during the day with general offshore or down valley winds during the morning hours and becoming onshore or up valley winds during the afternoon. Figure 2 is a typical wind rose giving percentages of wind directions during the daylight hours of 7 and 8 November 1970. At the coast and in the mouth of the valley, wind directions with a westerly component are onshore winds. Easterly wind components indicate offshore flow (Moss Landing, Salinas). Up the valley at Gonzales and Soledad, southerly winds are offshore or down valley winds and northerly winds are onshore or up valley winds.

Surface wind speeds vary with the time of the day and distance from the coast. Figure 3 gives wind profiles for a typical day when the sea breeze and marine air penetration is strong. Moss Landing and Salinas wind profiles are fairly similar although the afternoon winds at Salinas are generally stronger. At Soledad, the winds are much stronger throughout the day with maximum speed occurring late in the afternoon. Table 1 shows the times of occurrence of maximum winds, the strength of the wind, and the direction at three selected stations. The time occurrence generally seems to be later with distance

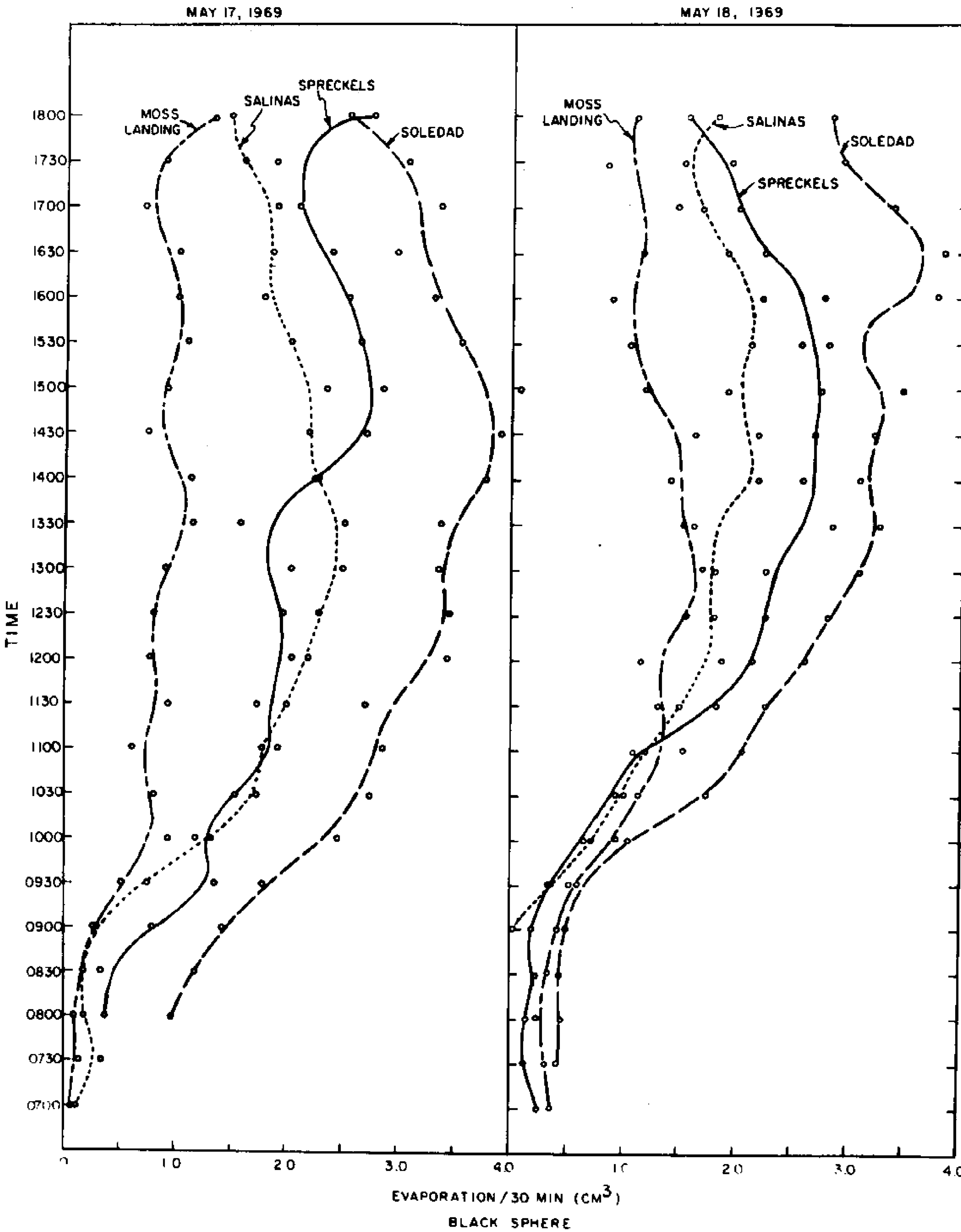


Figure 4. Maximum potential evapotranspiration profiles, 17-18 May 1969.

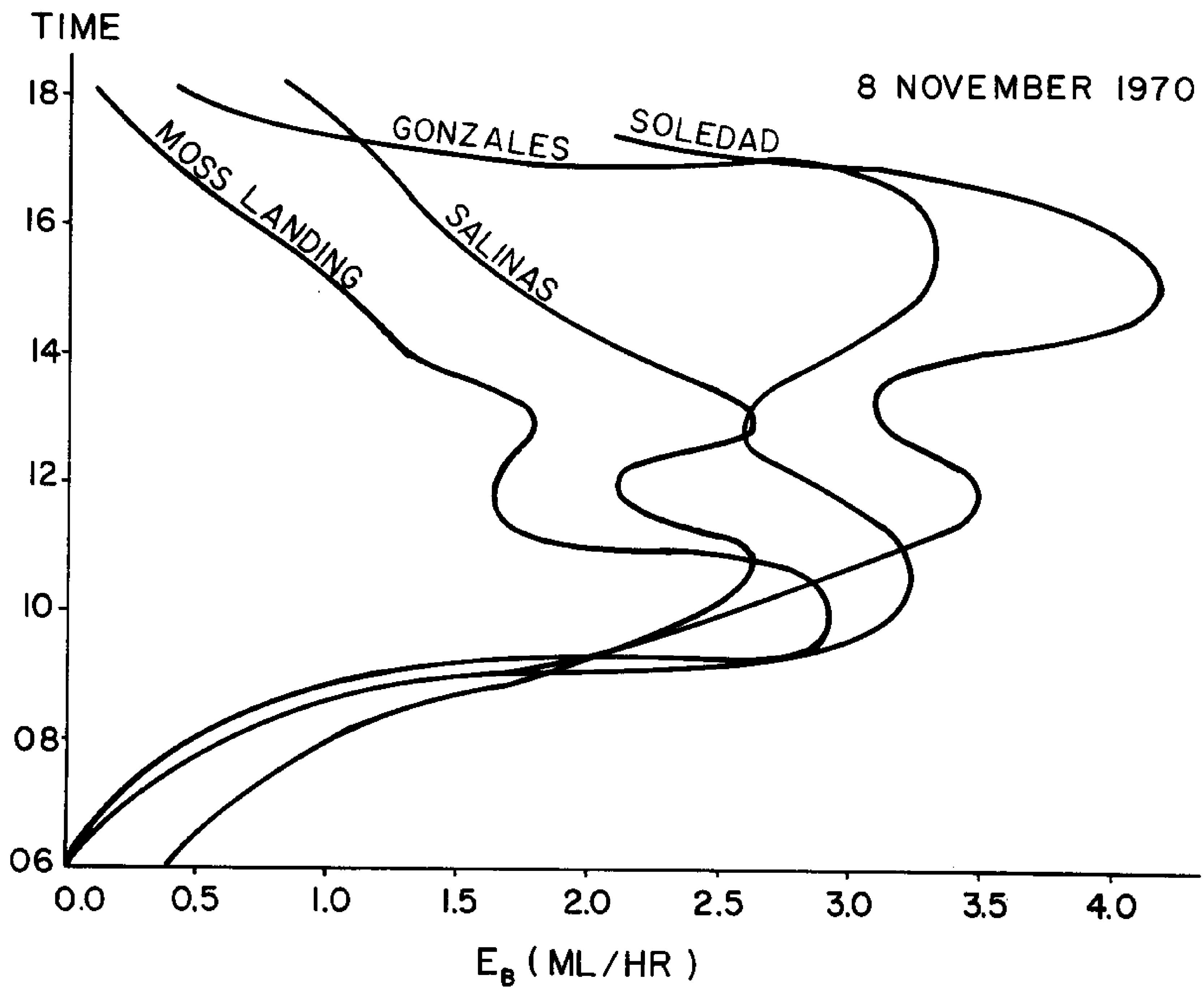


Figure 5. Maximum potential evapotranspiration profiles, 8 November 1970.

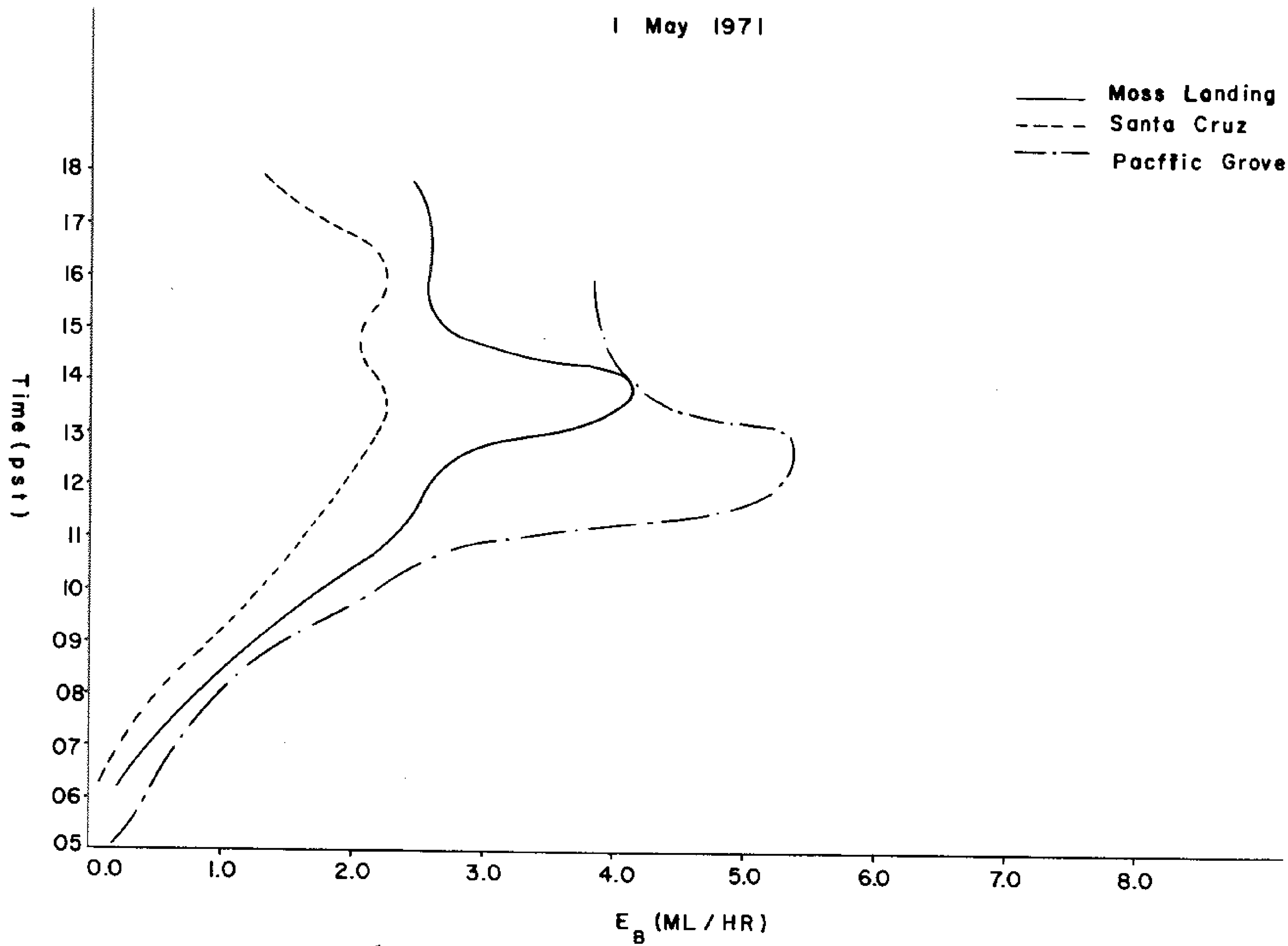


Figure 6. Maximum potential evapotranspiration profiles for Coastal stations, 1 May 1971.

inland, although the data for 1 May 1971 indicates little difference in time of maximum winds. Maximum wind speeds are usually stronger at Soledad than they are at the other stations. It is interesting to note the change in wind direction from Soledad to Salinas. This would appear to indicate turbulence and mixing close to the surface.

The maximum potential evapotranspiration as measured by the black spherical evaporimeter should show a space-time correlation with the penetration of marine air into the valley. Figure 4 shows evaporation rates during the day for 17-18 May 1969, when the synoptic situation was favorable for sea breeze circulation. Definite moisture zoning seems to be indicated here with increases in the potential evapotranspiration rate taking place from Moss Landing to Salinas to Soledad. Figure 5 shows the potential evapotranspiration rates on 8 November 1970, when the synoptic situation was not favorable for a local sea breeze circulation. The evaporation profiles here also show dependence on time of day and distance inland. An inspection of these profiles shows how sensitive the evaporation measurements were to wind shifts and advection of moist air. The wind shifts are shown below:

Moss Landing	1000 E	1100 WSW
Salinas	1200 ESE	1300 WNW
Gonzales	1300 SE	1400 NW
Soledad	1300 S	1400 NW

At each station the rate of evaporation decreases with the advection of moist air from the coast. Although the spherical atmometer is quite sensitive to wind flow, it is not known if the natural plant evapotranspiration surfaces are this sensitive.

Figure 6 shows the evaporation profiles at three coastal stations. Moss Landing and Santa Cruz face on to the bay, while the Pacific Grove station is located at the Point Pinos Lighthouse and was exposed directly to winds from the Pacific Ocean. Santa Cruz, located at the north end of the bay, showed less evaporation than Pacific Grove on the south end of the bay, with Moss Landing evaporation somewhere in between the two. Surface winds were greater at Pacific Grove and Moss Landing than they were at Santa Cruz.

Figure 7 and Figure 8 are smooth curves showing the vapor pressure deficit and dew point temperature as

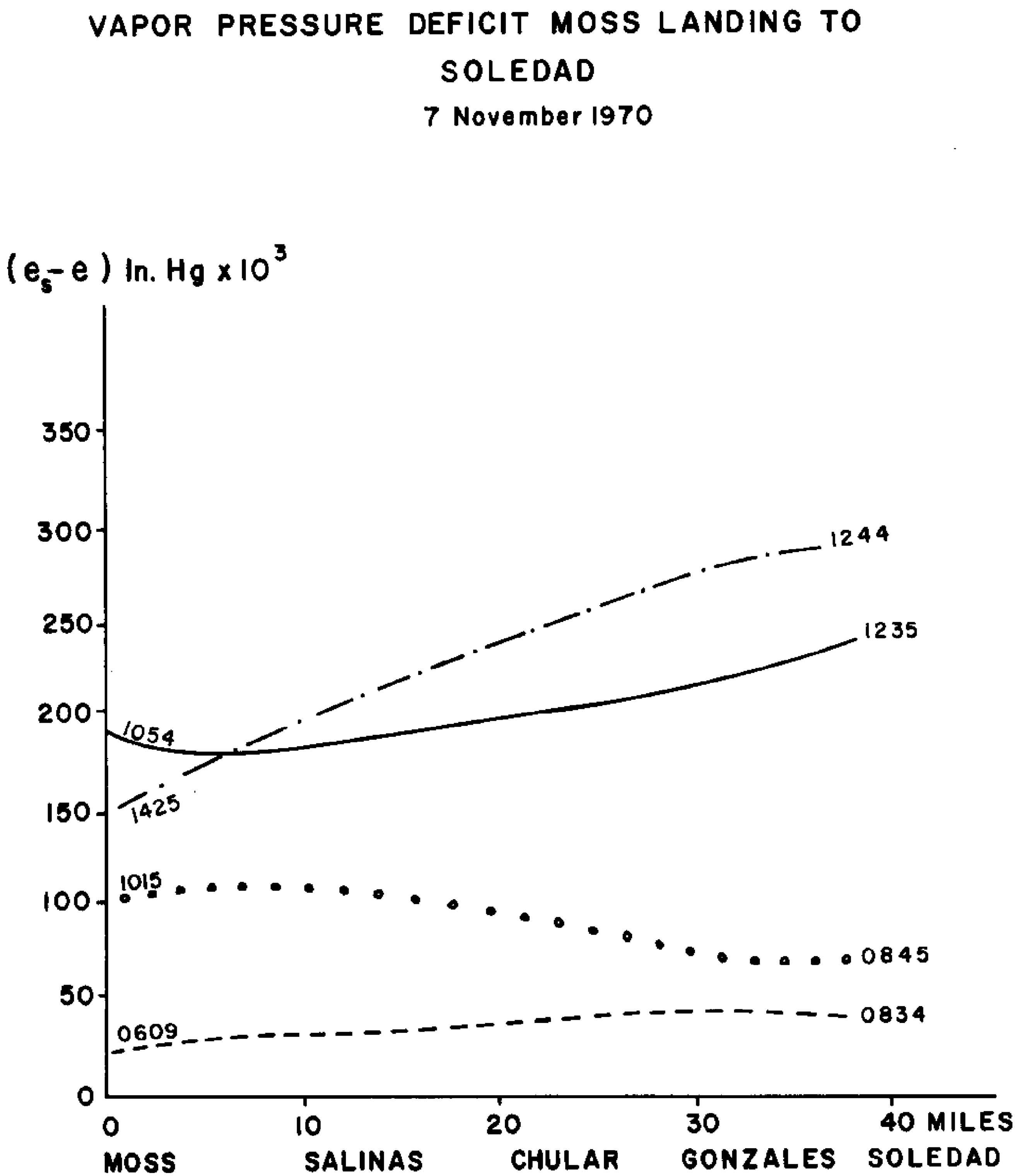
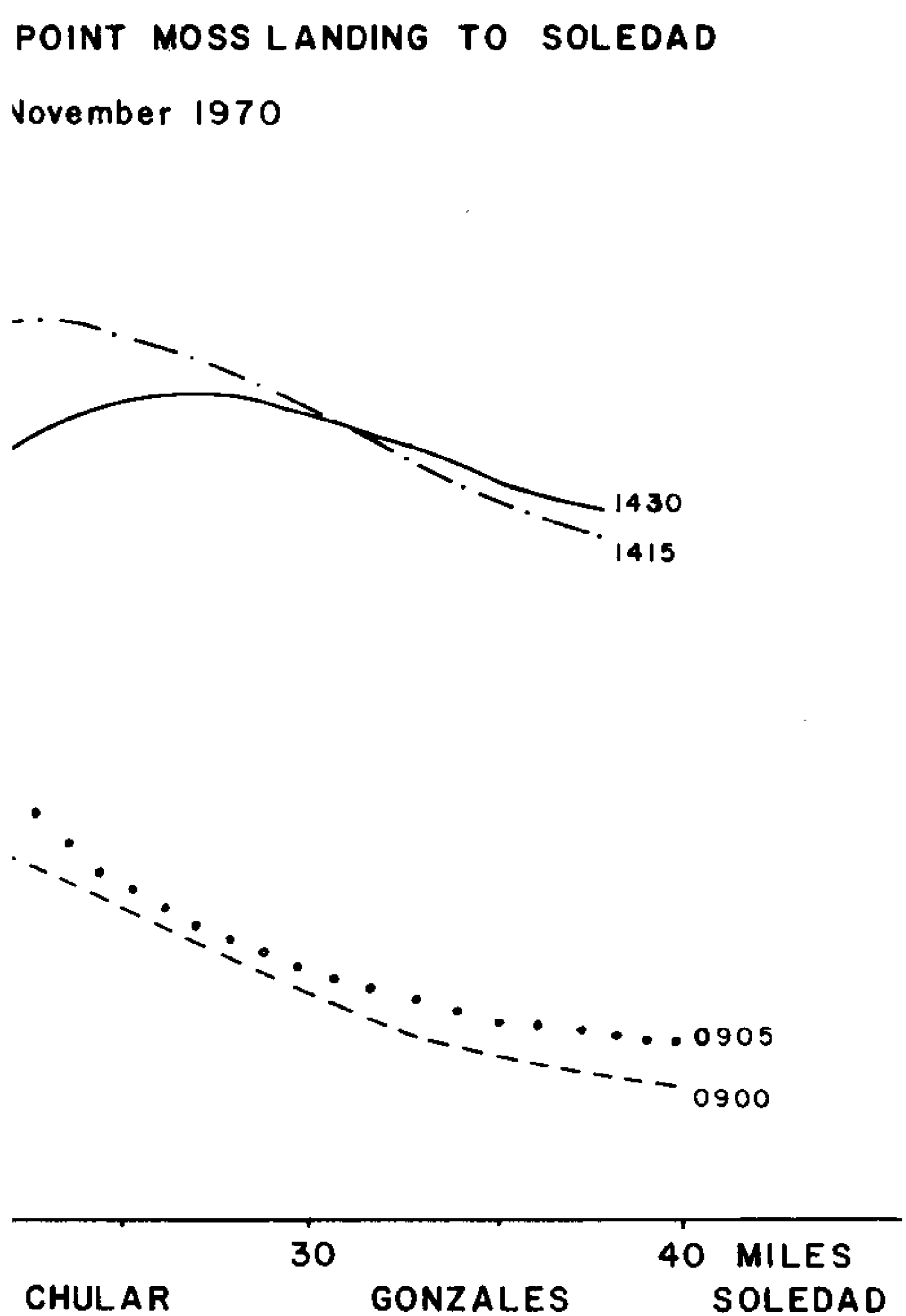


Figure 7. Vapor pressure deficit as a function of time and distance from coast, 7 November 1970.



:ure as a function of time and distance

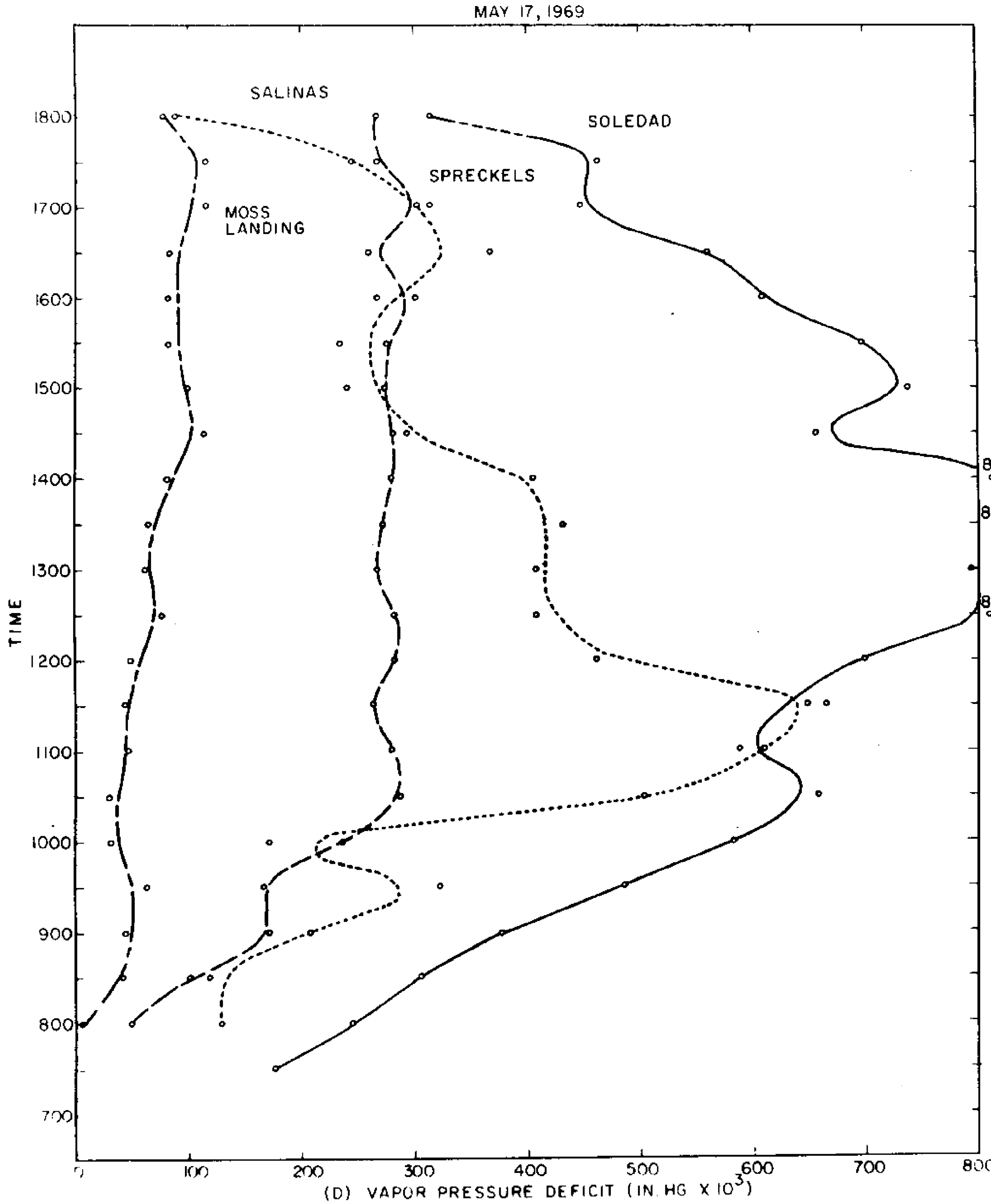


Figure 9. Vapor pressure deficit profiles, 17 May 1969.

a function of time and distance inland. During the early morning daylight hours, from 0600 to 0830, the vapor pressure deficit is about the same from the coast to some 40 miles inland. In the mid-afternoon curve, the air inland appears to have about twice the drying power of the coastal air. The dew point varied about 2 degrees near the coast and about 4 degrees inland at Soledad. The dew point temperature seemed to indicate low moisture content over the city area of Salinas. Dew point curves showed persistent dips throughout the day as the observer moved along the highway through agricultural areas into the city and suburb environs.

Figure 9 shows the vapor pressure deficit as a function of time and distance inland. Quite apparent moisture zoning is indicated as the vapor pressure deficit increases appreciably with distance from the coast.

In order to effectively display and analyze the upper air wind directions, the data were displayed as isogon-sector analyses. To simplify the data reduction, the compass rose was divided into 12 thirty-degree sectors which were oriented around the major axis of the valley, as shown in Figure 10. The data reduction was accomplished by a computer program which places the wind

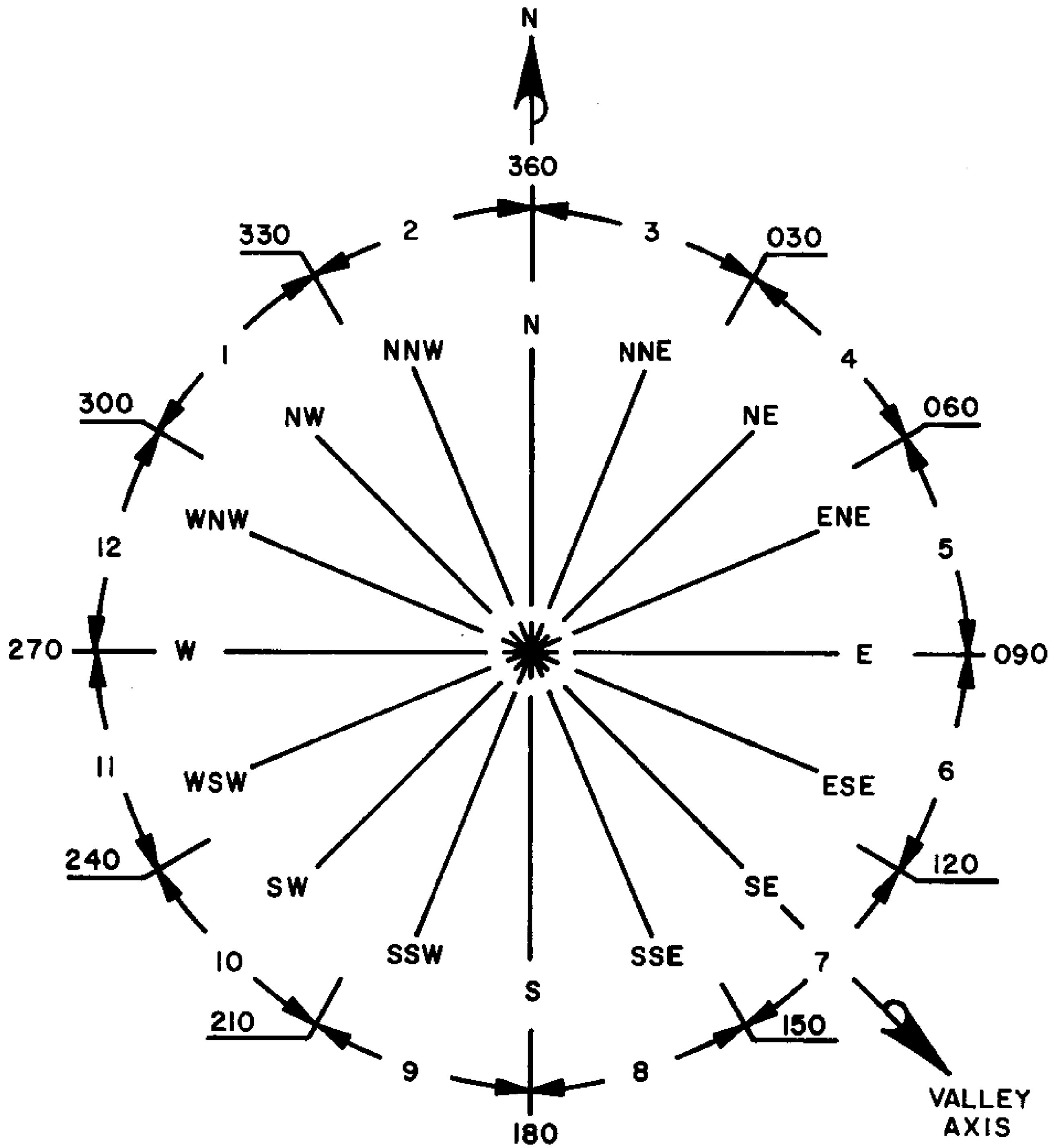


Figure 10. Compass rose with 30 degree isogon sectors oriented to the major axis of the Salinas Valley.

direction at any level, time and station in a sector as indicated below:

Direction	Sector	Direction	Sector
301-330	1	121-150	7
331-360	2	151-180	8
001-030	3	181-210	9
031-060	4	211-240	10
061-090	5	241-270	11
091-120	6	271-300	12

The data then are applied to a station tailored grid chart with coordinates of height and time. In this way a time averaged isogon sector analysis is made. At Moss Landing and Salinas, the sectors 9, 10, 11, 12, 1, 2 are onshore or up valley winds, and sectors 3, 4, 5, 6, 7, 8 are offshore or down valley winds. At Soledad, sectors 12, 1, 2 are onshore or up valley winds, and sectors 6, 7, 8 are offshore or down valley winds. Sectors 3, 4, 5 are cross valley winds from the east, and 9, 10, 11 are cross valley winds from the west at Soledad.

Figure 11 is an example of the grid display used to plot the isogon sector numbers. Each column of figures represents the isogon sector number from a pilot balloon observation taken at the time indicated.

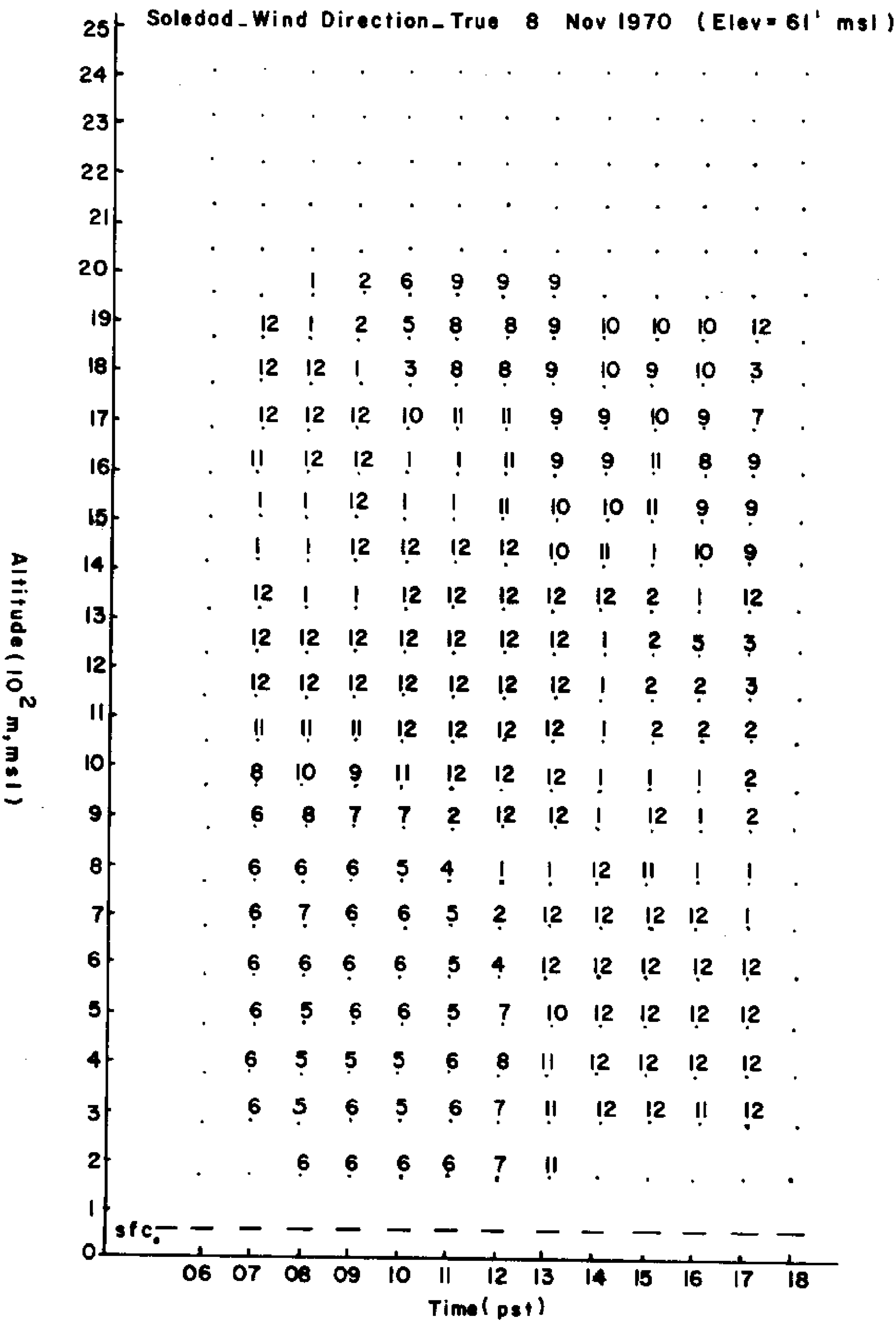


Figure 11. Grid display of isogon sectors for Soledad, 8 November 1970.

Figures 12, 13, 14, 15, 16, 17 are isogon sector analyses for 7-8 November 1970. Isogon sector analyses for the 1-2 May 1971 field study are shown in Appendix 1. Patterns of wind flow in the first 2000 meters above the surface seem to indicate alternating cells of offshore to onshore flow in the lower 800 to 900 meters above the ground from morning to afternoon at all stations. There also appears to be mid-level and upper level wind cells which may flow in an opposite sense to the flow in the lower levels. If the vertical axis is arbitrarily divided into a low cell (surface to 900 meters), a mid-level cell (900 to 1500 meters), and an upper cell (1500 to 2000 meters), the analysis shows the structure summarized in Table 2. Inspection of this table shows that in almost all cases the low level cell has offshore flow in the morning and onshore flow in the afternoon. This is of interest because during the period of these field studies, the synoptic situation did not indicate conditions favorable for a sea breeze circulation. It is also interesting to note the reversals of flow that take place in the vertical, i.e., offshore flow over onshore flow. These conditions of flow would indicate appreciable turbulent mixing taking place in the first 2000 meters above the ground in this air shed.

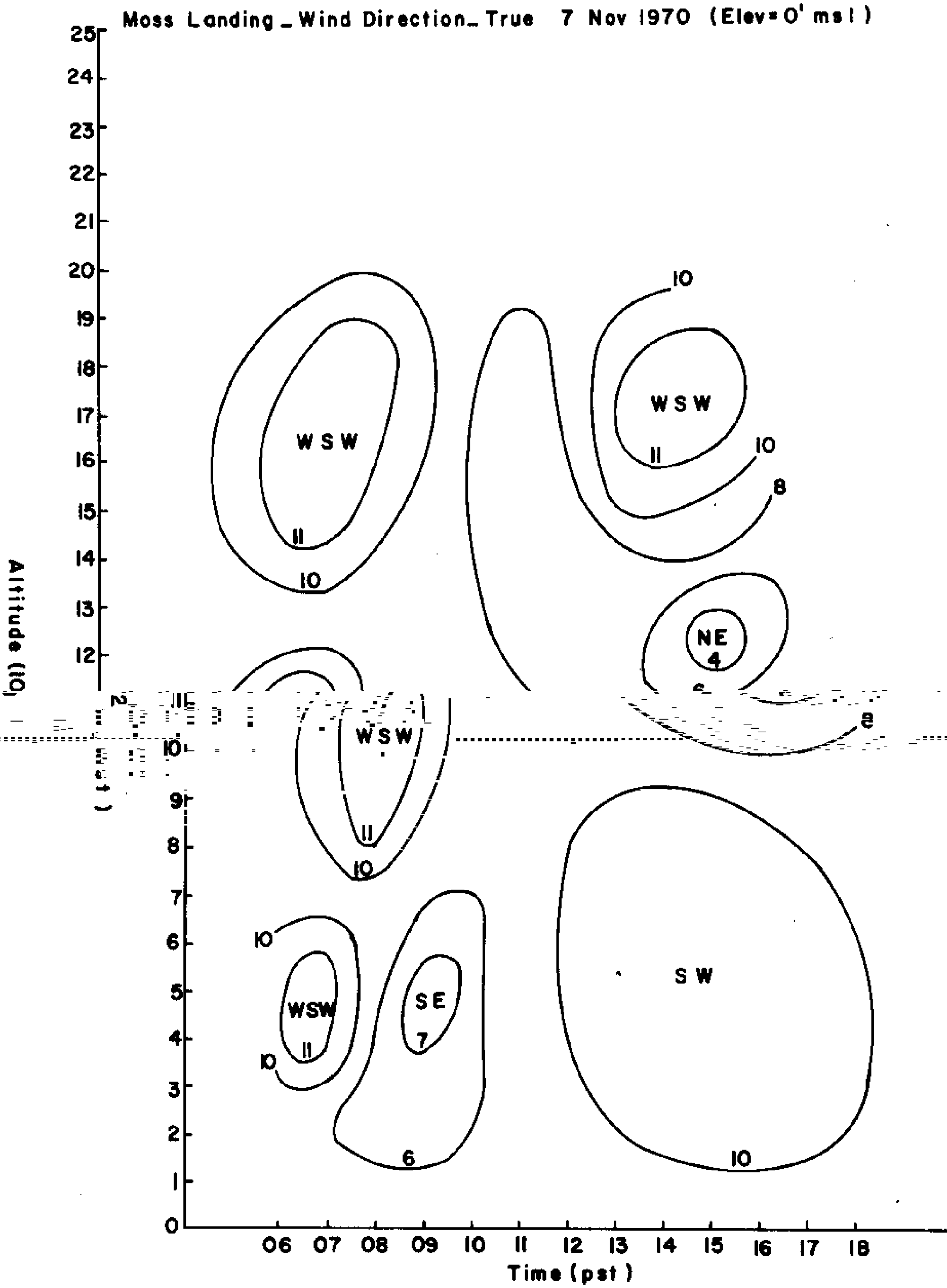


Figure 12. Time averaged isogon sector analysis, Moss Landing, 7 November 1970.

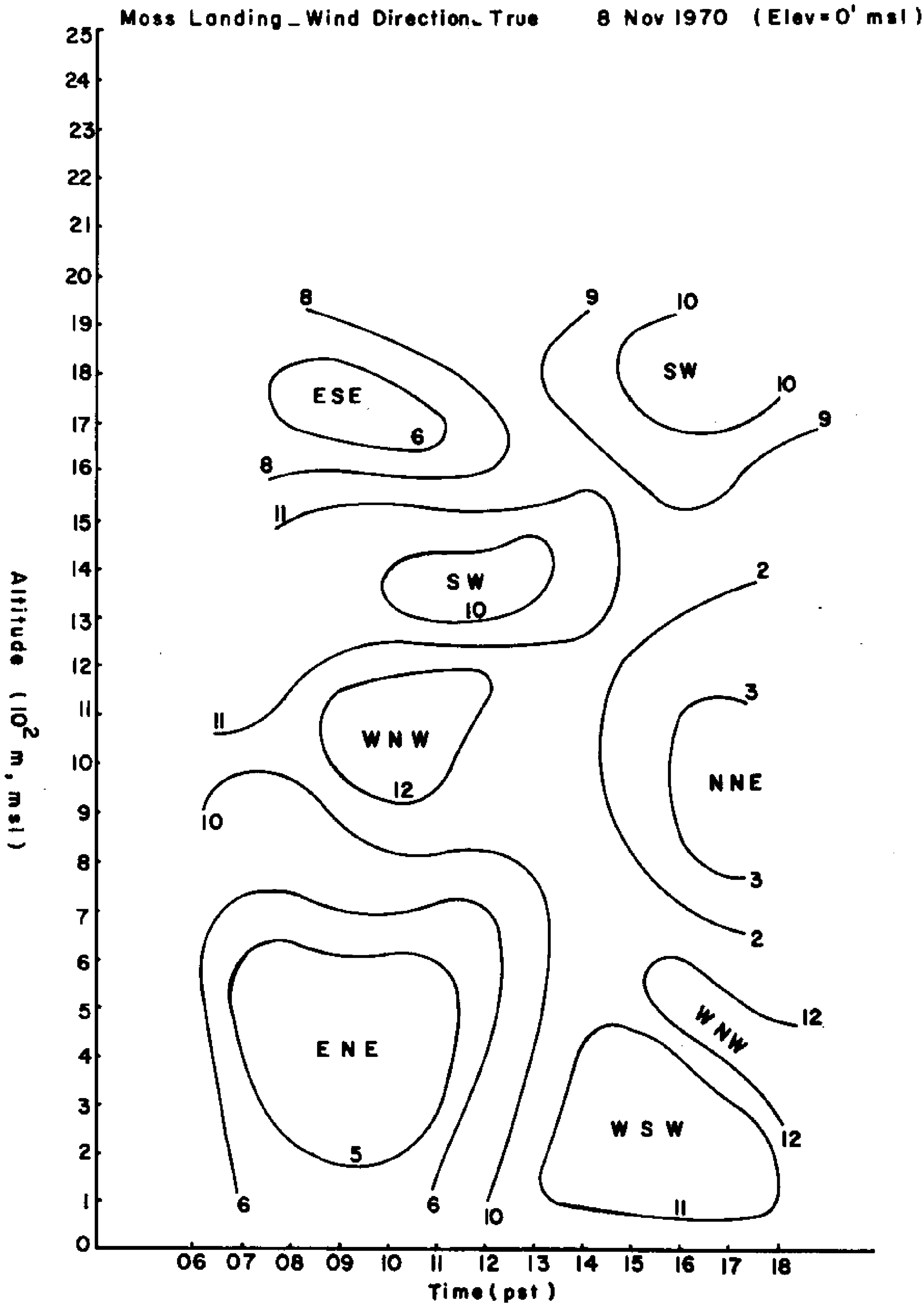


Figure 13. Time averaged isogon sector analysis, Moss Landing, 8 November 1970.

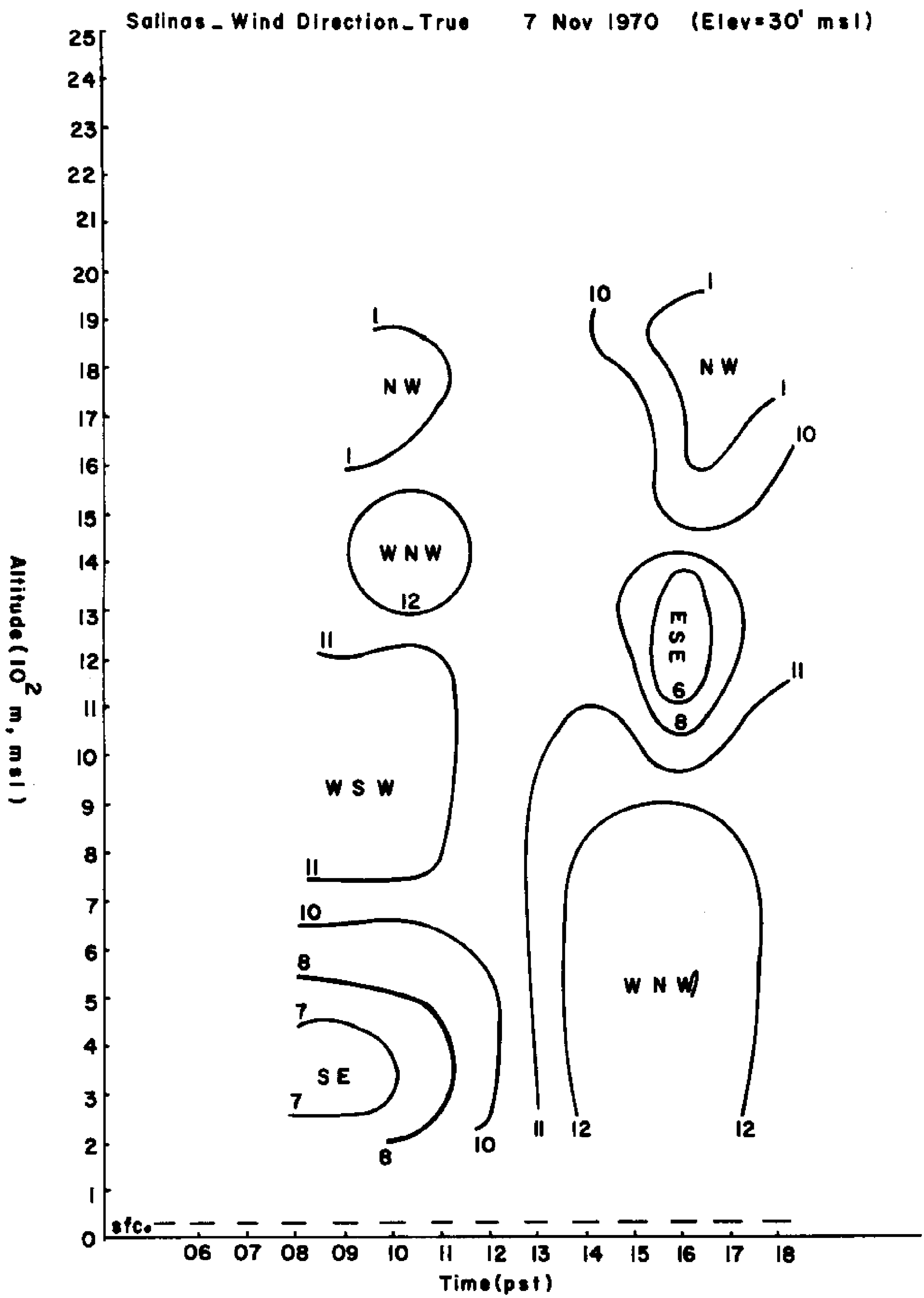
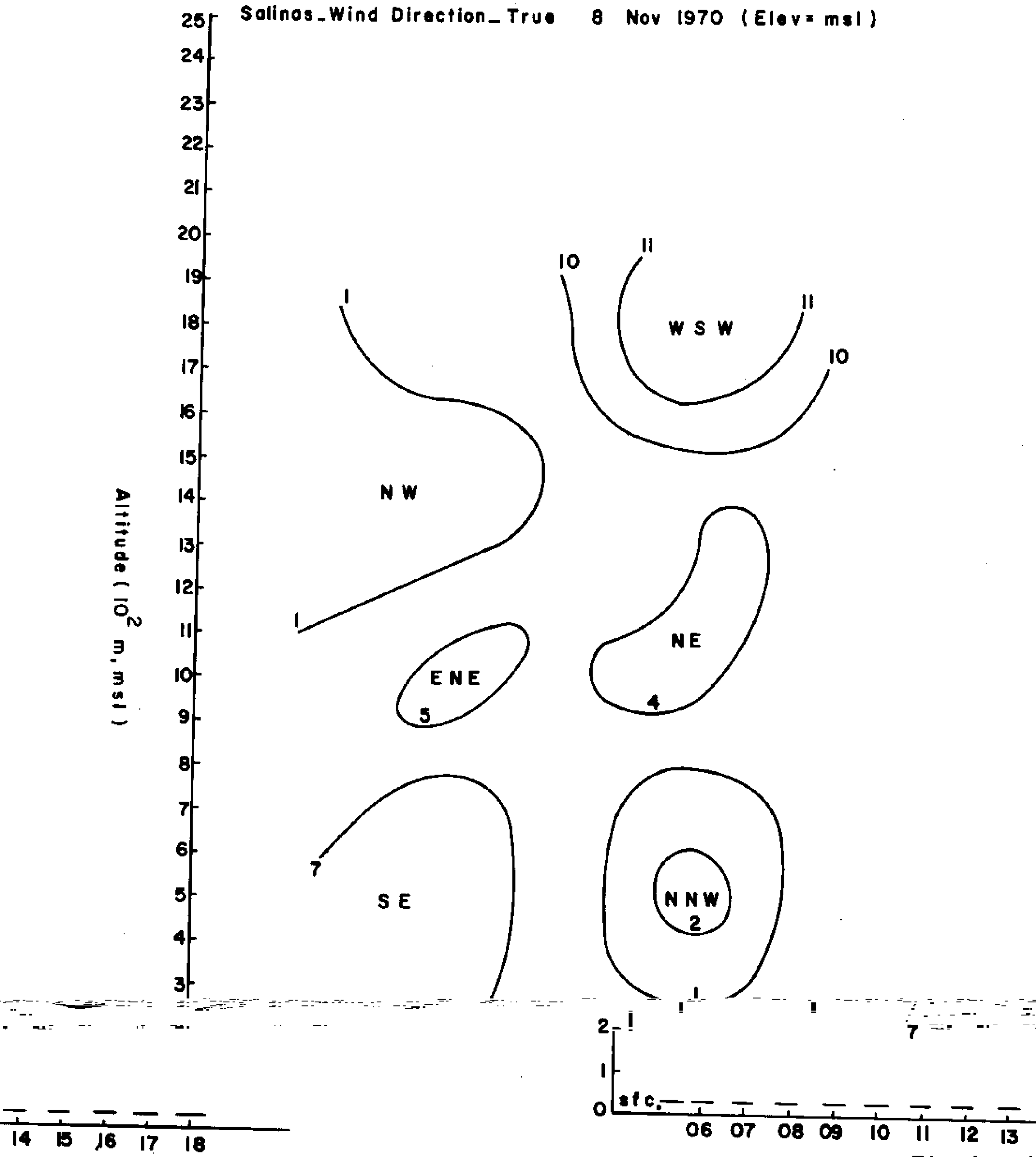


Figure 14. Time averaged isogon sector analysis, Salinas, 7 November 1970.



ed isogon sector analysis,

Figure 15. Time average
Salinas, 8 November 1970.

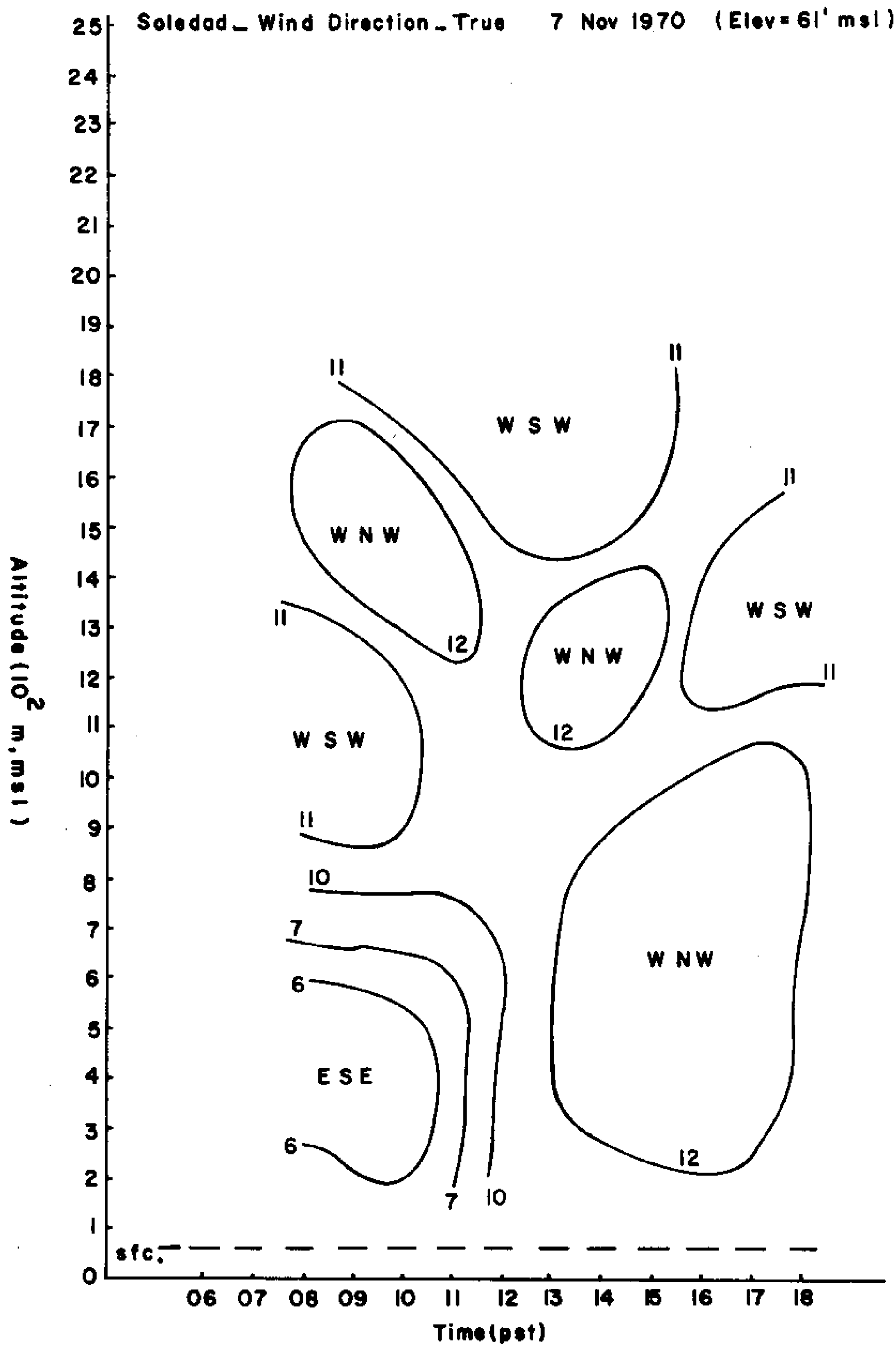


Figure 16. Time averaged isogon sector analysis, Soledad, 7 November 1970.

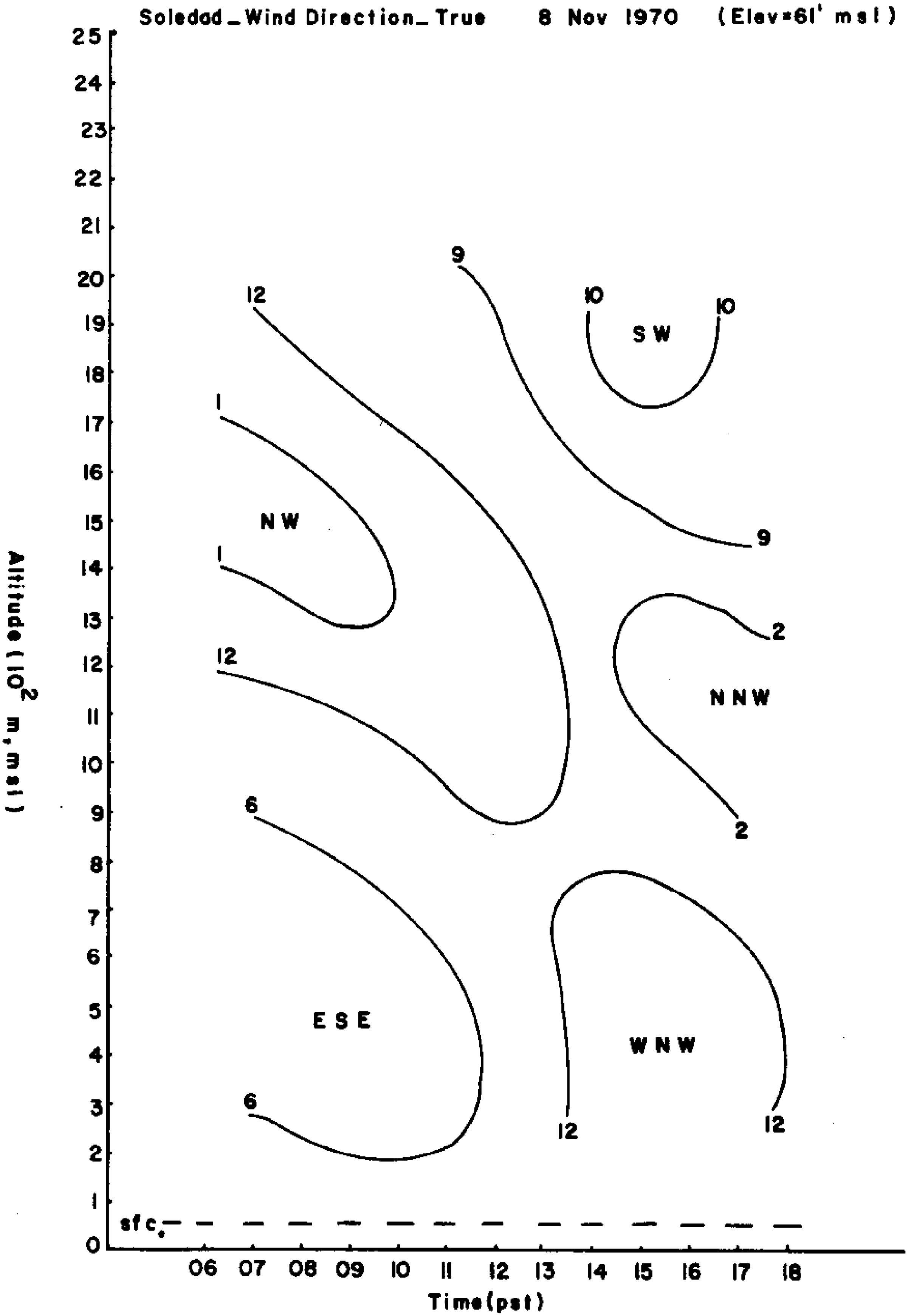


Figure 17. Time averaged isogon sector analysis, Soledad, 8 November 1970.

Table 2

Isogon Sector Analysis Summary

Date	Station	Morning Low Sfc-900 m	Morning Mid 900-1500 m	Morning Upper 1500-2000 m	Afternoon Low Sfc-900 m	Afternoon Mid 900-1500 m	Afternoon Upper 1500-2000 m
11/7/70	Moss Landing	SE	WSW	WSW	SW	NE	WSW
11/8/70		ENE	WNW SW	ESE	WSW WNW	NNE	SW
5/1/71		SE SW			WNW SW	SE	
5/2/71		ESE WSW			SW	WSW SSW	ESE
11/7/70	Salinas	SE	WSW WNW	NW	WNW	ESE	NW
11/8/70		SE	ENE	NW	NNW	NE	WSW
5/1/71		SE NE			WNW NW	ESE	
5/2/71		SE	SW	SE	NW	WNW	SSW
11/7/70	Soledad	ESE	WSW	WNW	WNW	WSW	WSW
11/8/70		ESE	NW	NW	WNW	NNW	SW
5/1/71		SSE	SW	SSW	SE	SW	SSW
5/2/71		SE	SW	SSW	SSW NW	SSE	SSW

Table 3

Wind Profile Summary

*All Heights in Meters

Date	Station	Morning	Mid-Day	Late Afternoon
11/7/70	Moss Landing	Max 100 Min 600-1000	Max 100-200 Min 800-1600	Max 100-200 Min 1000-1200
11/8/70	Moss Landing	Max 100-200 Min 800	Weak Winds	Max 200 & 700 Min 400-600 & 1400
5/1/71	Moss Landing	Max 100-200	Max 900 Min 100 & 1500	Max 100 Min 500-900
5/2/71	Moss Landing	Max 100 Min 400-500	Max 200 & 500 Min 300	Max 300-400 Min 1500
11/7/70	Salinas	Max 200-300 Min 600	Weak Winds	Max 200 Min 1000-1500
11/8/70	Salinas	Max 200 Min 700-800	Weak Winds	Max 200-300 Min 600-1000
5/1/71	Salinas	Max 200 Min 900-1000	Max 2100	Max 200-300 Min 600-700
5/2/71	Salinas	Max 200-500 Min 700-1100	Max 100-200	Max 200 Min 800-900

<u>Table 3 (continued)</u>

Wind Profile Summary

*All Heights in Meters

Date	Station	Morning	Mid-Day	Late Afternoon
11/7/70	Soledad	Max 200 & 1200 Min 800-1000	Weak Winds	Max 200-400 Min 1000-1800
11/8/70	Soledad	Max 100-300 Min 900	Weak Winds	Max 200-300 Min 1200-1400
5/1/71	Soledad	Max 200-300 Min 700-800	Max 200 Min 300-900	Max 200 Min 700-1600
5/2/71	Soledad	Max 200 Min 600-800	Max 200 Min 400	Max 200-400 Min 600-700

Wind profiles for a morning, mid-day and late afternoon pilot balloon observation on 8 November 1970, are shown in Figures 18, 19, 20, 21, 22, 23, 24, 25, 26. Wind profiles for 7 November, and for 1-2 May 1971, are shown in Appendix 1. Nearly all of these profiles show a low level wind speed maximum at 100 to 300 meters above the surface, and a low level minimum at 600 to 1500 meters above the surface. A summary of these maxima and minima is given in Table 3. These profiles, when considered along with the isogon sector analyses, also indicate an unsteady and turbulent wind state in the first 2000 meters above ground in this air shed.

On 6 April 1971, and 1 May 1971, temperature and relative humidity were measured by airborne instrumentation in a U.S. Navy helicopter. Measurements were made only up to 3000 feet above ground because of limitations placed on flight operations in this area. The temperature and dew point temperature soundings plotted on an expanded Skew-T thermodynamic diagram are shown in Figures 27 through 31. On both of these days the synoptic situation was such that low pressure troughs were in the area. The April 6 soundings indicate a well-mixed marine layer with the temperature and dew point temperatures approximating the slope of the dry and moist adiabat, although with complete mixing, the dew point temperature should become parallel to the saturation mixing ratio lines. The marine layer appears to be capped by a strong temperature inversion which has a base near 1300-1400 feet on the coast, 1600 feet at Salinas, and about 1800 feet at Soledad. The dew point sounding looks quite similar to a subsidence inversion as the dew point temperature decreases rapidly in the inversion layer. Since there are no synoptic indications of subsidence taking place, one must look to other causes for the formation of this type of inversion. The most obvious cause appears to arise out of the turbulent flow [illegible] above the ground in the air shed. The turbulence causes vertical mixing to occur and this in turn causes the temperature lapse rate through the mixed layer to approach the dry or moist adiabatic lapse rate. For an initially stable layer, this means a decrease in temperature at the top of the mixed layer and a temperature increase at the base. As a result, the temperature sounding through the mixed layer becomes nearly dry adiabatic and a temperature inversion develops at the top of the layer. Even on May 1, 1971, when a deep low pressure system was off the coast and strong southerly gradient flow was indicated,

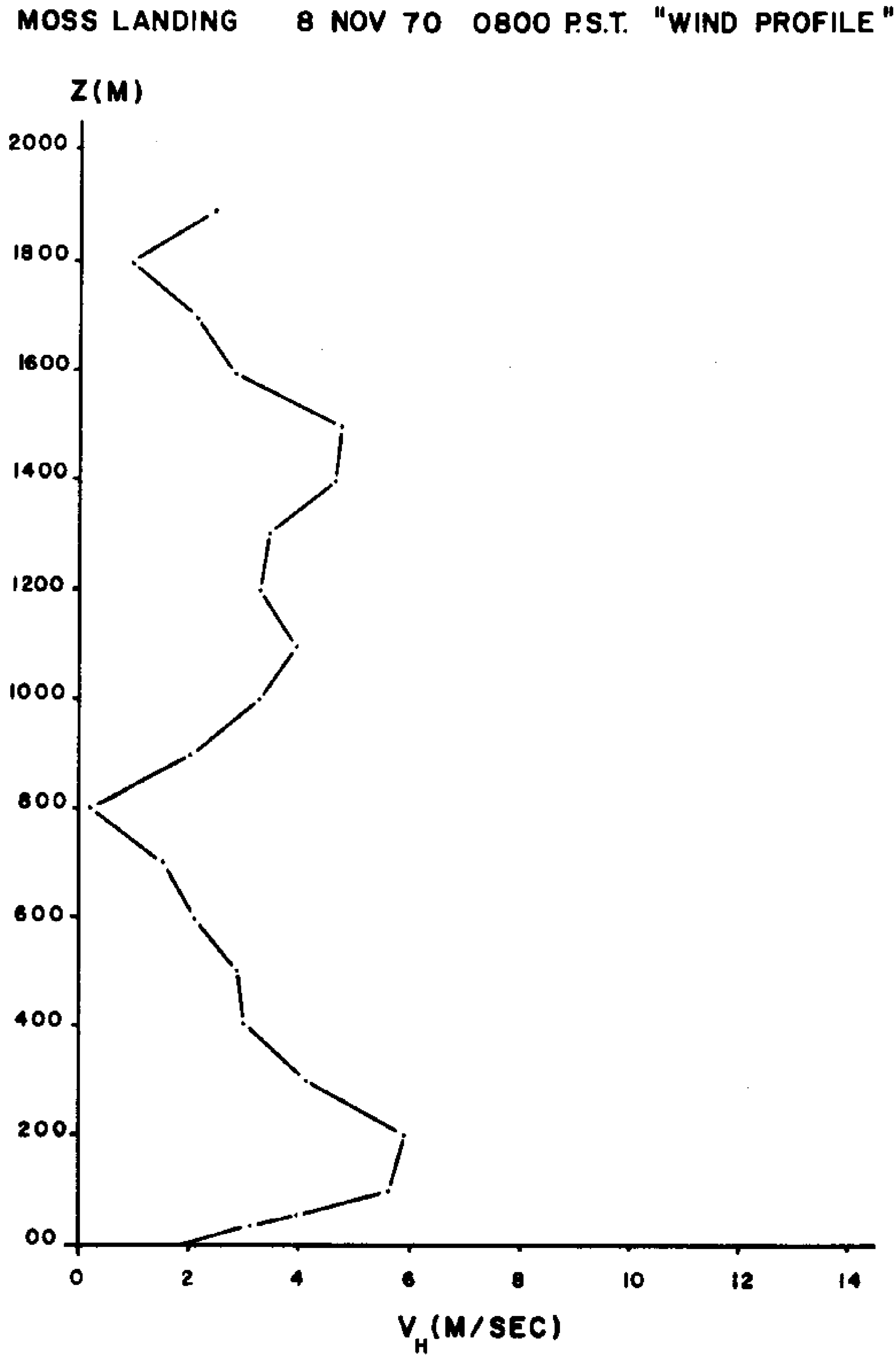


Figure 18. Moss Landing wind speed profile, 0800, 8 November 1970.

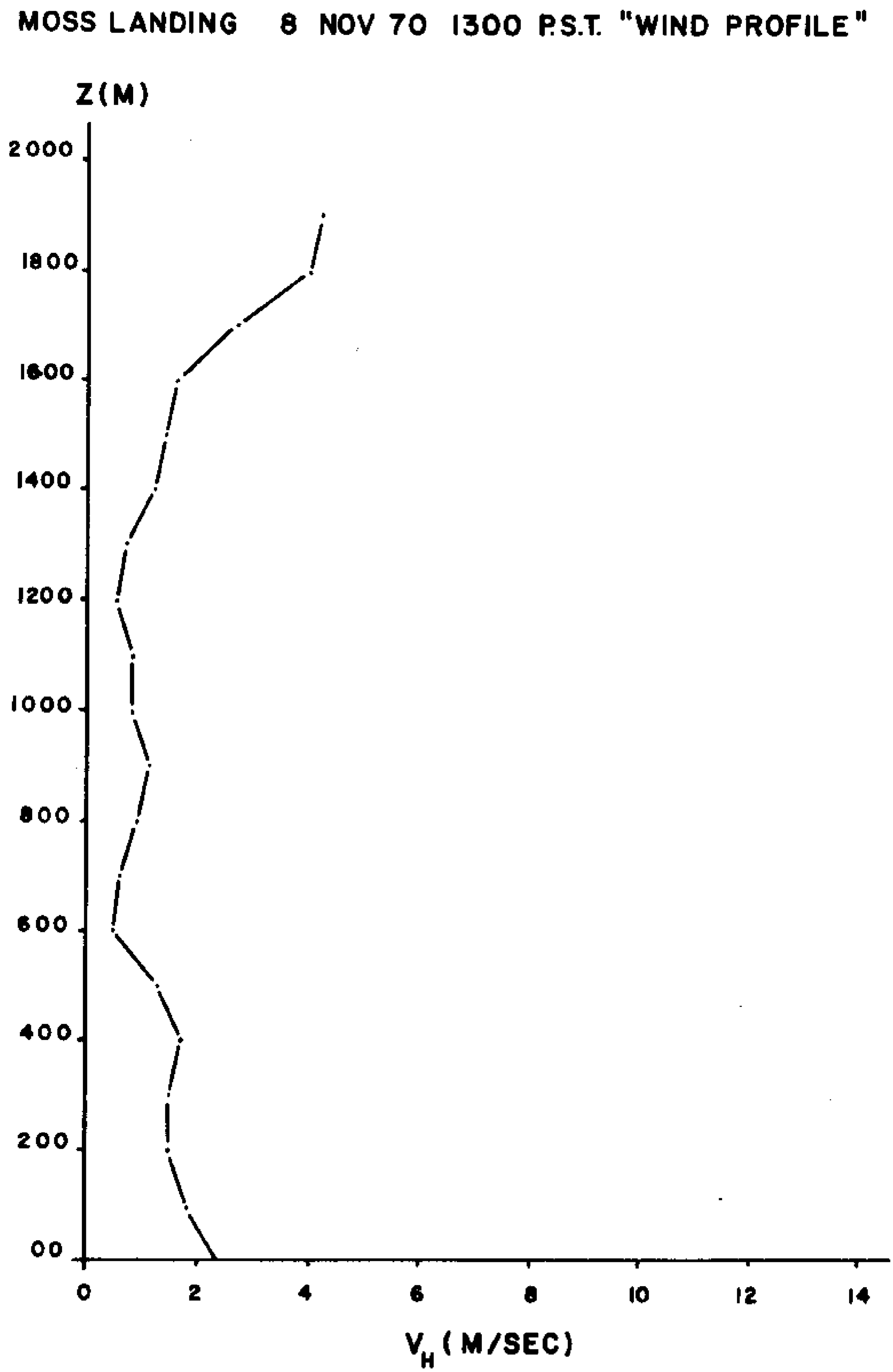


Figure 19. Moss Landing wind speed profile, 1300, 8 November 1970.

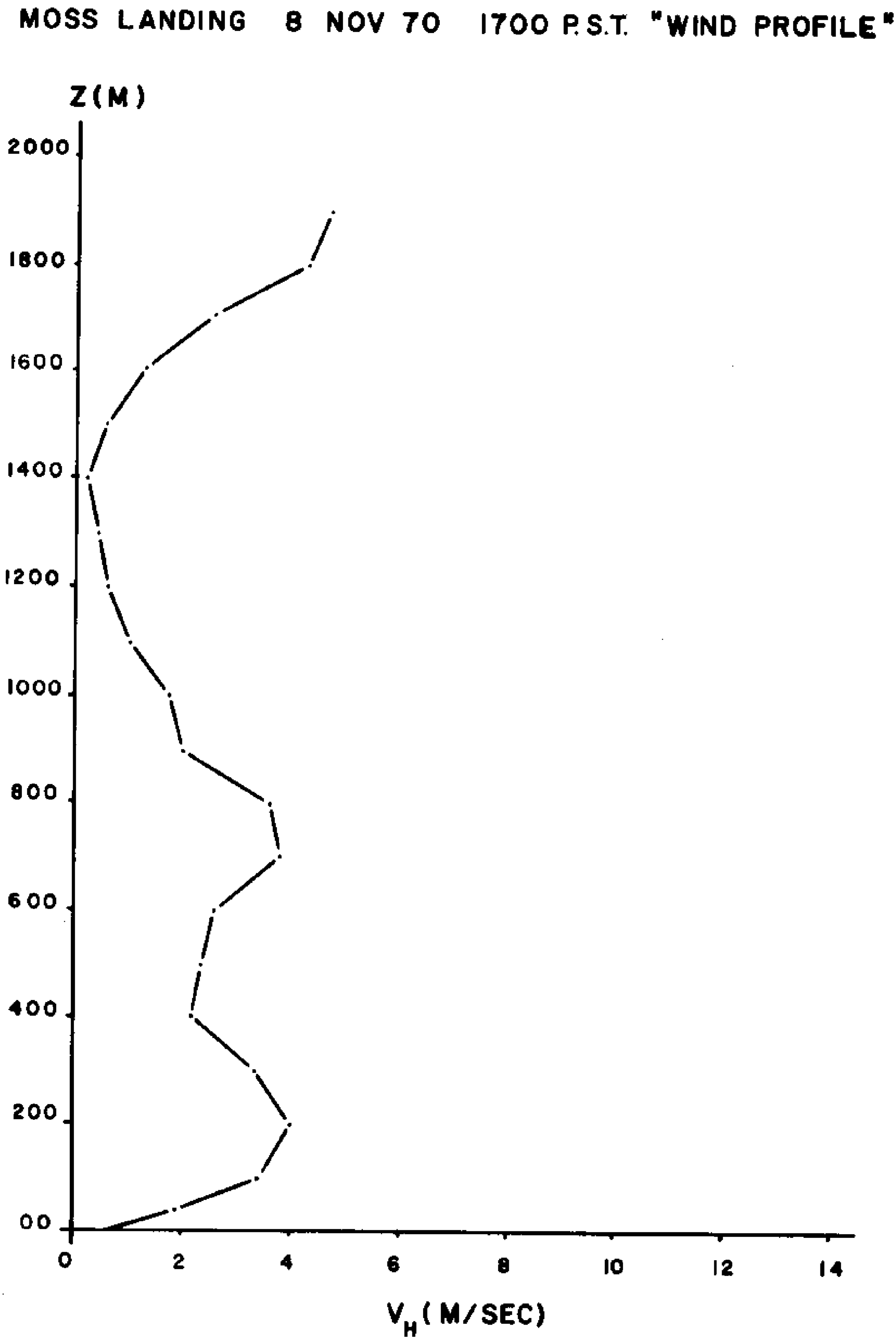


Figure 20. Moss Landing wind speed profile, 1700, 8 November 1970.

Figure 21. Salinas wind speed profile, 0800, 8 November, 1970.

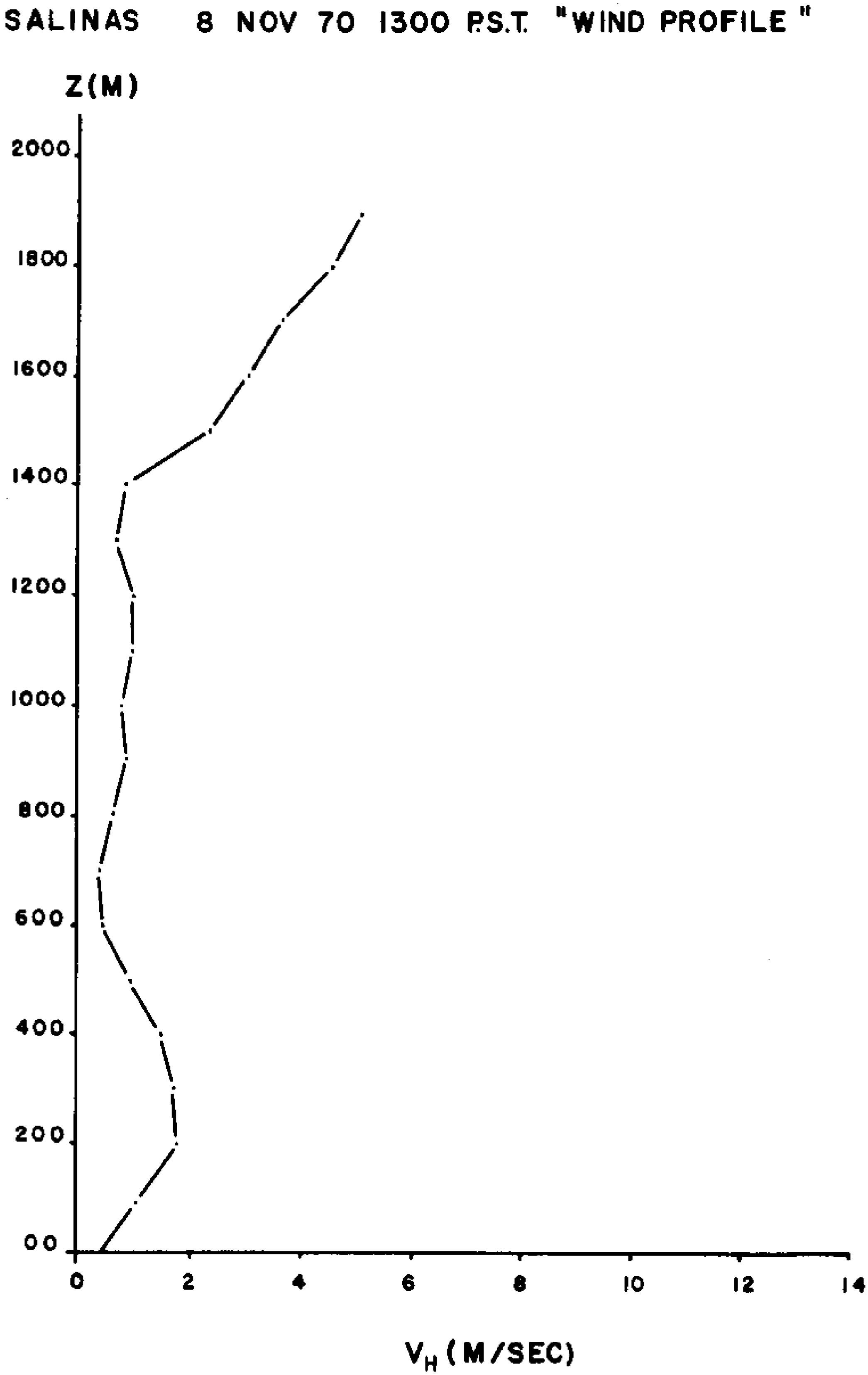


Figure 22. Salinas wind speed profile, 1300, 8 November 1970.

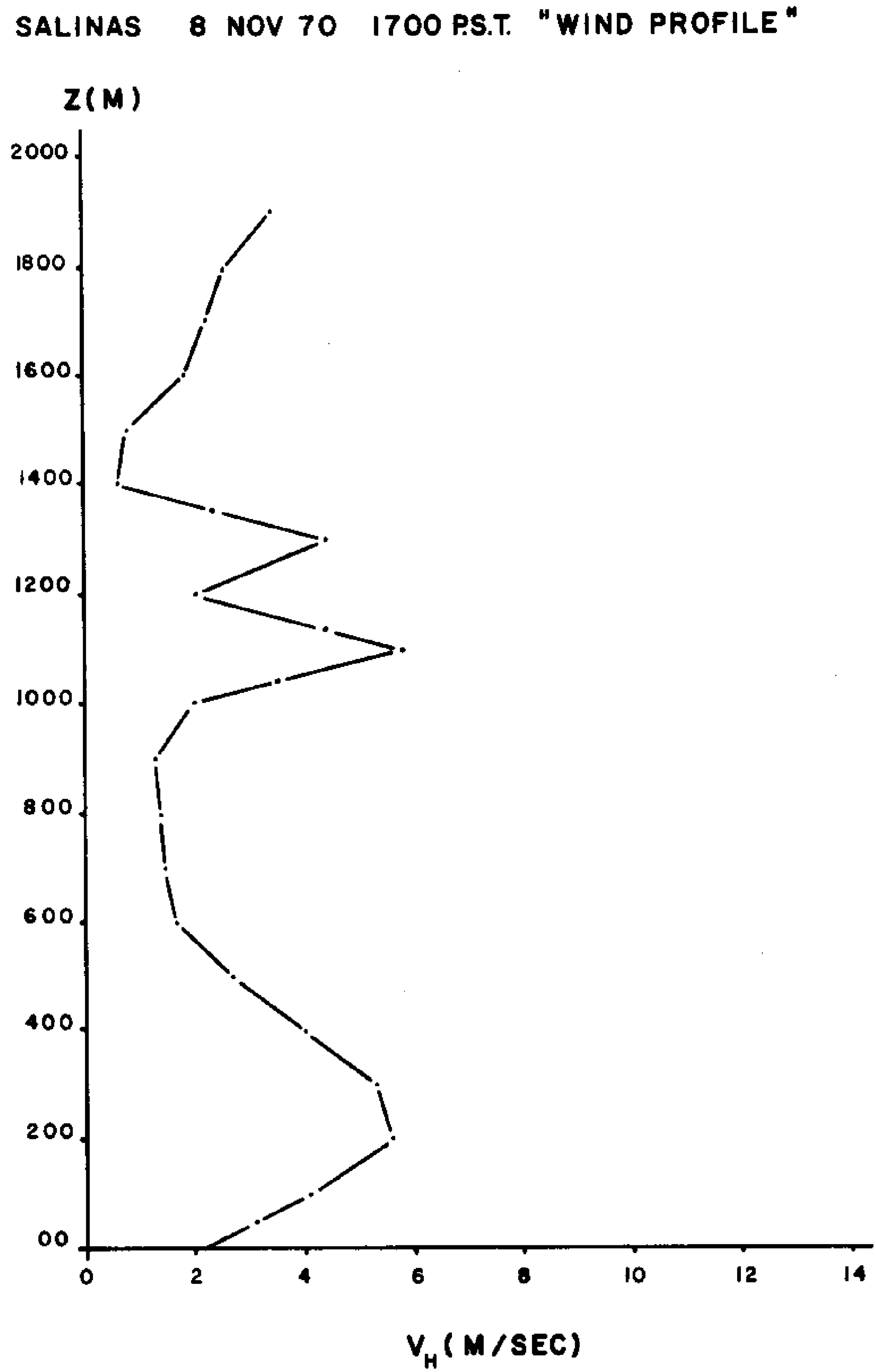


Figure 23. Salinas wind speed profile, 1700, 8 November 1970.

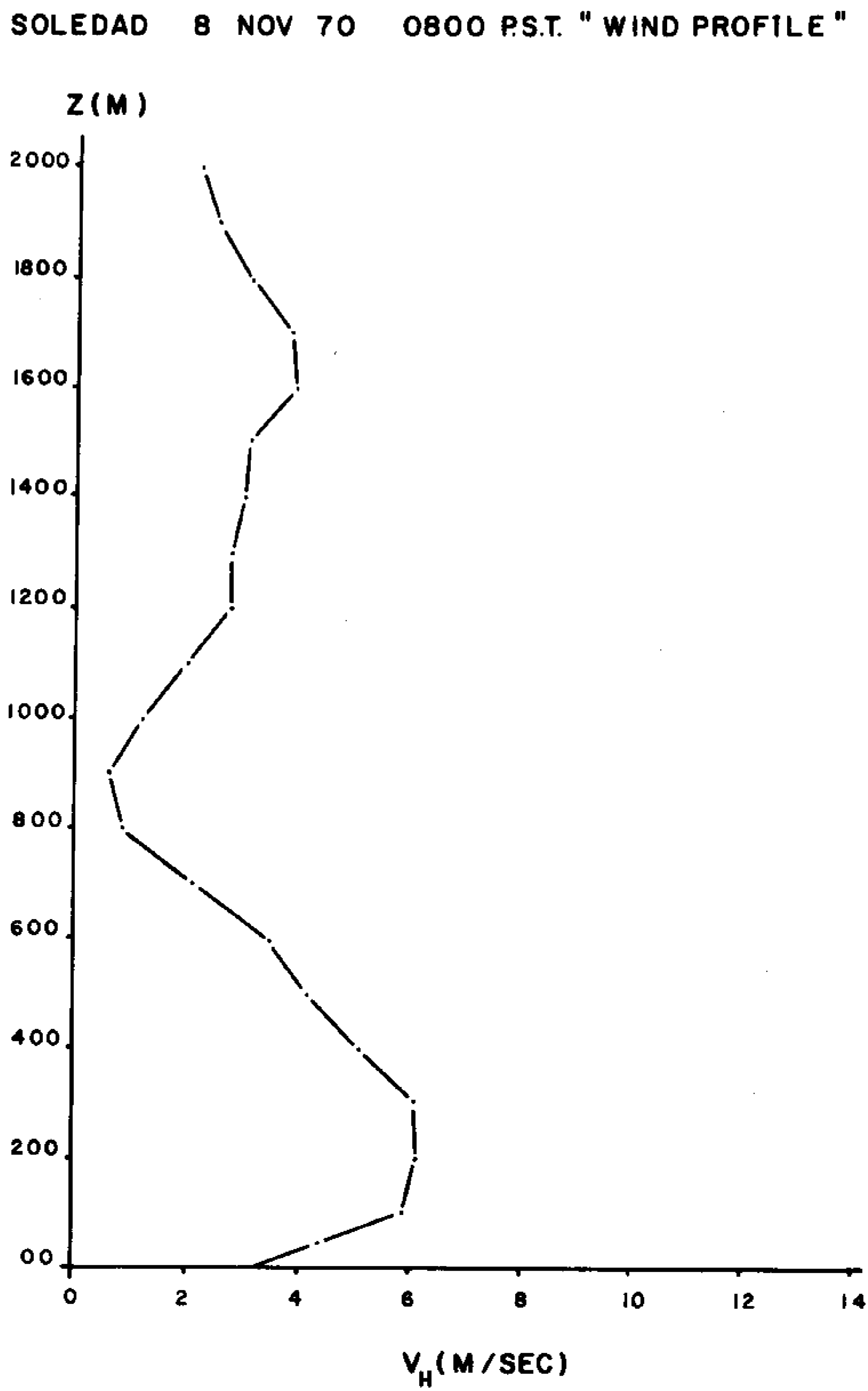


Figure 24. Soledad wind speed profile, 0800, 8 November 1970.

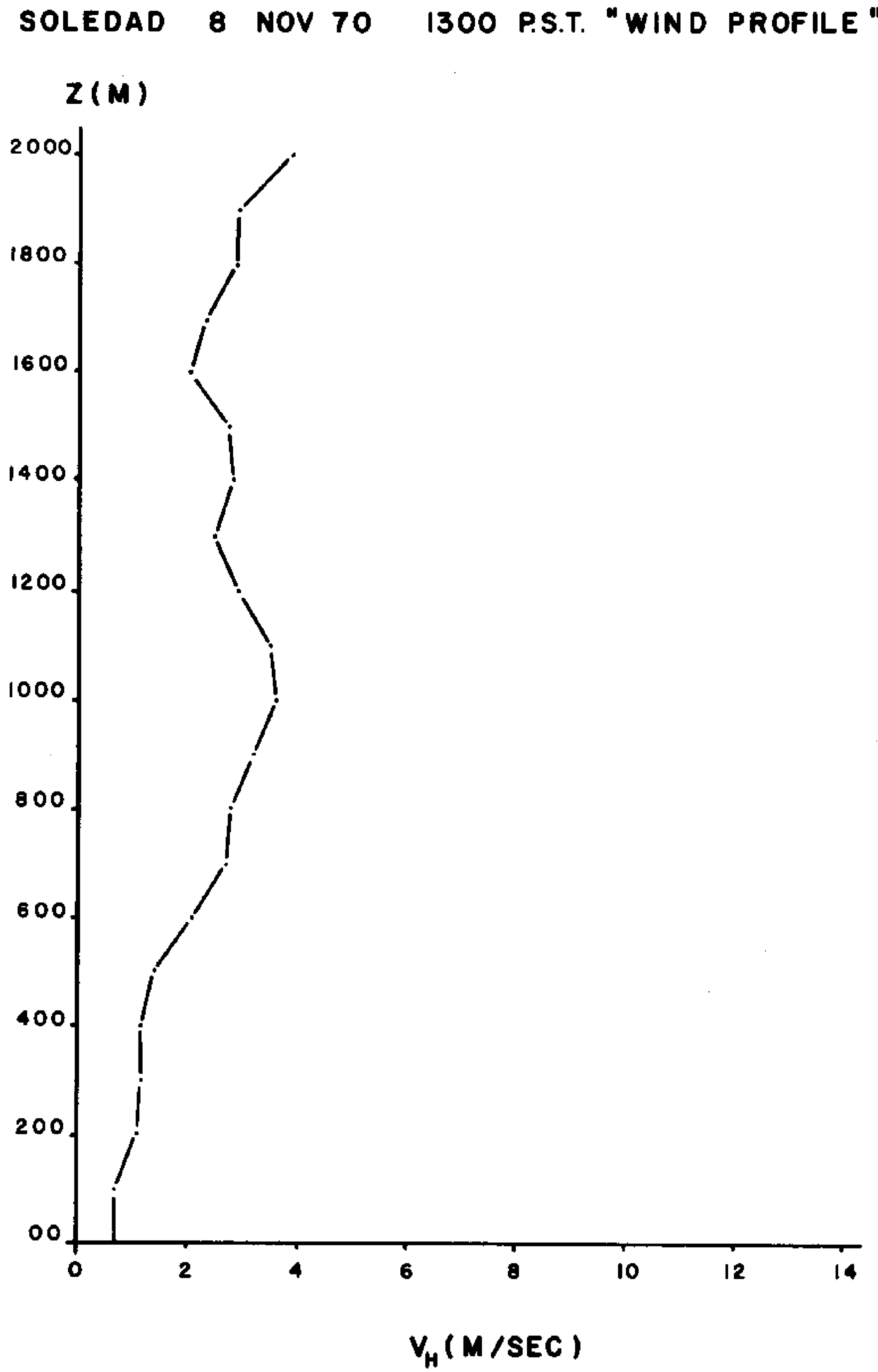


Figure 25. Soledad wind speed profile, 1300, 8 November 1970.

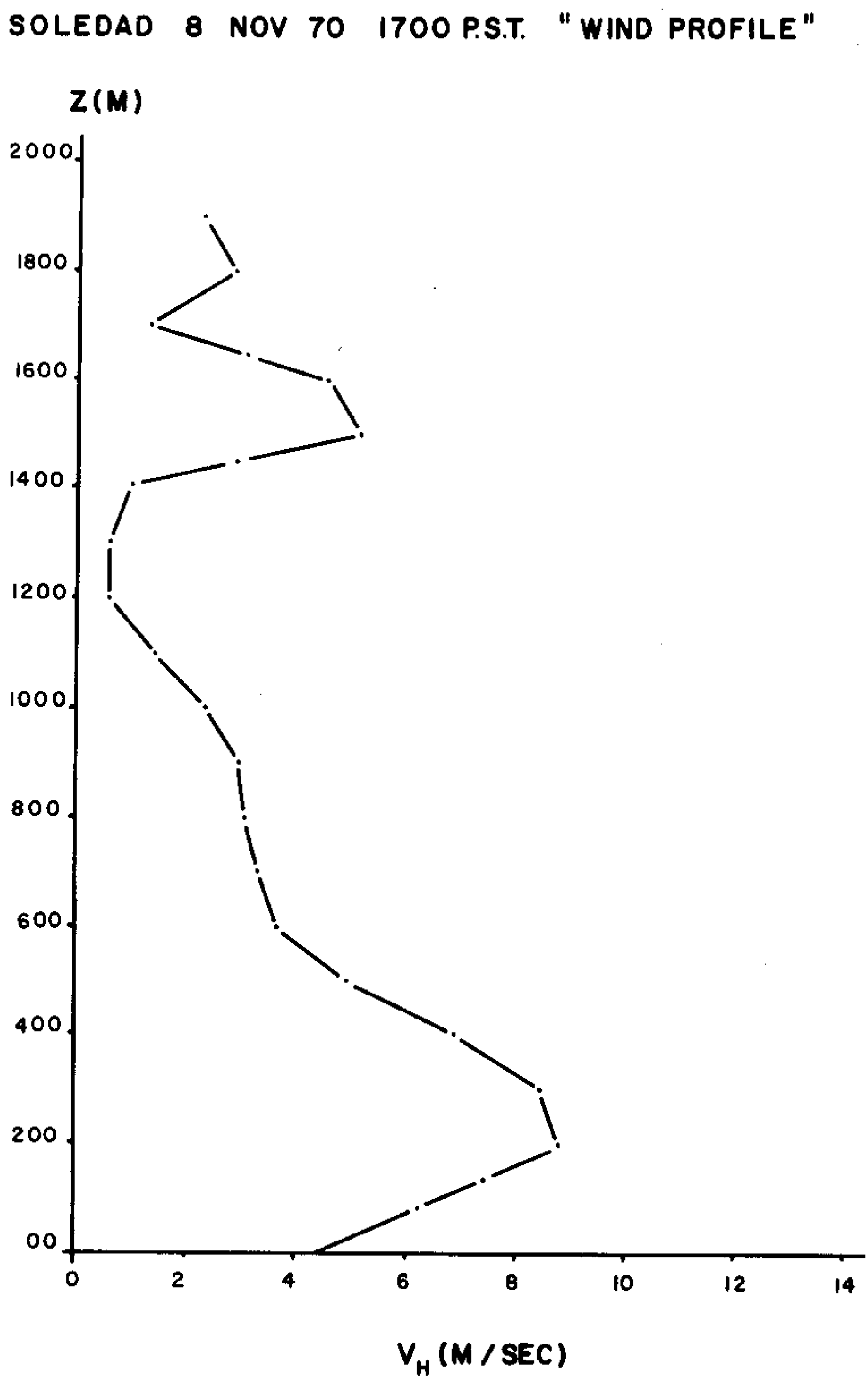
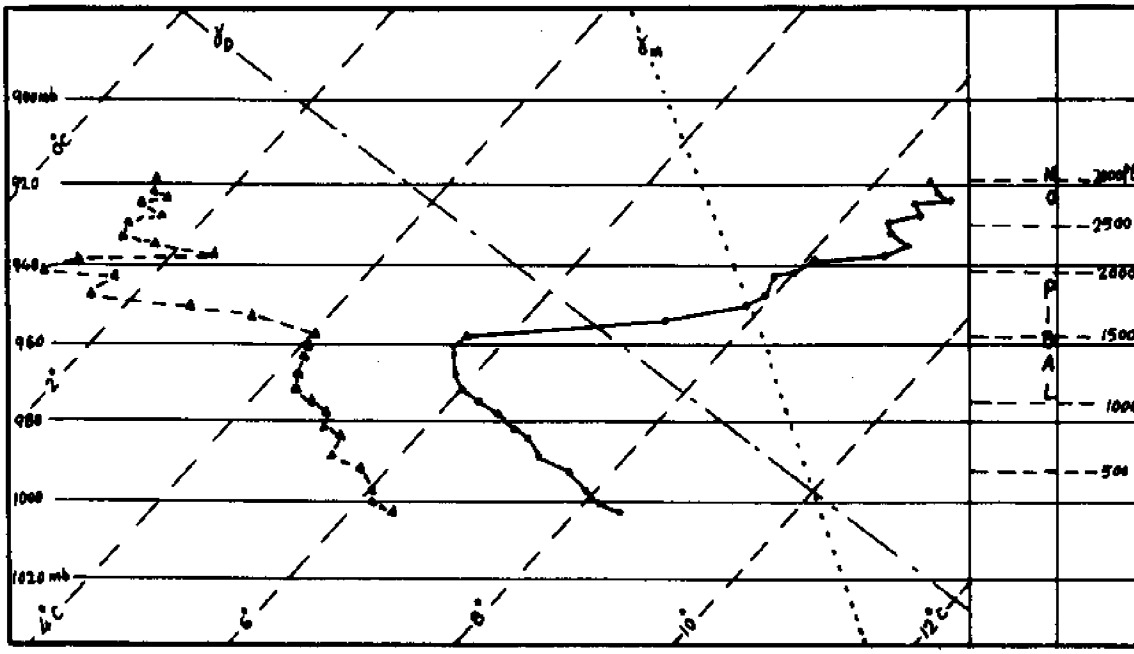
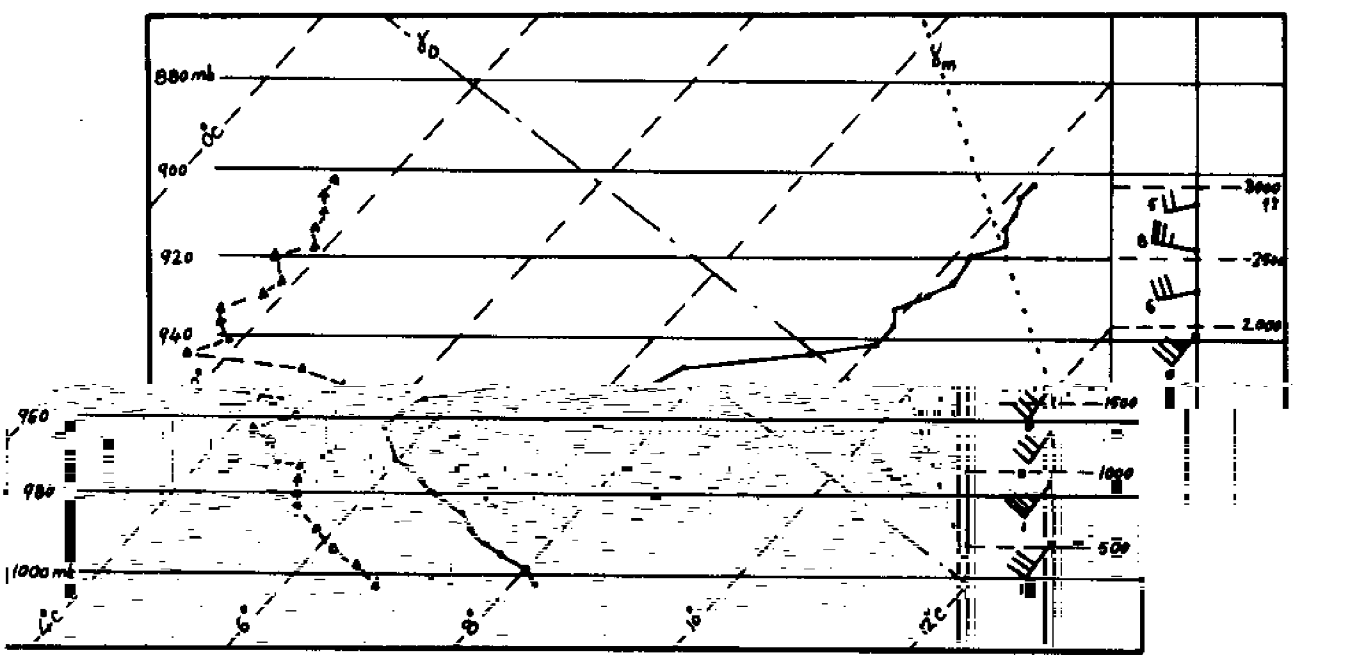


Figure 26. Soledad wind speed profile, 1700, 8 November 1970.



6 April 1971 09:20 pst Sounding, Monterey Bay
(5 nm NW of Moss Landing, Ca.)



6 April 1971 09:44 pst Sounding & 10:00 pst PIBAL, Moss Landing, Ca.

—•—•— : t (°c) —4—4— : t (°c) ◄— : 5 m/sec └— : 1 m/sec ┴— : 0.5 m/sec

Figure 27. Temperature and dew point temperature soundings, Monterey Bay and Moss Landing, 6 April 1971.

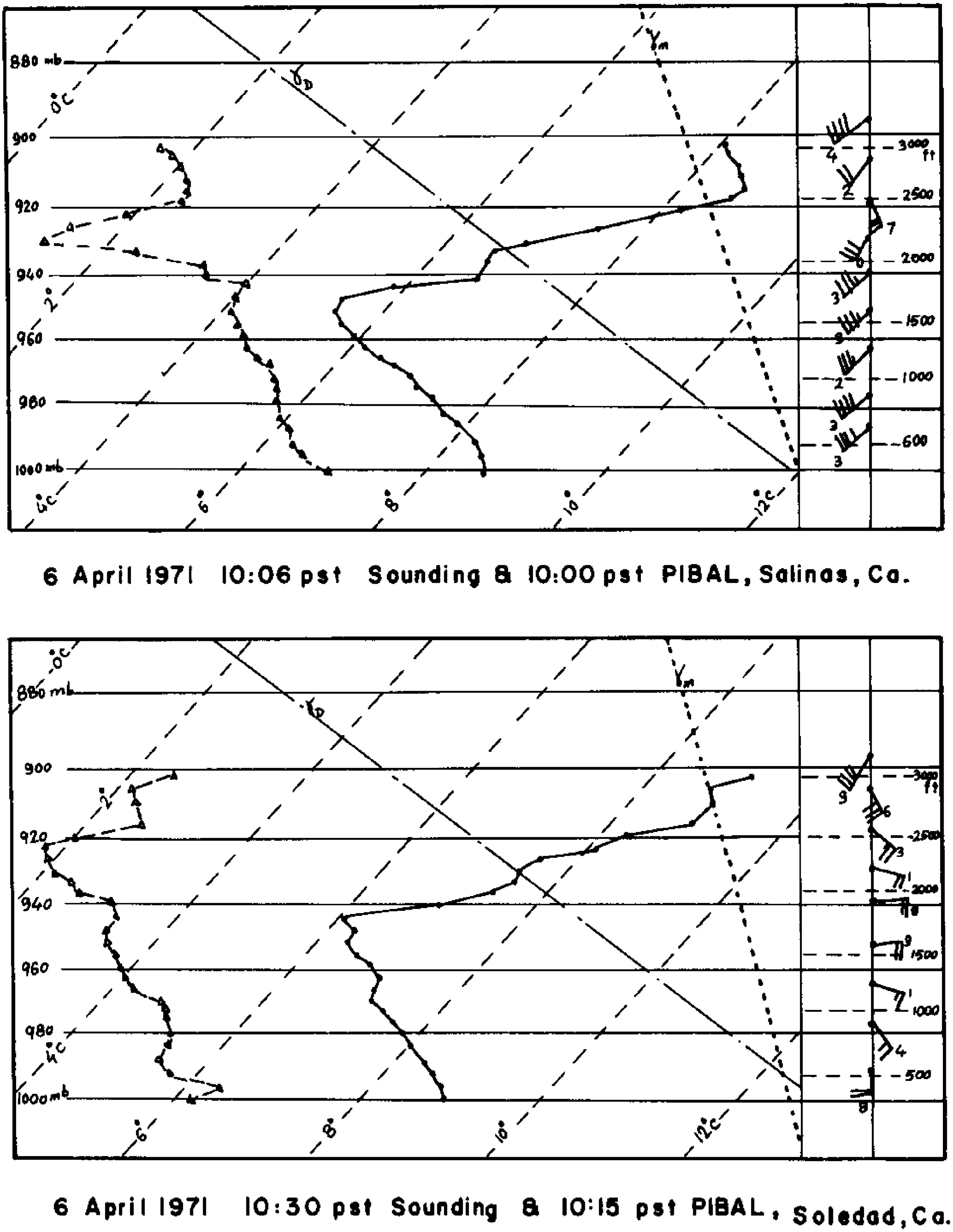
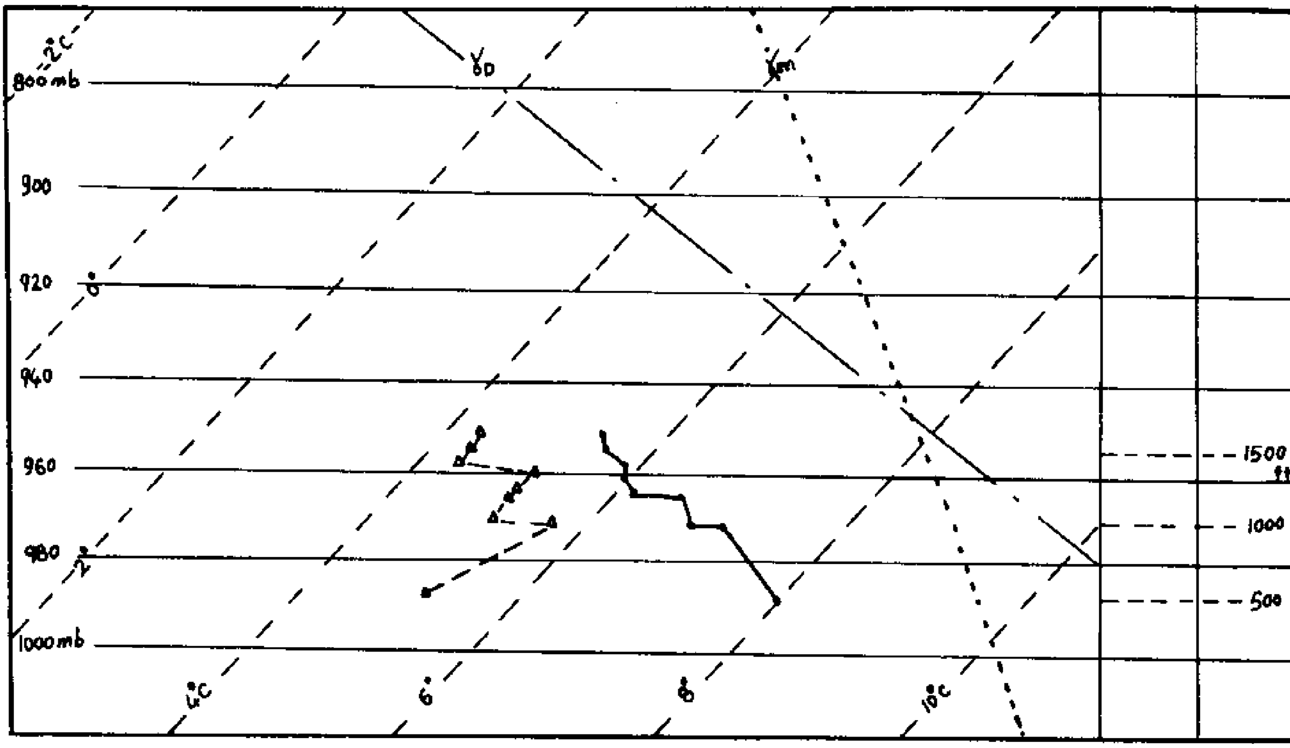
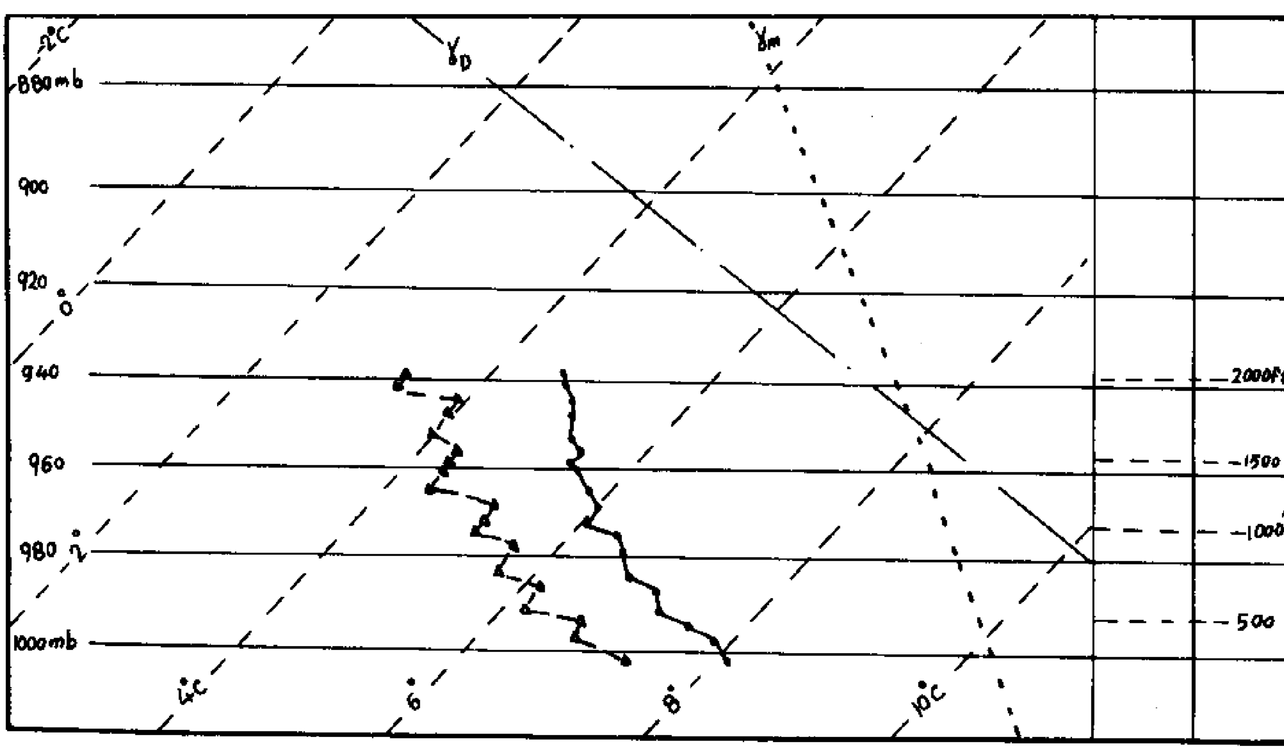


Figure 28. Temperature and dew point temperature soundings, Salinas and Soledad, 6 April 1971.



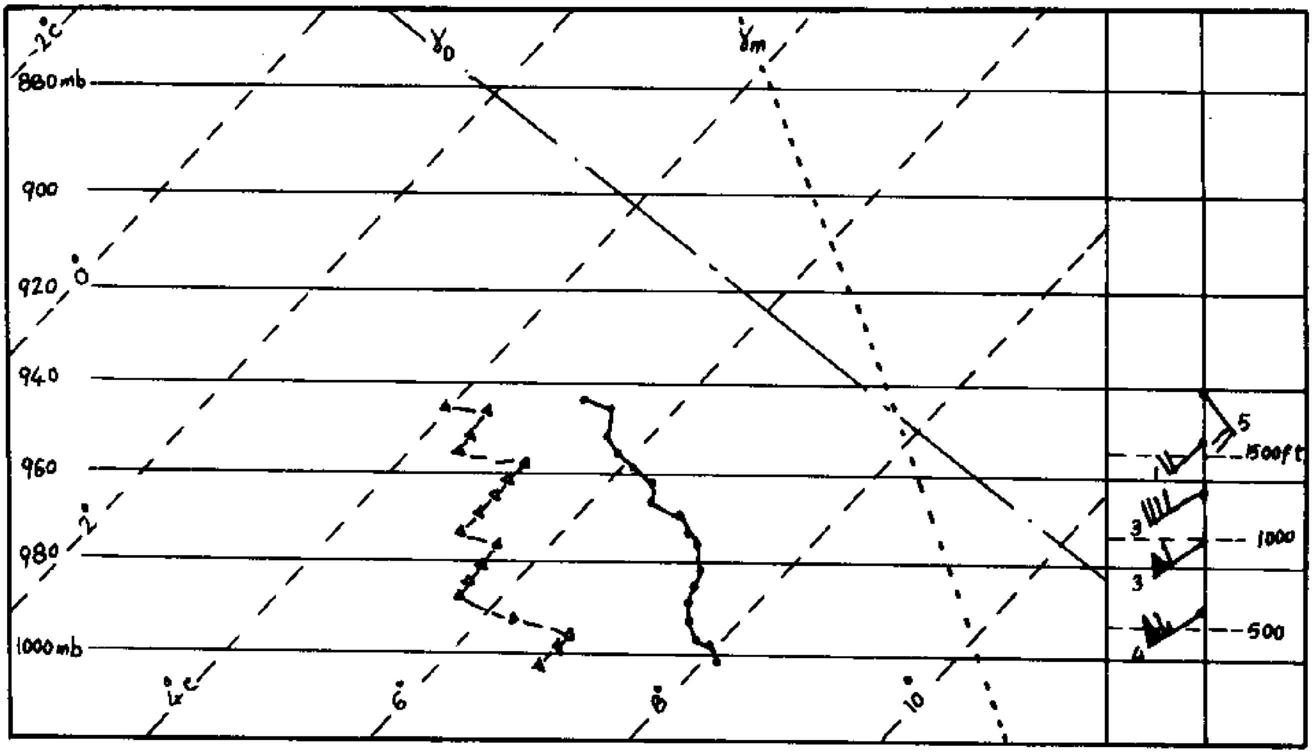
1 May 1971 08:00 pst Soundig, USNPGS, Monterey, Ca.



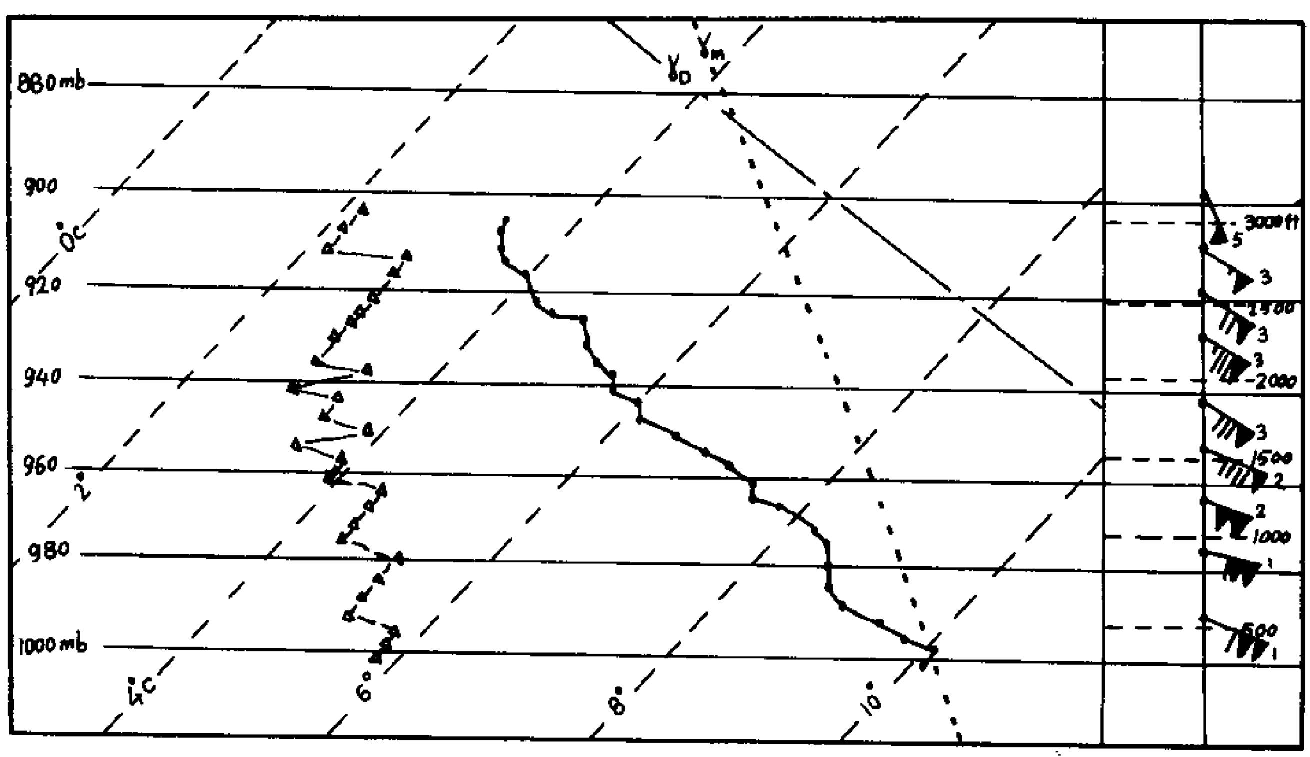
1 May 1971 08:20 pst Sounding, Monterey Bay

(5 nm NW of Moss Landing, Ca.)

Figure 29. Temperature and dew point temperature soundings, Monterey and Monterey Bay, 1 May 1971.

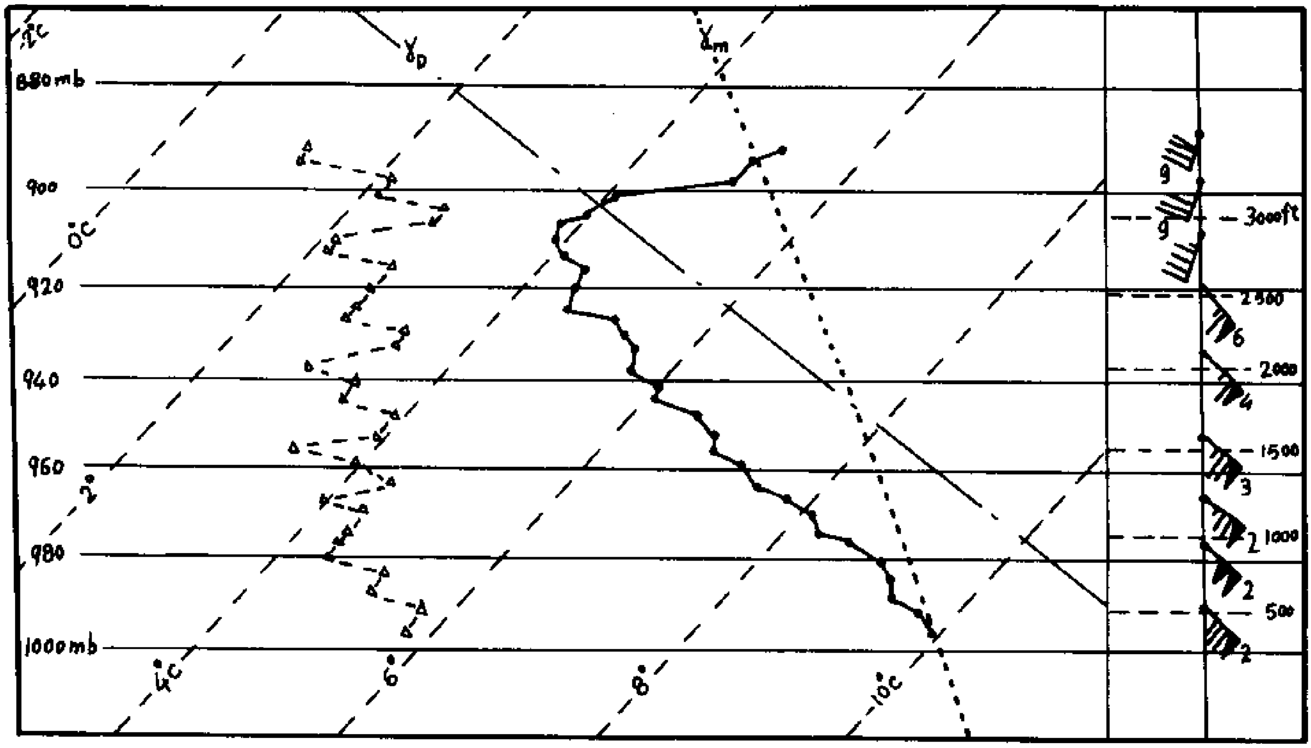


1 May 1971 08:30 pst Sounding & 08:05 pst PIBAL, Moss Landing, Ca.

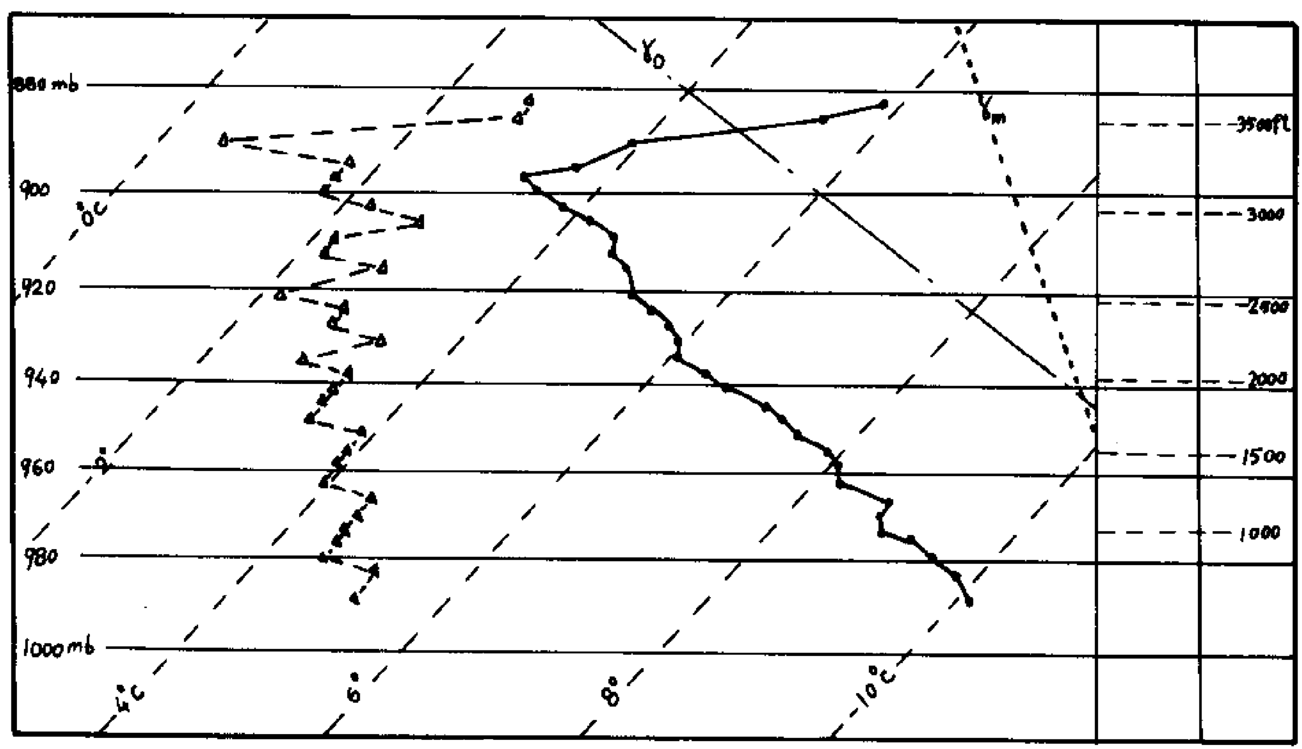


1 May 1971 08:35 pst Sounding & 09:00 pst PIBAL, Salinas, Ca.

Figure 30. Temperature and dew point temperature soundings, Moss Landing and Salinas, 1 May 1971.



1 May 1971 09:35 pst Sounding & 09:30 pst PIBAL, Soledad, Ca.



1 May 1971 10:00 pst Sounding, King City, Ca.

Figure 31. Temperature and dew point temperature soundings, Soledad and King City, 1 May 1971.

degrees out of phase from Salinas to Soledad. The winds above the surface also seem to show a bimodal distribution in the lower 800 to 900 meters above the ground with offshore and down valley winds during the morning hours and onshore and up valley winds in the afternoons, even though the synoptic situation may dictate otherwise. There is usually a reverse flow indicated above this low level flow. The wind direction patterns indicate mixing and turbulence in the air shed. The wind profiles indicate low level maxima at 100 to 300 meters above the ground with a minimum at 600 to 1500 meters above ground at all stations. This also indicates turbulent flow in the mixed marine layer. The temperature sounding indicates a thoroughly mixed marine layer which is capped by a turbulence inversion which may have the appearance of a strong subsidence inversion. This inversion appears to be present even with synoptically unstable conditions present. Thus, it is possible that an inversion may be present over this air shed a large part of the year.

Recommendations

As coastal valleys in California have been developed from agricultural to urban usages, the pattern of development has been first near the coast and then inland. As a result, heavy industry, highway systems, and residential patterns have concentrated near the coast and atmospheric waste disposal of pollutants has been a serious problem. The field studies reported here indicate that an inversion may cap the valley air shed even though the synoptic situation would indicate strong flushing of the air shed. If the valley is to be urbanized and industry does settle here, it would be wise to locate some distance from the coast, i.e., between Soledad and King City, where conditions are favorable for more ventilation and spreading out in the vertical of the atmospheric waste. The problem will still be there, but the concentrations of pollutants would be much less than with development near the coast. The coastal plain and the flat wide section of the valley floor would be profitably utilized in agriculture, and well-planned residential areas could be placed on the slopes leading into the valley floor.

<u>Acknowledgments</u>

Many persons played essential roles in these field studies. I wish to thank, in particular, two graduate students, Joe Duquette and John Feldmeier, for enthusiastic help in taking observations and in data reduction. I would also like to thank Jak Beattie and the other undergraduate students for their help in taking observations.

My thanks go also to the U.S. Naval Post Graduate School Department of Meteorology, for their cooperation in helping with the May 1971 field study.

References

Defant, F., 1951: Local Winds. Compendium of Meteorology, Boston, Amer. Meteor. Soc., 655-675.

Fosberg, M.A. and M.J. Schroeder, 1966: Marine Air Penetration into Central California. J. Appl. Meteor., 5, 573-589.

Garstang, M., 1965: Sensible and Latent Heat Exchange in Low Latitude Synoptic Scale Systems. Sea Air Interface Lab. Report No. 1, U.S. Department of Commerce, 105-146.

Malkus, J.S., 1962: Large Scale Interaction. The Sea, Vol. 1, M.N. Hill, Gen. Ed. New York, Wiley and Sons, 88-294.

____________, 1965: A Survey of the Role of Sea Air Interface in Tropical Meteorology. Sea Air Interface Report No. 1, U.S. Department of Commerce, 65-103.

Miller, A., 1968: Wind Profiles in West Coast Temperature Inversions. San Jose State College Report No. 4, NSFGP-4248, 1-56.

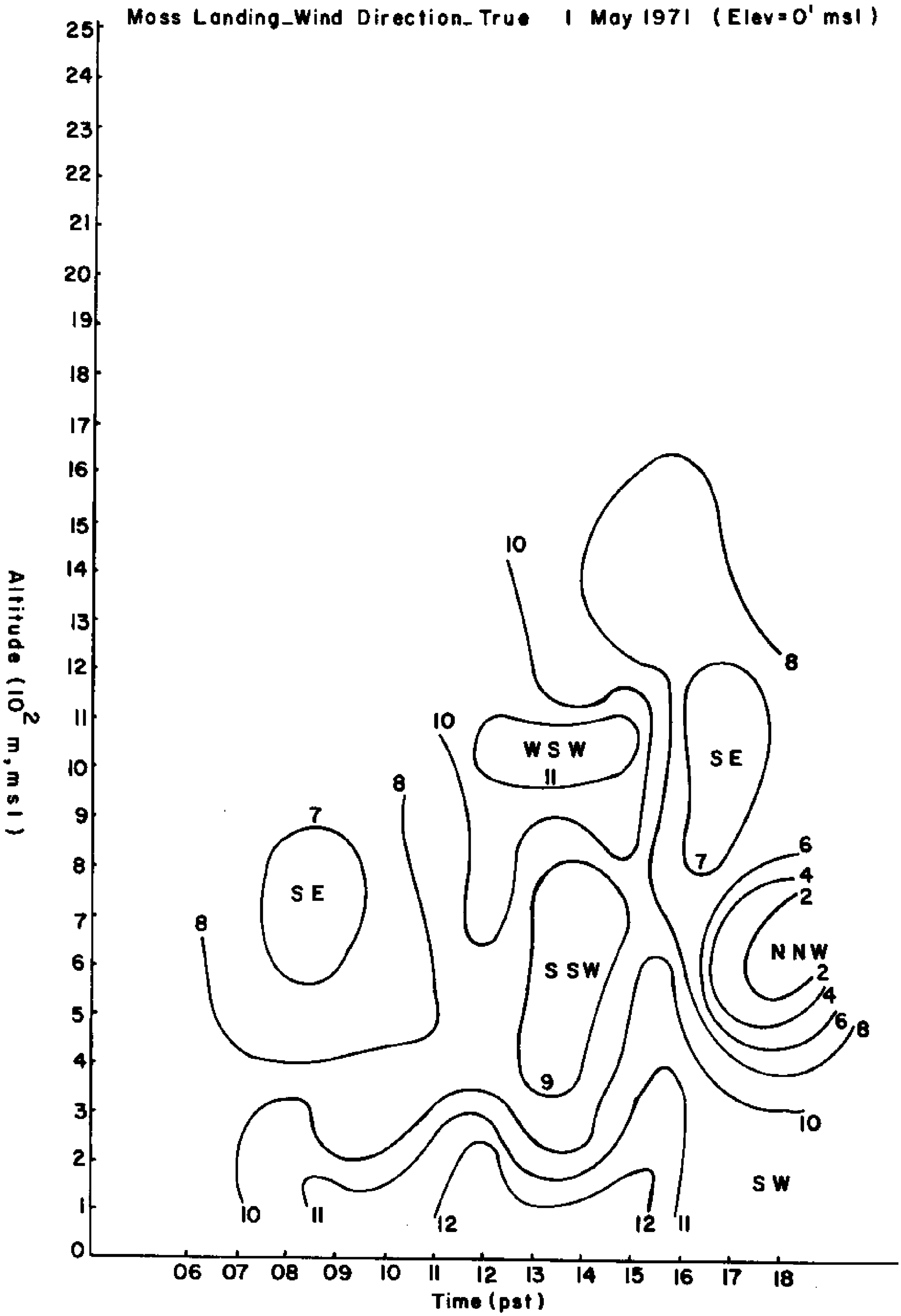
Read, R.G., 1968: Evaporative Power in the Tropical Forest of the Panama Canal Zone. J. Appl. Meteor., 3, 417-424.

Schroeder, M.J., M.A. Fosberg, O.P. Cramer, and C.A. O'Dell, 1967: Marine Air Invasion of the Pacific Coast: A Problem Analysis. Bull. Amer. Meteor. Soc., 48, 802-808.

Sutton, O.G., 1953: Micrometeorology. New York, McGraw-Hill, 333 pp.

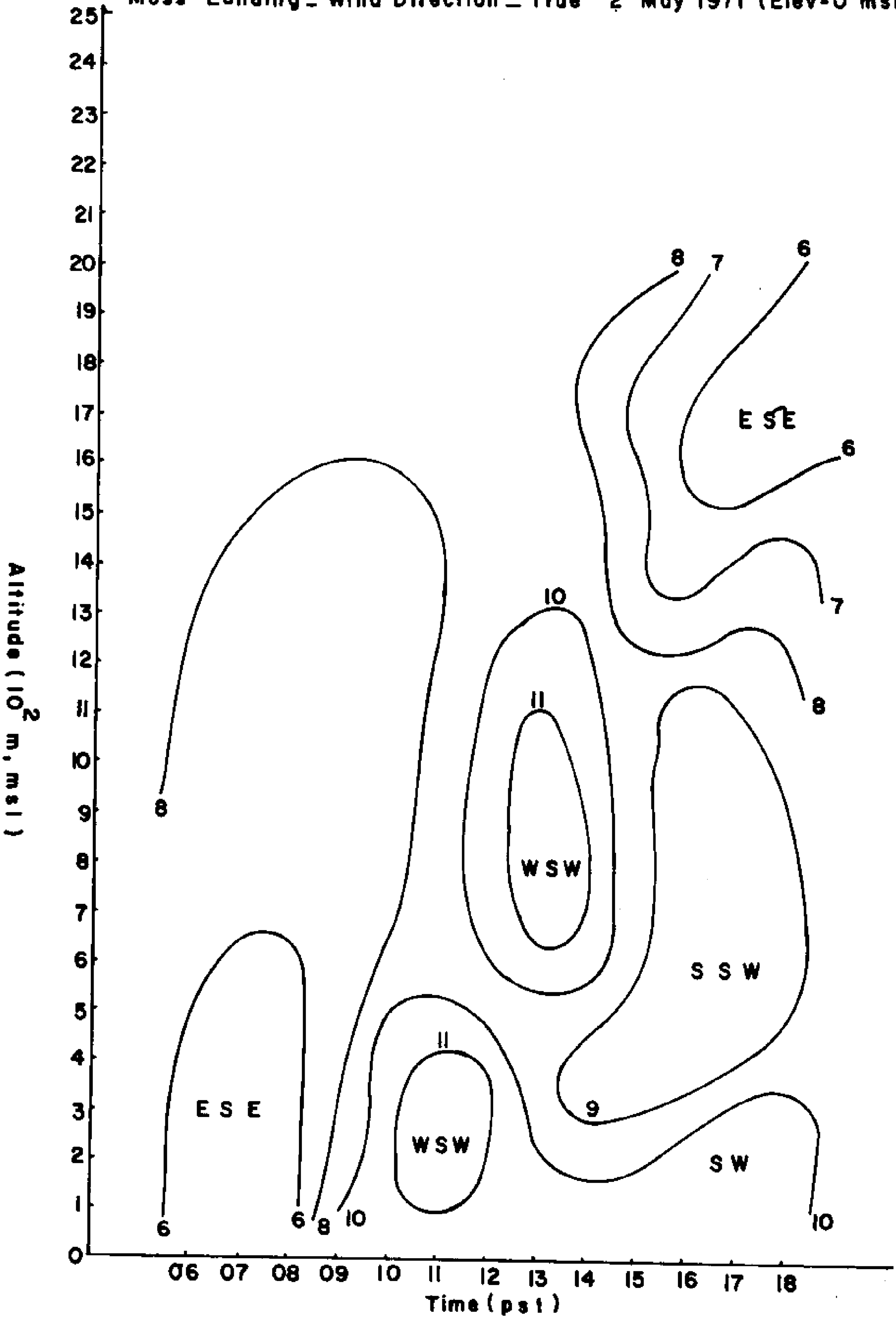
Appendix 1

Time averaged isogon sector analyses for 1-2 May 1971. Wind speed profiles, Moss Landing, Salinas, and Soledad for 7 November 1970, and 1-2 May 1971.

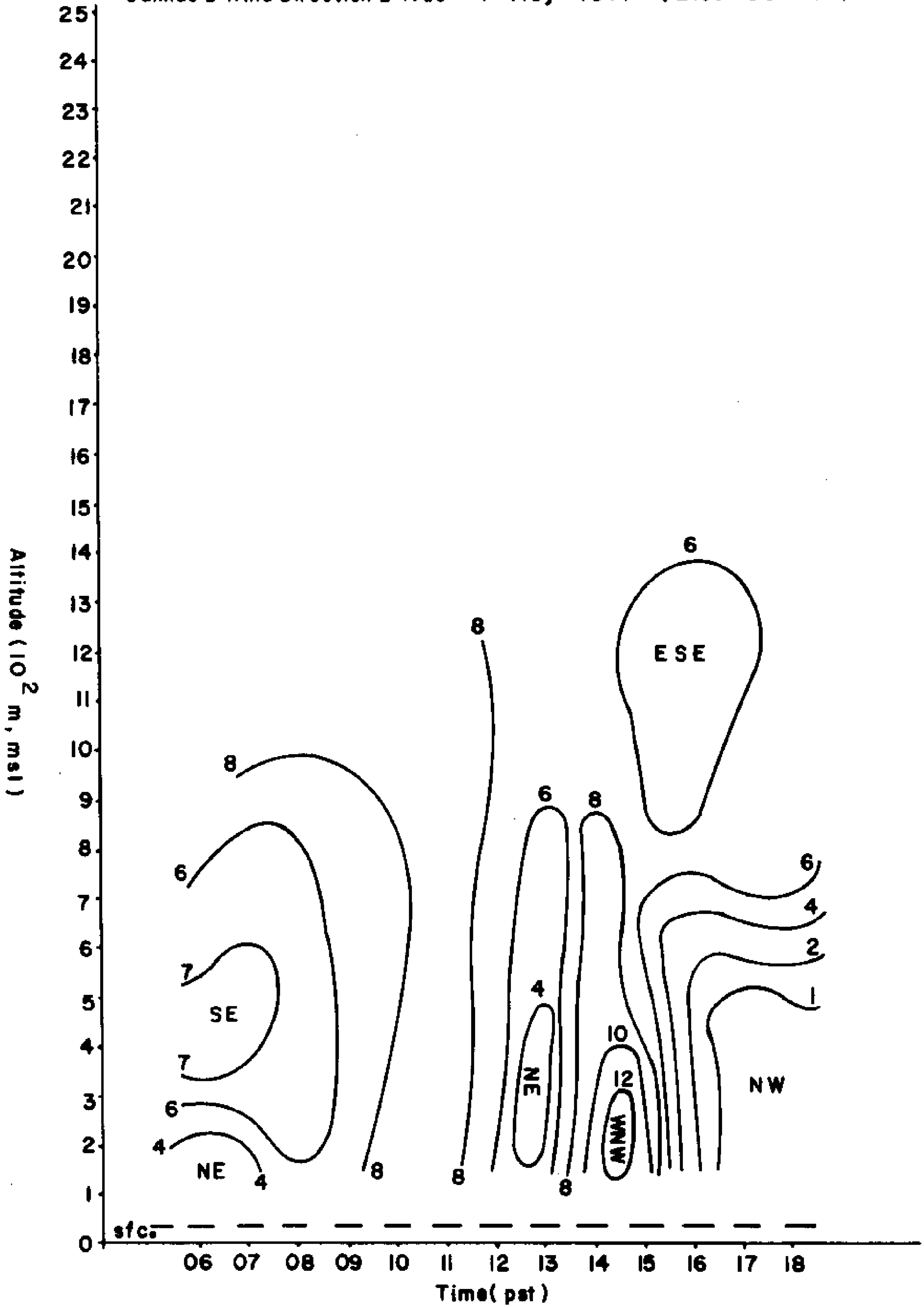


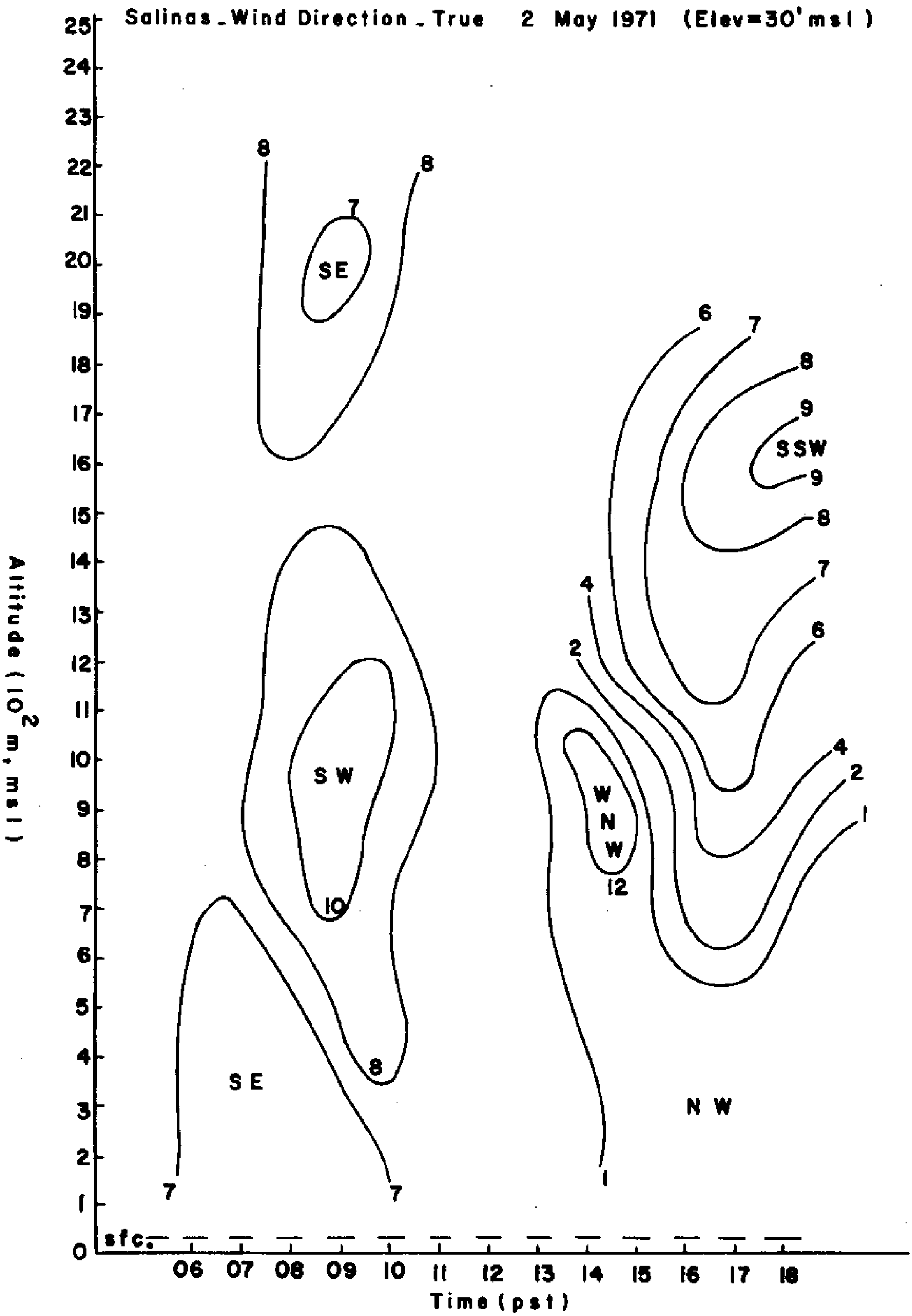
Moss Landing_Wind Direction_True 1 May 1971 (Elev=0' msl)
Altitude (10^2 m, msl)
Time (pst)
SE
WSW
SE
SSW
NNW
SW

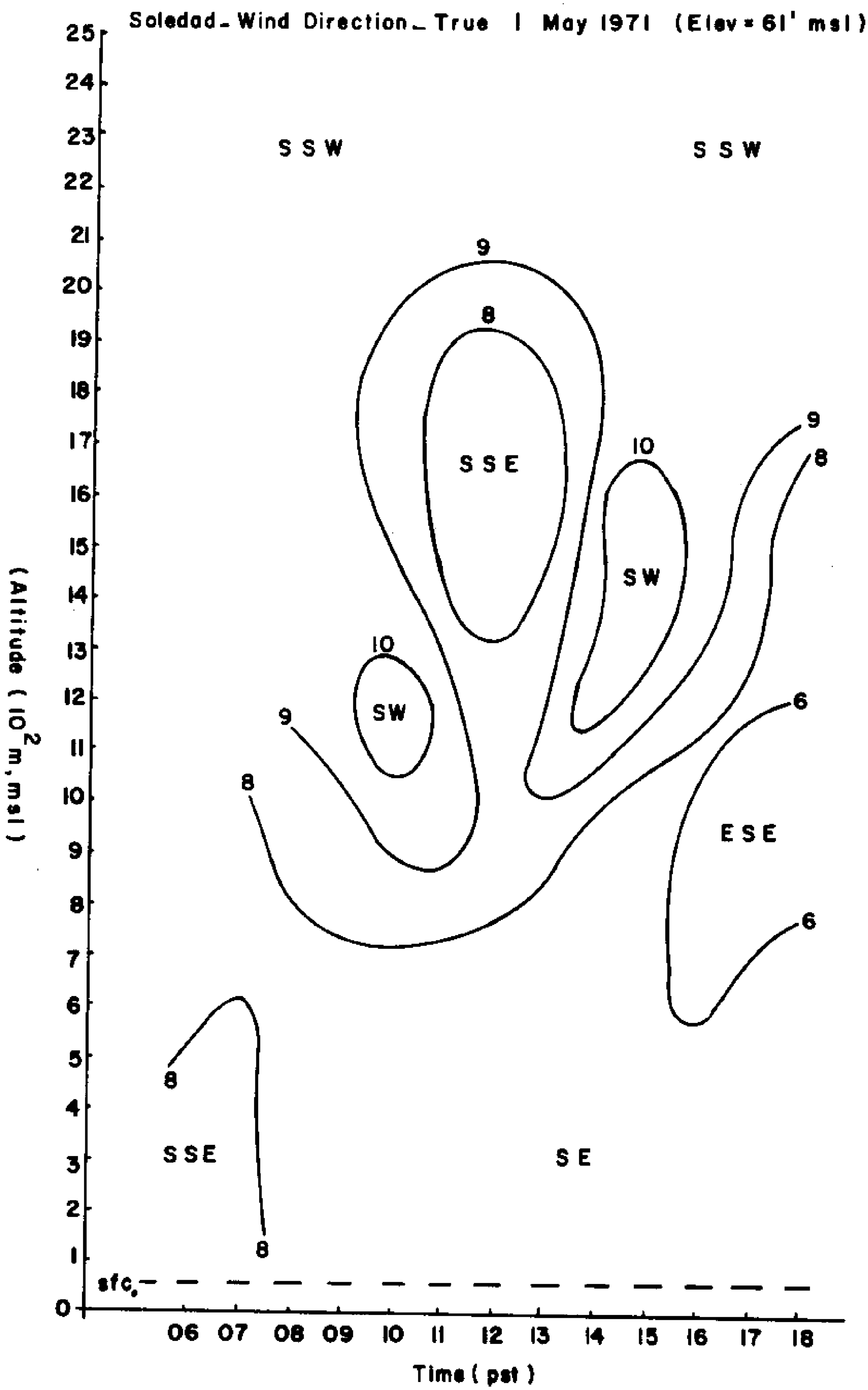
Moss Landing _ Wind Direction _ True 2 May 1971 (Elev=0' msl)

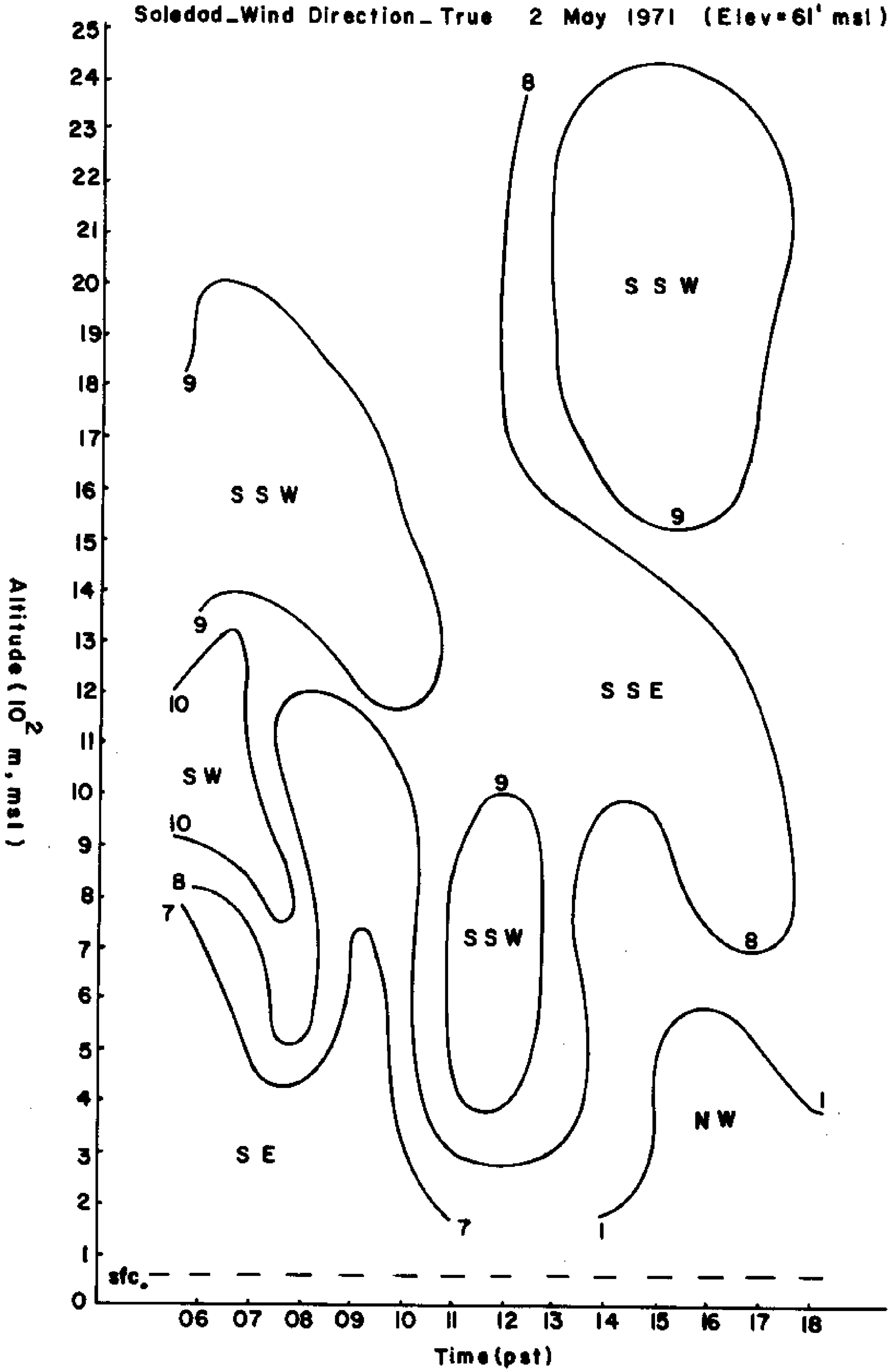


Salinas _ Wind Direction _ True 1 May 1971 (Elev= 30' msl)




Salinas _ Wind Direction _ True 2 May 1971 (Elev=30' msl)
Altitude (10^2 m, msl)
Time (pst)
sfc.
06 07 08 09 10 11 12 13 14 15 16 17 18
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
SE
SW
SE
WNW
SSW
NW
8
7
8
10
8
7
7
6
7
8
9
9
8
7
6
4
2
4
2
1
12
1


Soledad - Wind Direction - True 1 May 1971 (Elev = 61' msl)
SSW
SSW
SSE
SW
SW
ESE
SSE
SE
9
8
10
10
9
8
9
8
6
6
8
8
sfc.
(Altitude (10^2 m, msl)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
06 07 08 09 10 11 12 13 14 15 16 17 18
Time (pst)



Soledad_Wind Direction_True 2 May 1971 (Elev=61' msl)
Altitude (10^2 m, msl)
Time (pst)
sfc.
SSW
SSW
SSE
SW
SSW
SE
NW
9
9
9
9
10
10
8
8
8
7
7
1
1
25
24
23
22
21
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19
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17
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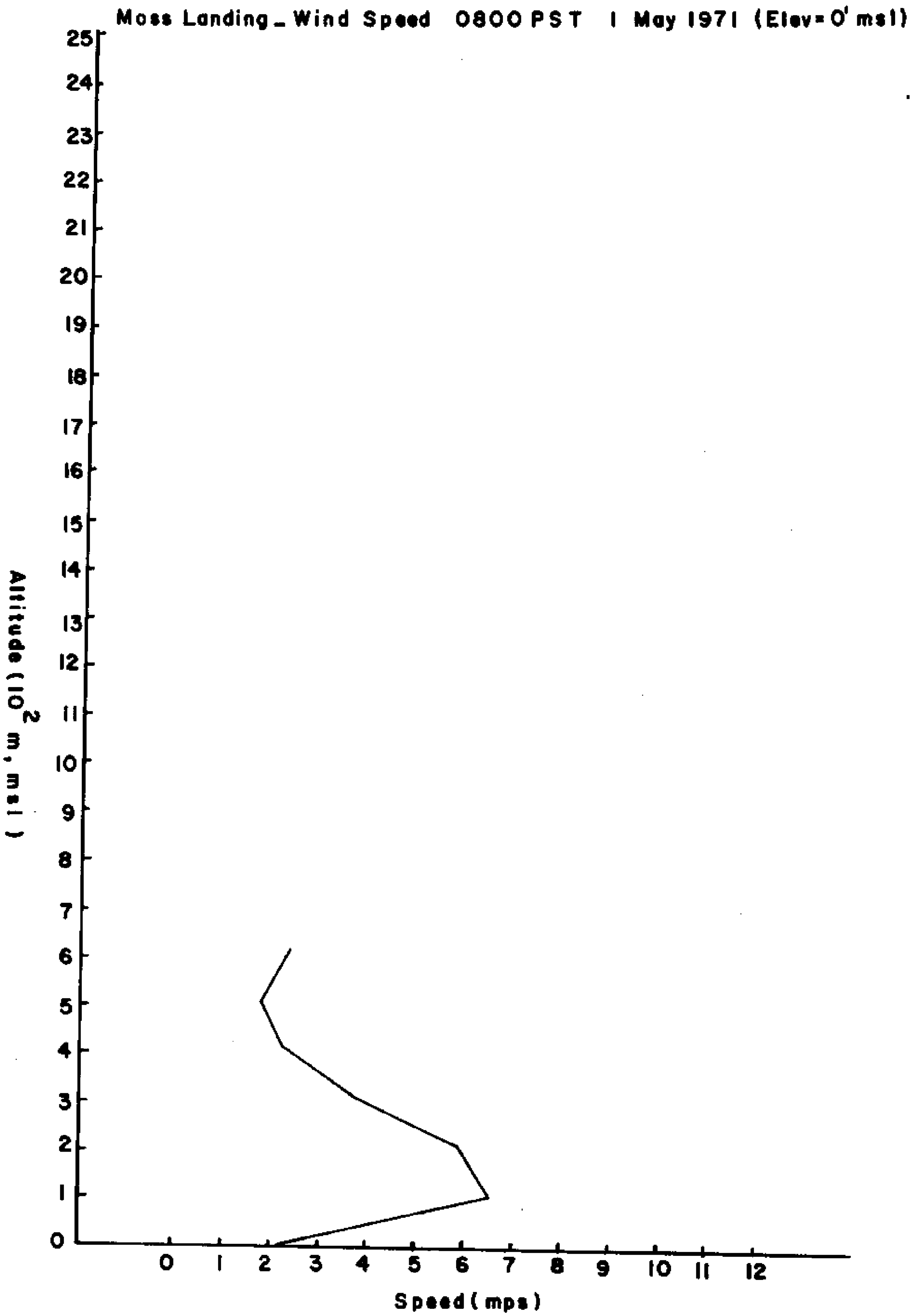
16
17
18



Moss Landing _ Wind Speed 0800 PST 1 May 1971 (Elev=0' msl)
Altitude (10^2 m, msl)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
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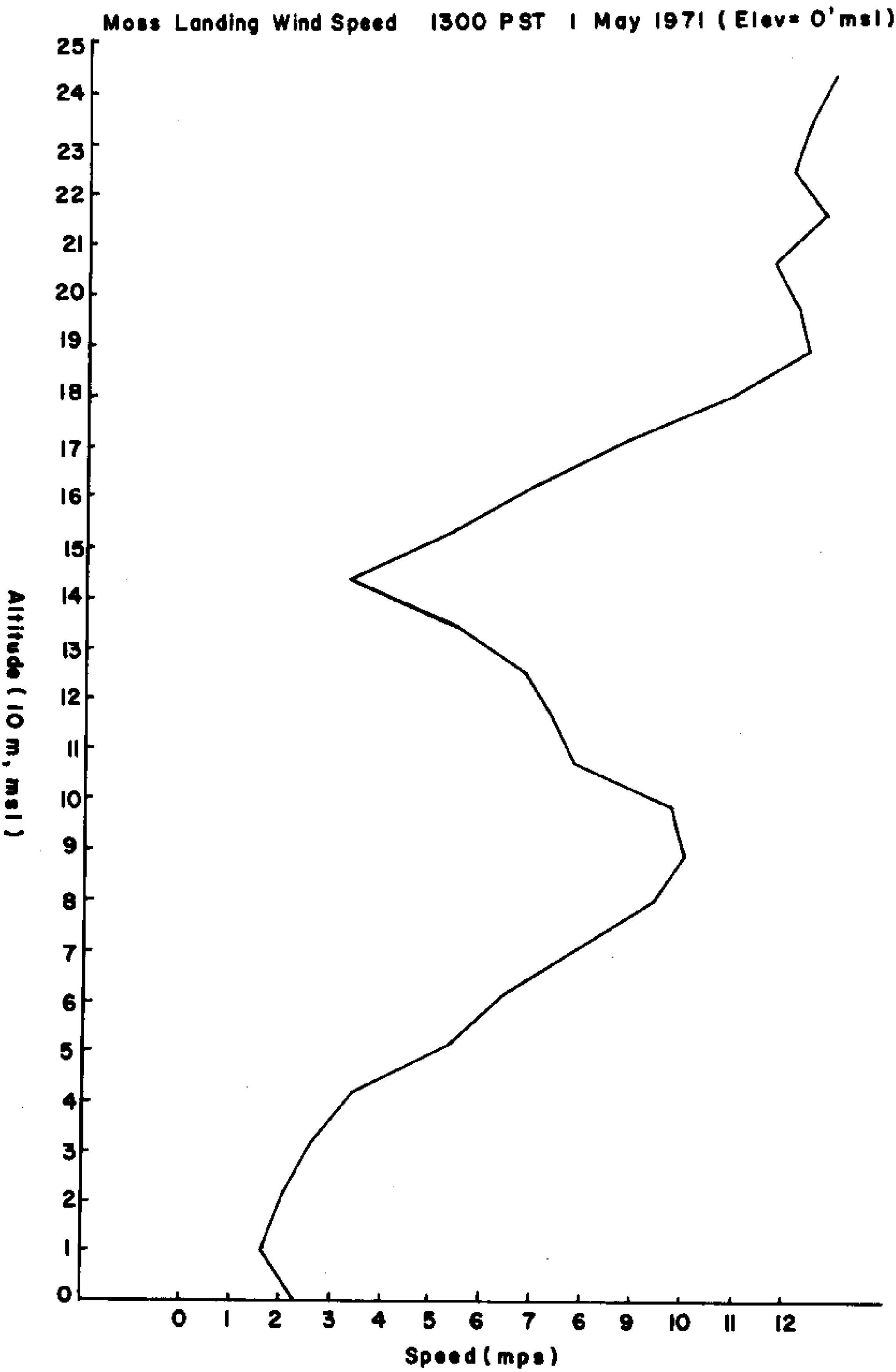
4
3
2
1
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Moss Landing Wind Speed 1300 PST 1 May 1971 (Elev= 0'msl)
Altitude (10 m, msl)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
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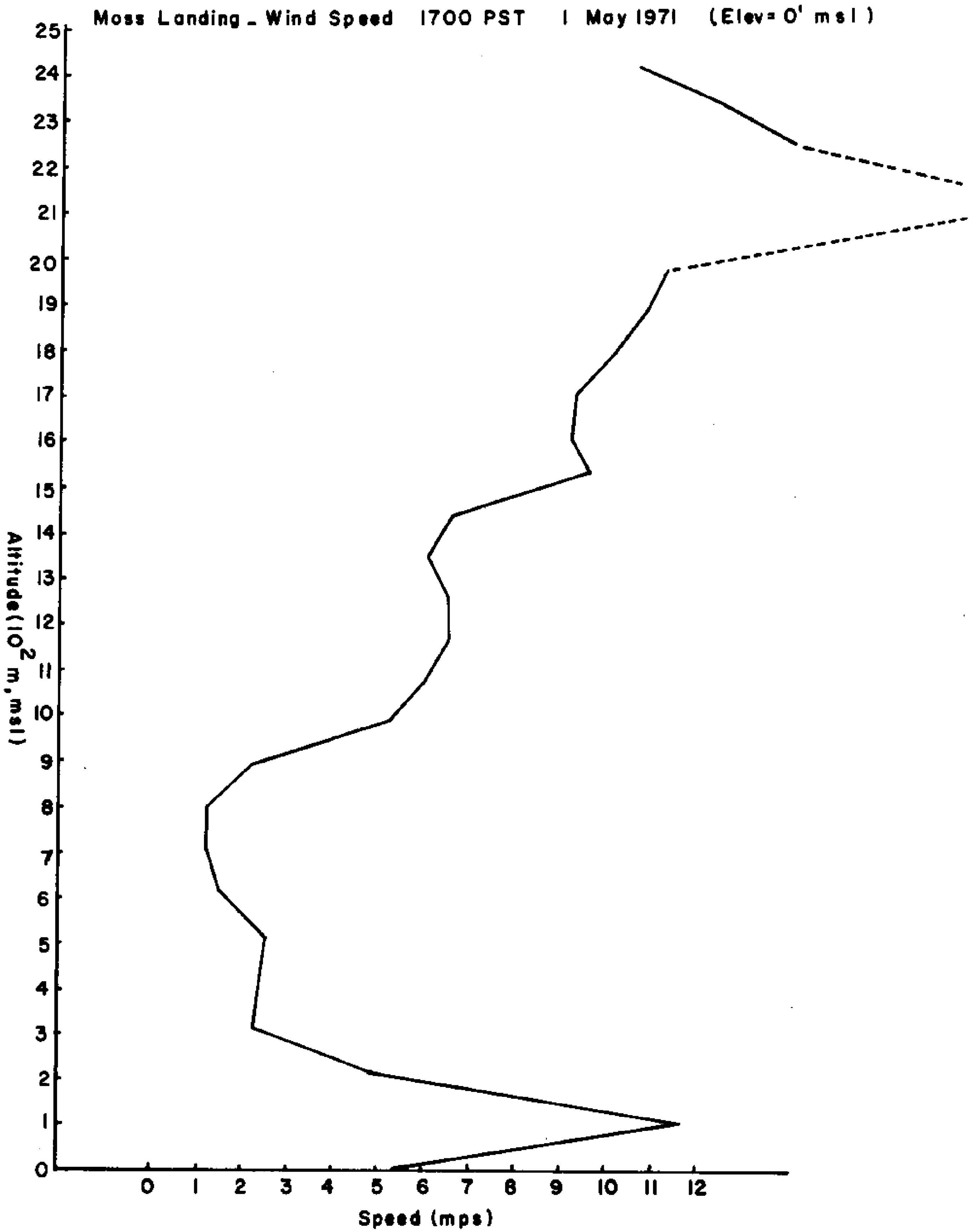
4
3
2
1
0
0 1 2 3 4 5 6 7 6 9 10 11 12
Speed (mps)


Moss Landing _ Wind Speed 1700 PST 1 May 1971 (Elev= 0' msl)
Altitude (10^2 m, msl)
0
1
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3
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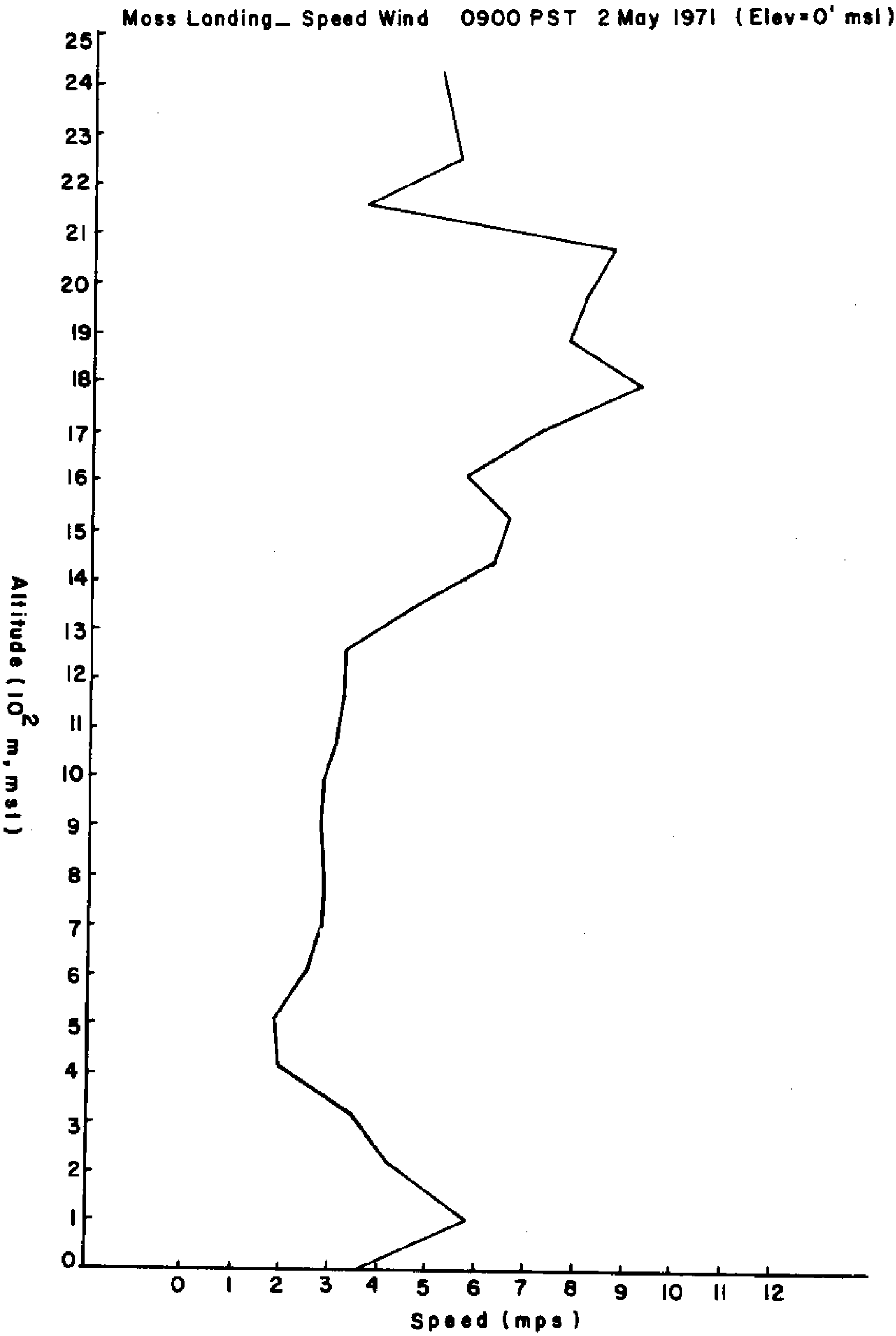
24
25
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Moss Landing_ Speed Wind 0900 PST 2 May 1971 (Elev=0' msl)
Altitude (10^2 m, msl)
0
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2
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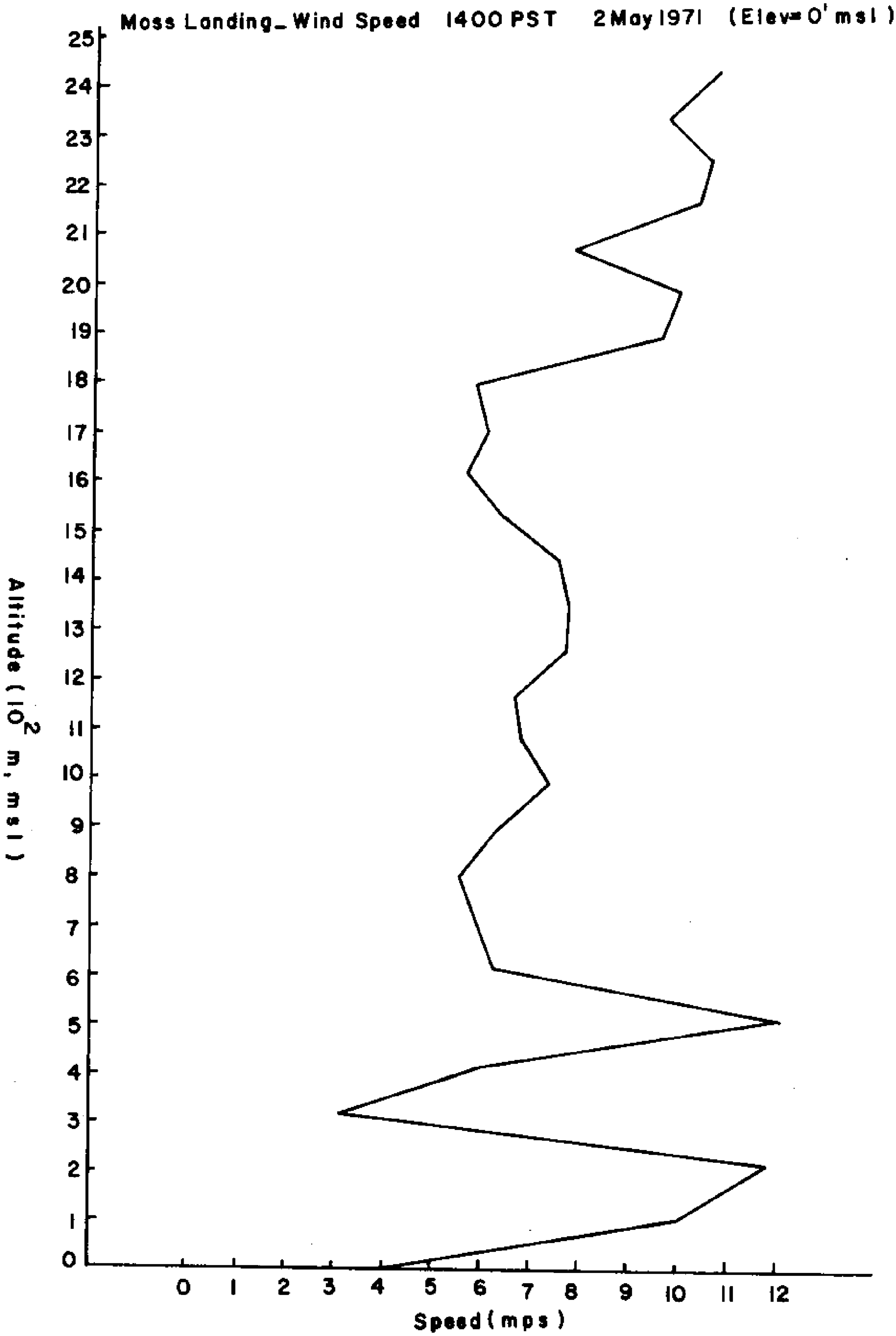
25
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Moss Landing_Wind Speed 1400 PST 2 May 1971 (Elev=0' msl)
Altitude (10^2 m, msl)
0
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12
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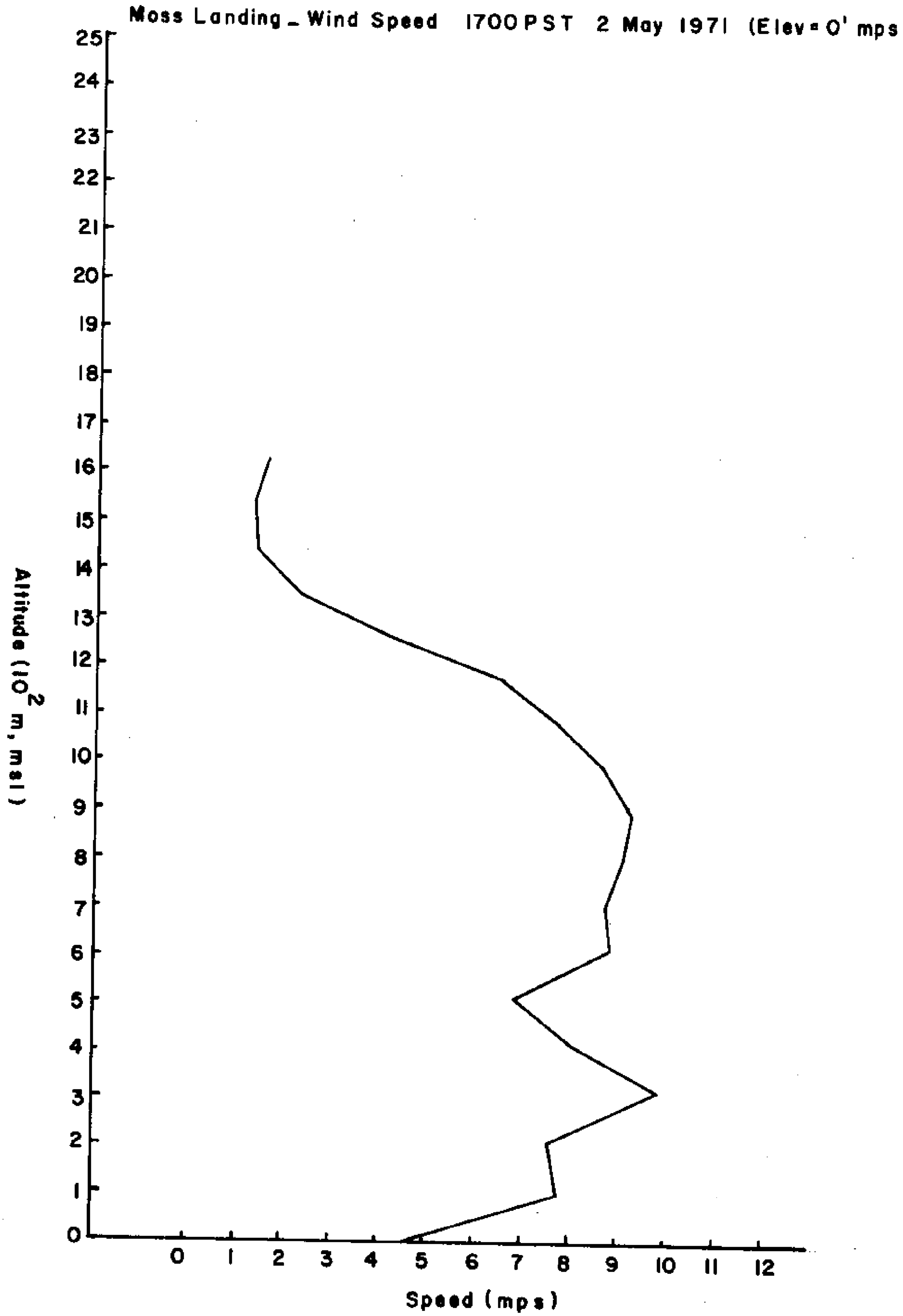
23
24
25
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Moss Landing _ Wind Speed 1700 PST 2 May 1971 (Elev = 0' mps)
Altitude (10^2 m, msl)
0
1
2
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4
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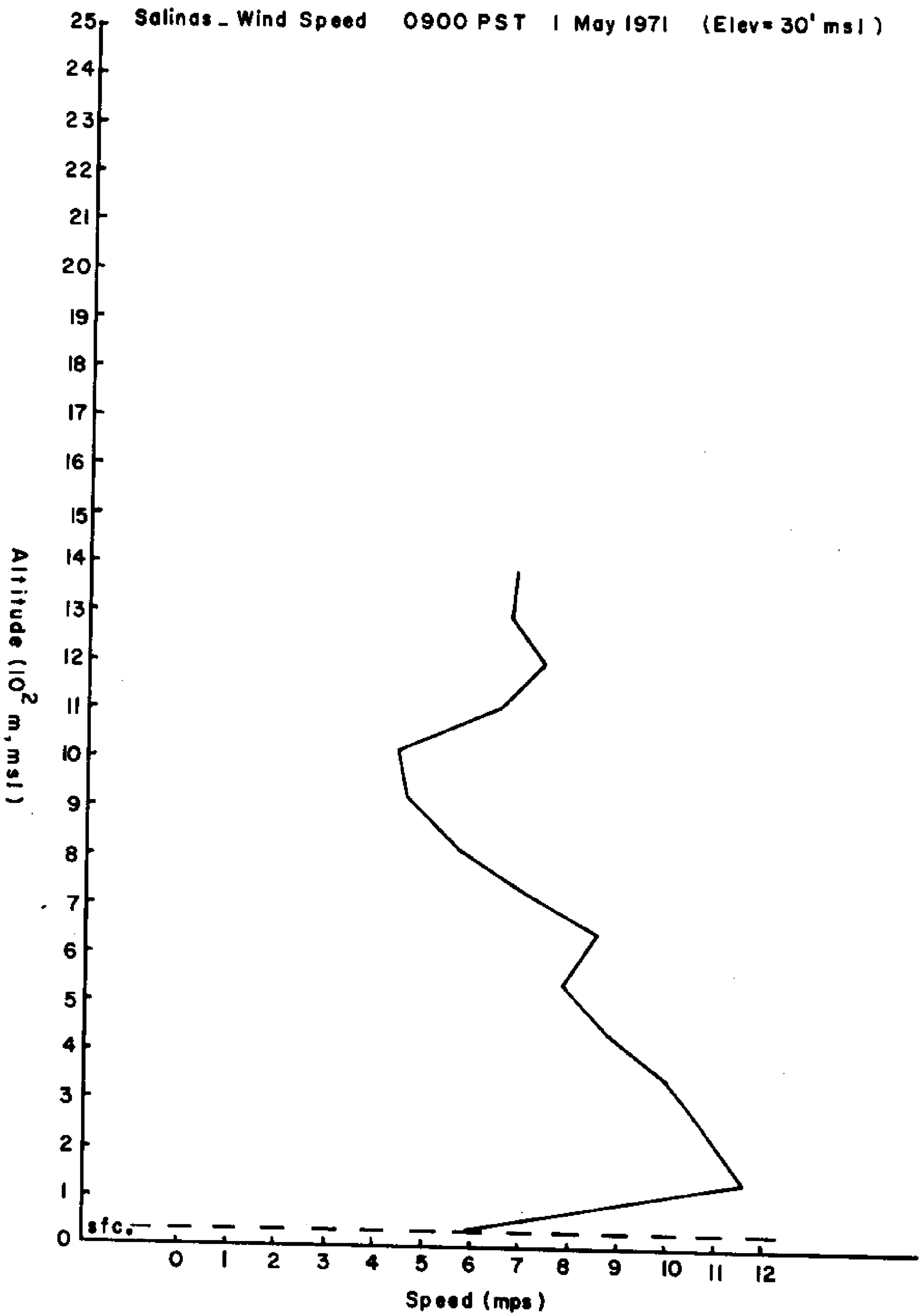
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Salinas _ Wind Speed 0900 PST 1 May 1971 (Elev= 30' msl)
Altitude (10^2 m, msl)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
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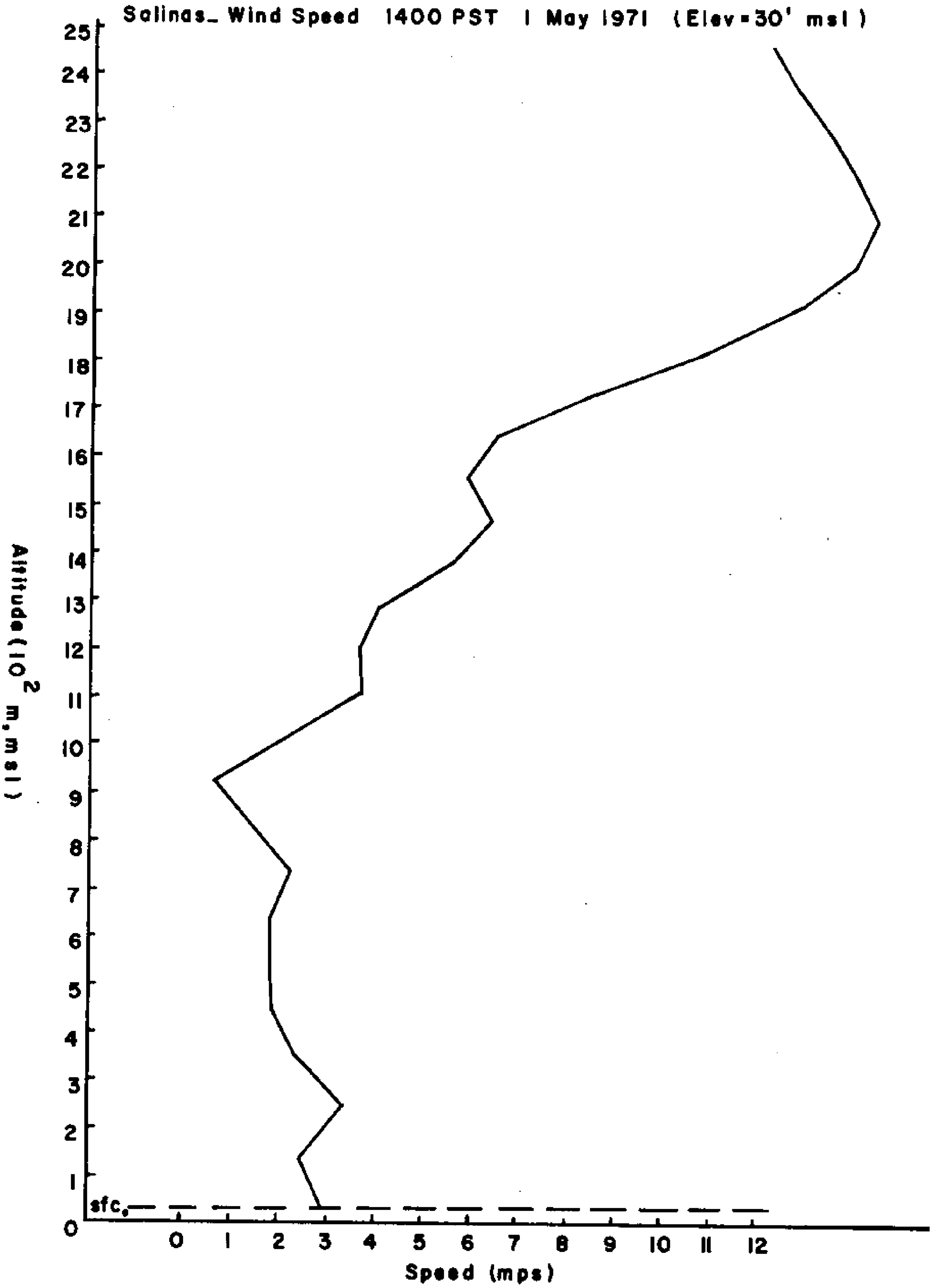
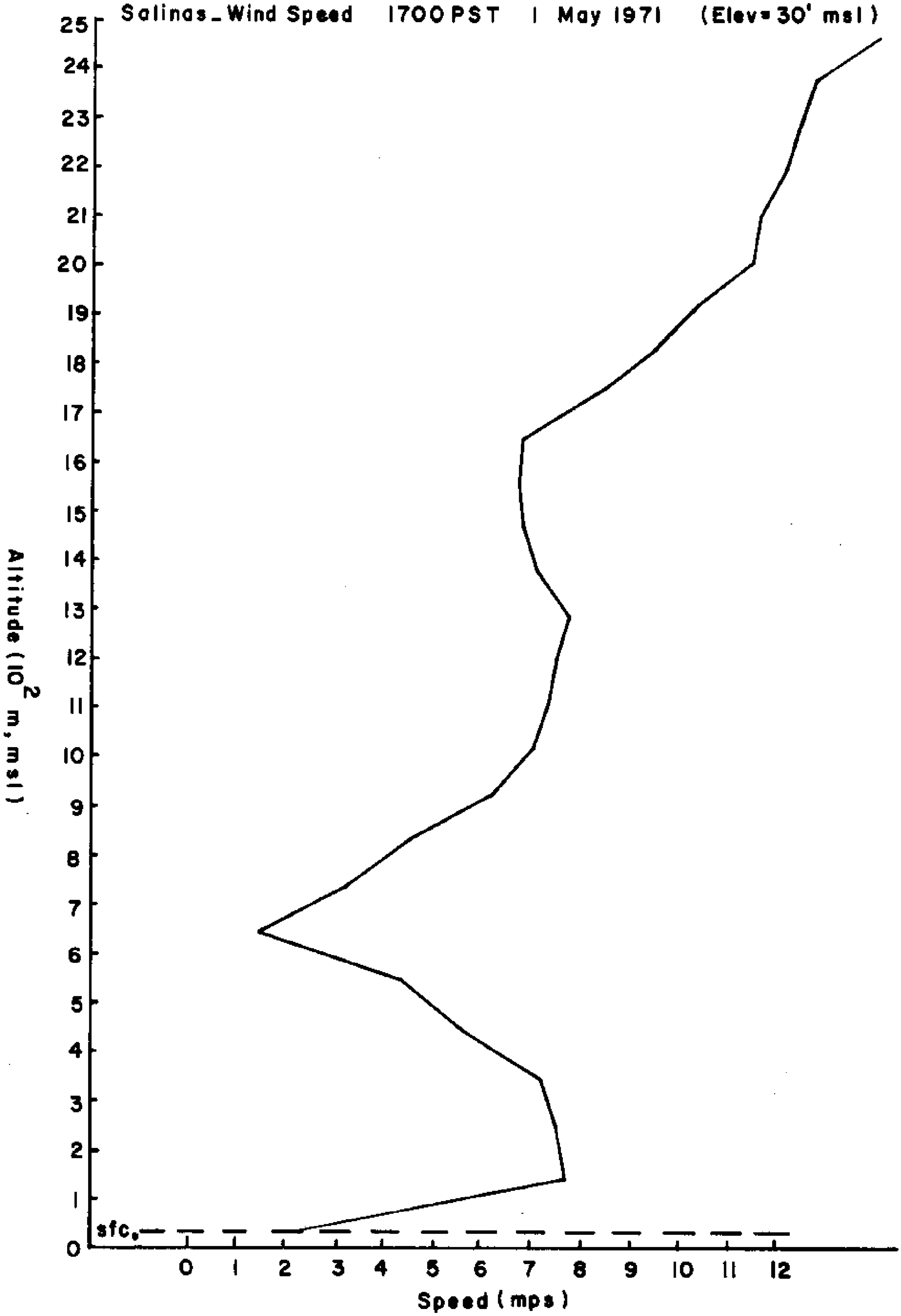
6
5
4
3
2
1
0
sfc.
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Salinas_ Wind Speed 1400 PST 1 May 1971 (Elev=30' msl)
Altitude (10^2 m, msl)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
sfc.
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Salinas_Wind Speed 1700 PST 1 May 1971 (Elev=30' msl)
Altitude (10^2 m, msl)
25
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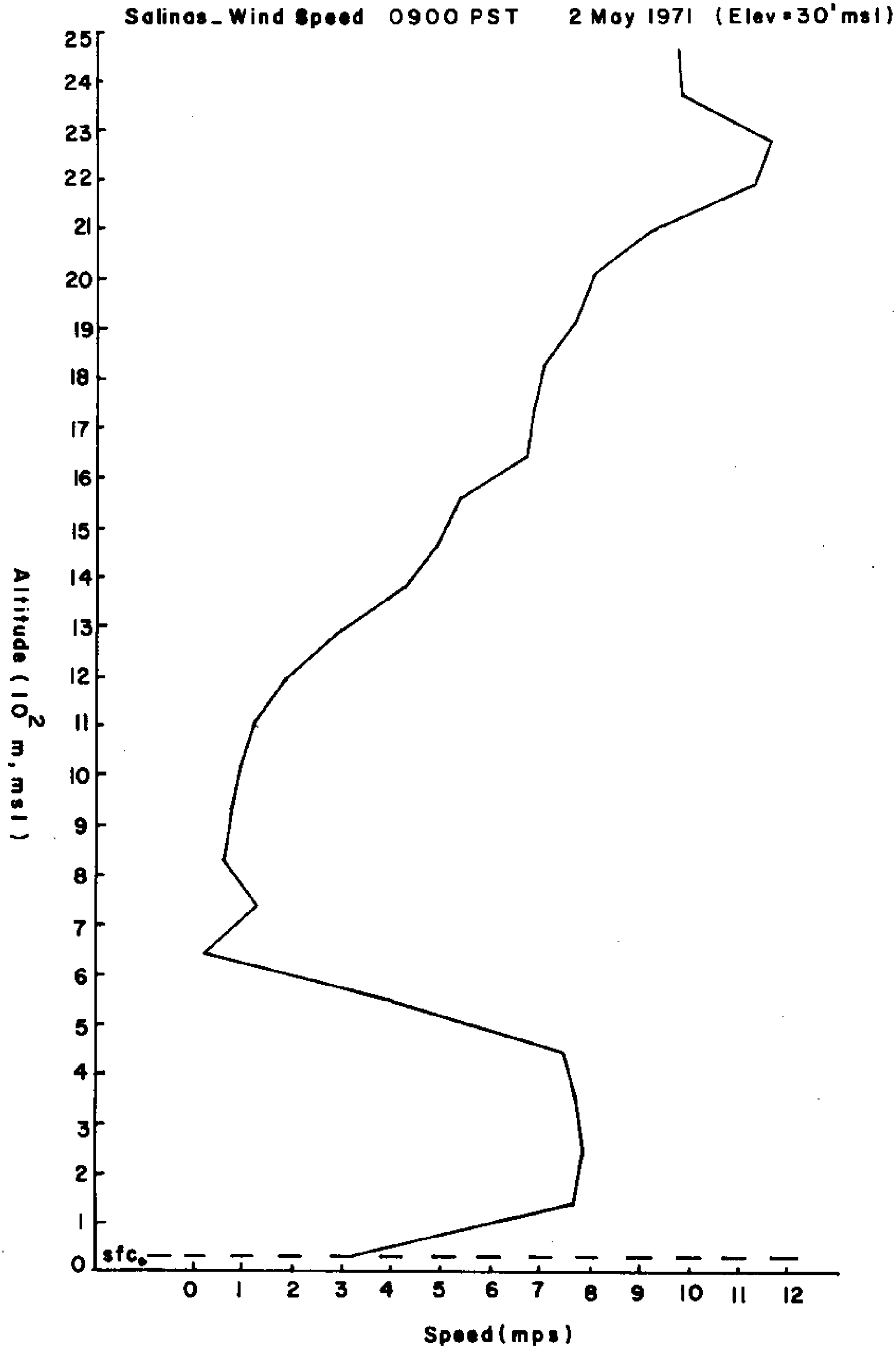
sfc.
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Salinas_ Wind Speed 0900 PST 2 May 1971 (Elev = 30' msl)
Altitude (10^2 m, msl)
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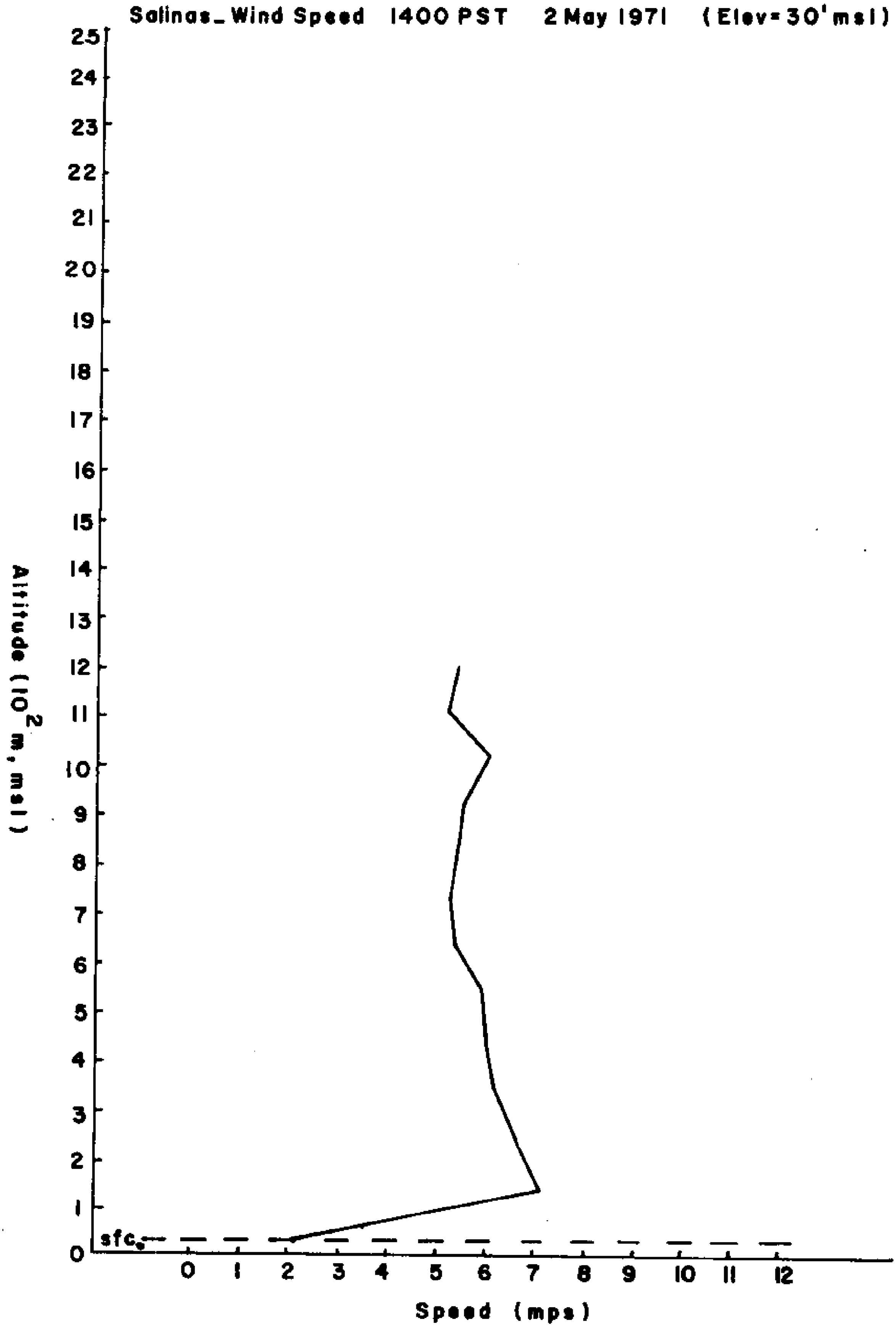
sfc.
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Salinas_Wind Speed 1400 PST 2 May 1971 (Elev=30' msl)
Altitude (10^2 m, msl)
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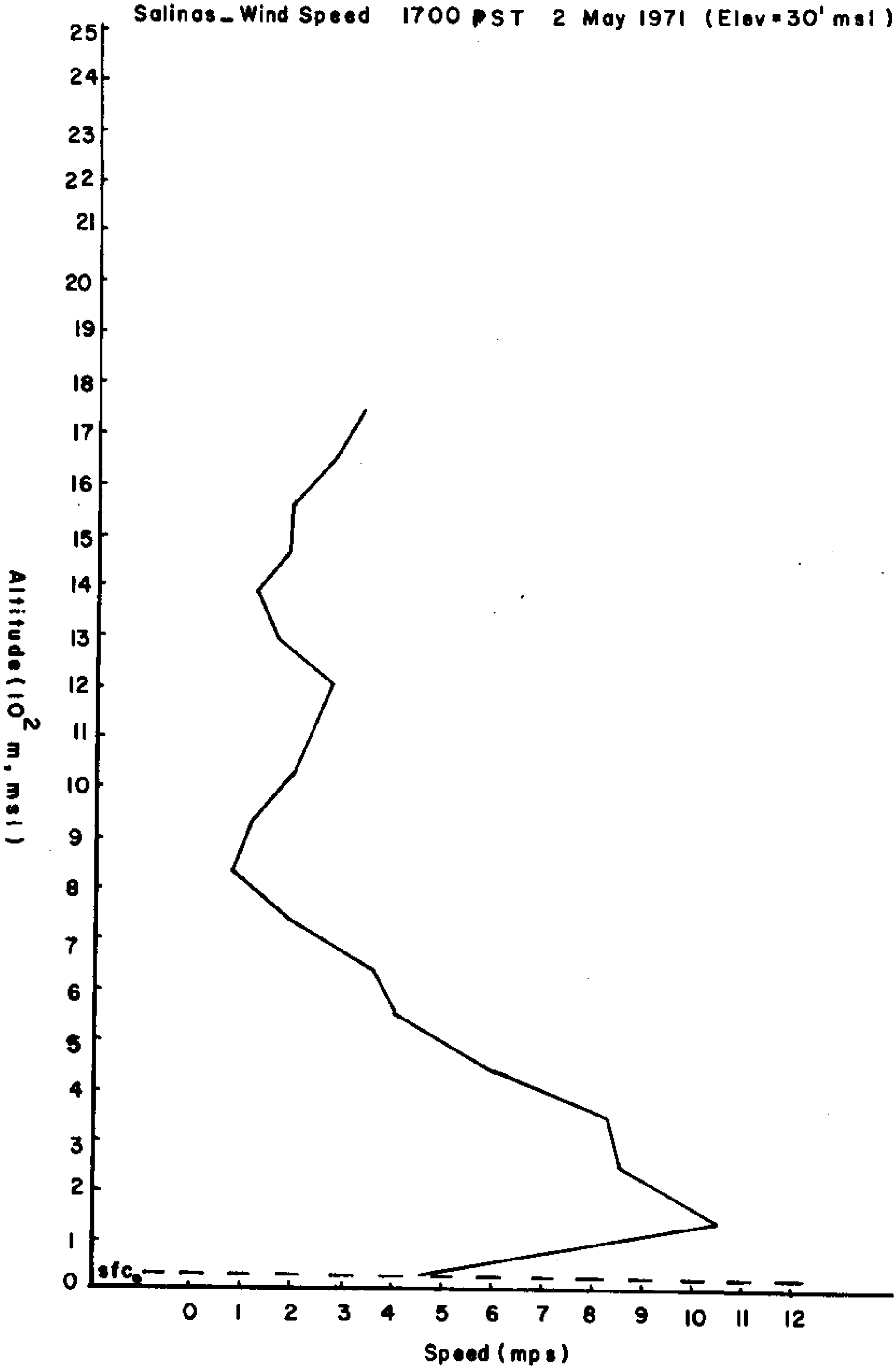
sfc.
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Salinas _ Wind Speed 1700 PST 2 May 1971 (Elev = 30' msl)
Altitude (10^2 m, msl)
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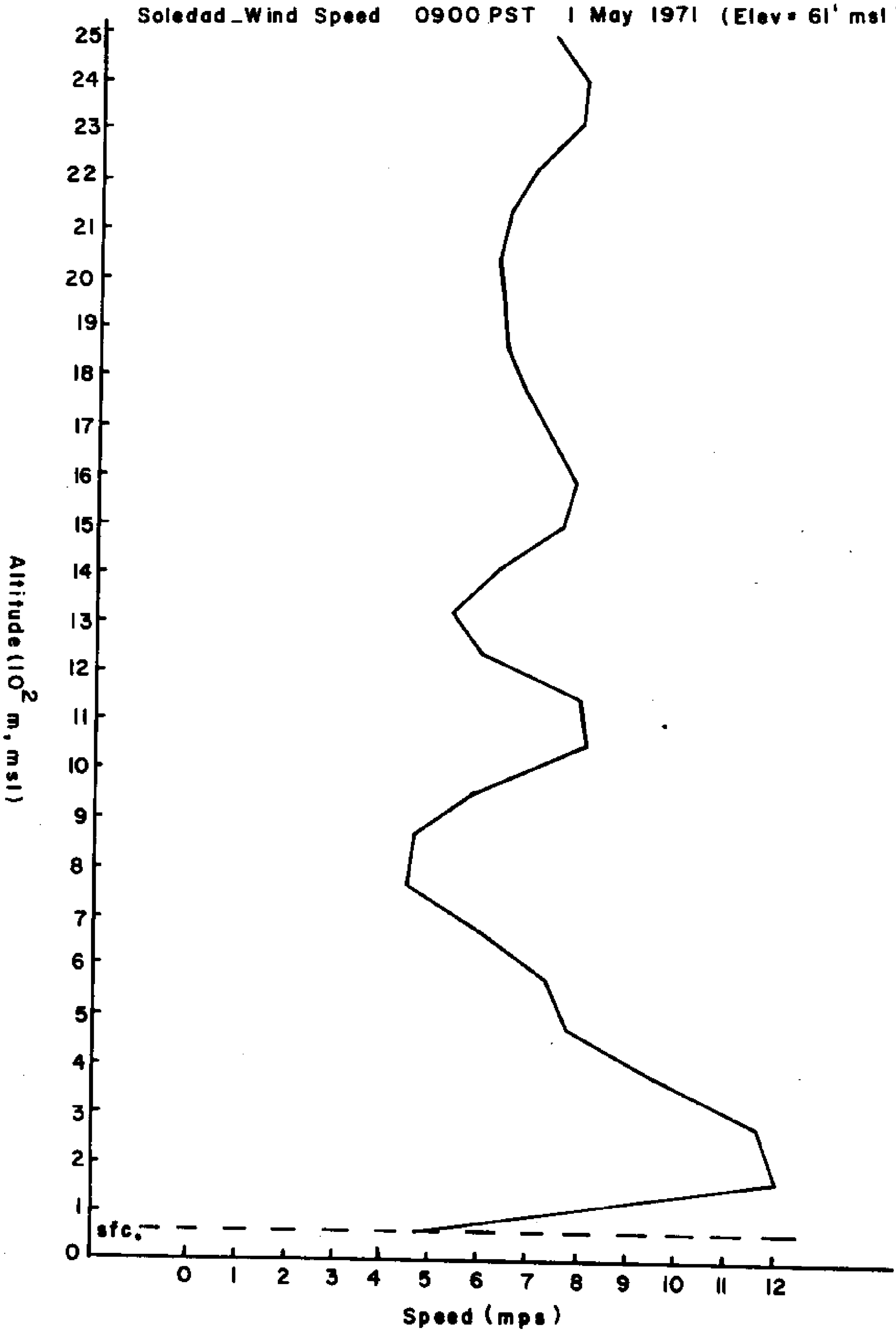
0
sfc.
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)


Soledad_Wind Speed 0900 PST 1 May 1971 (Elev= 61' msl)
Altitude (10^2 m, msl)
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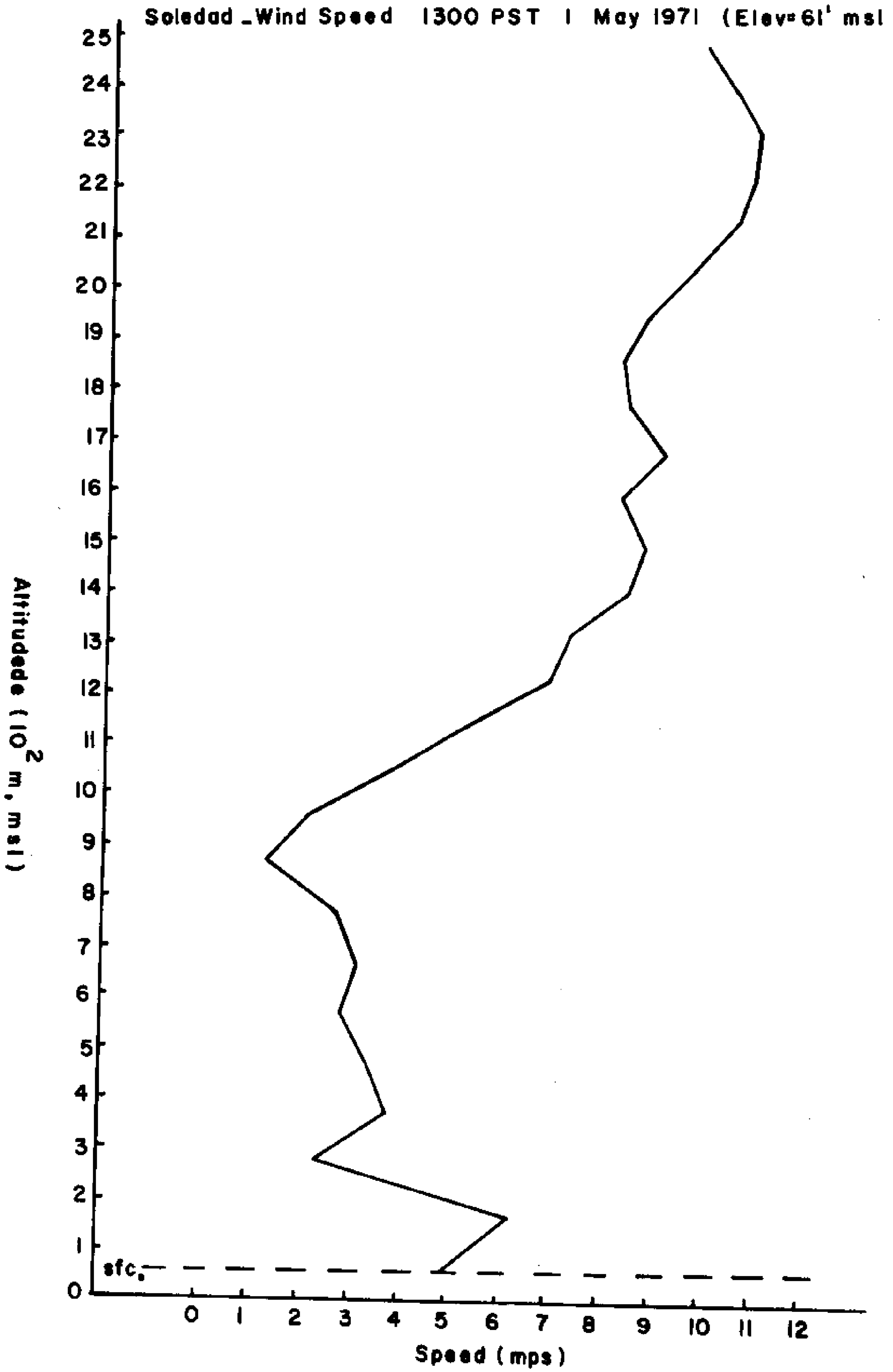
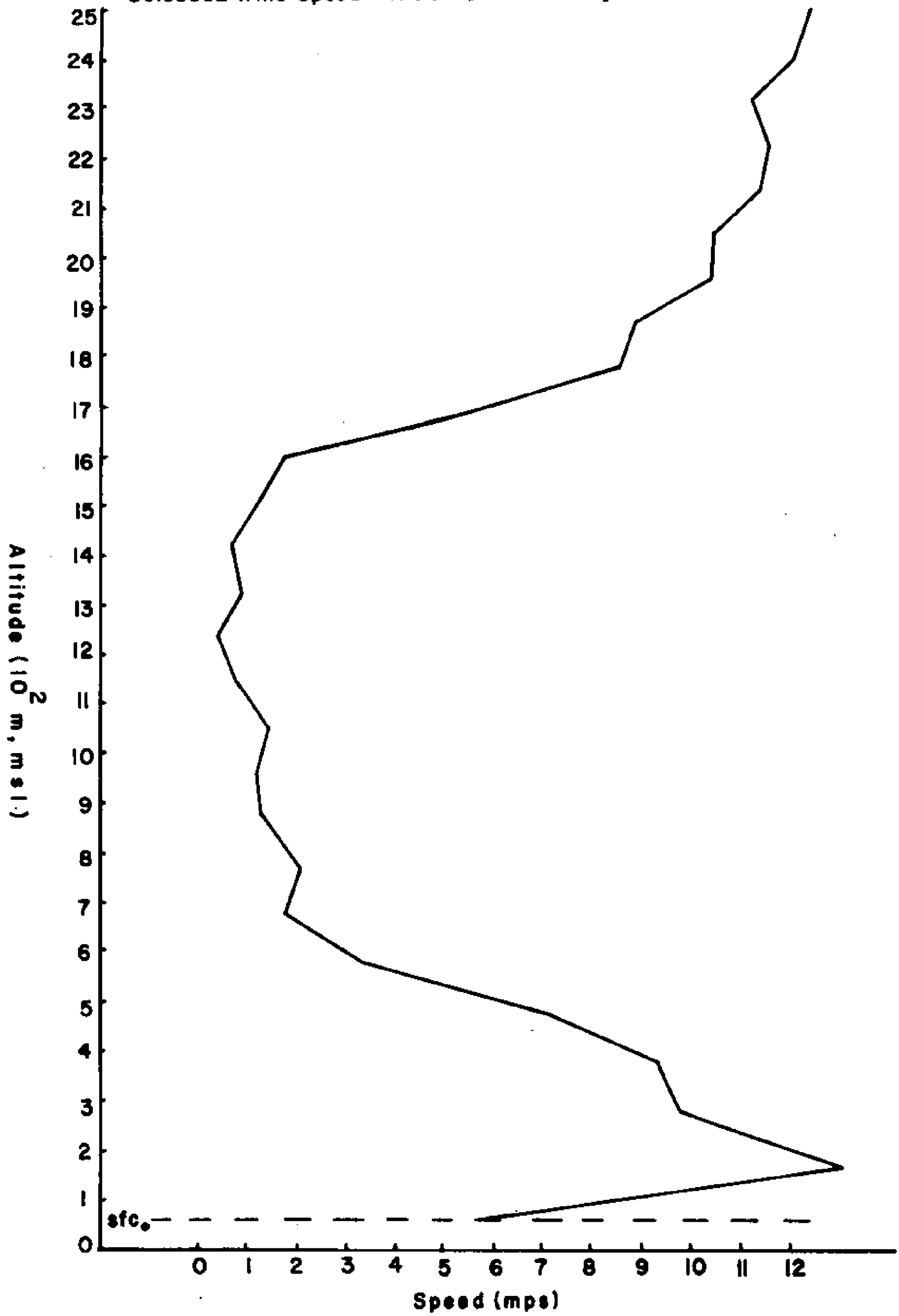
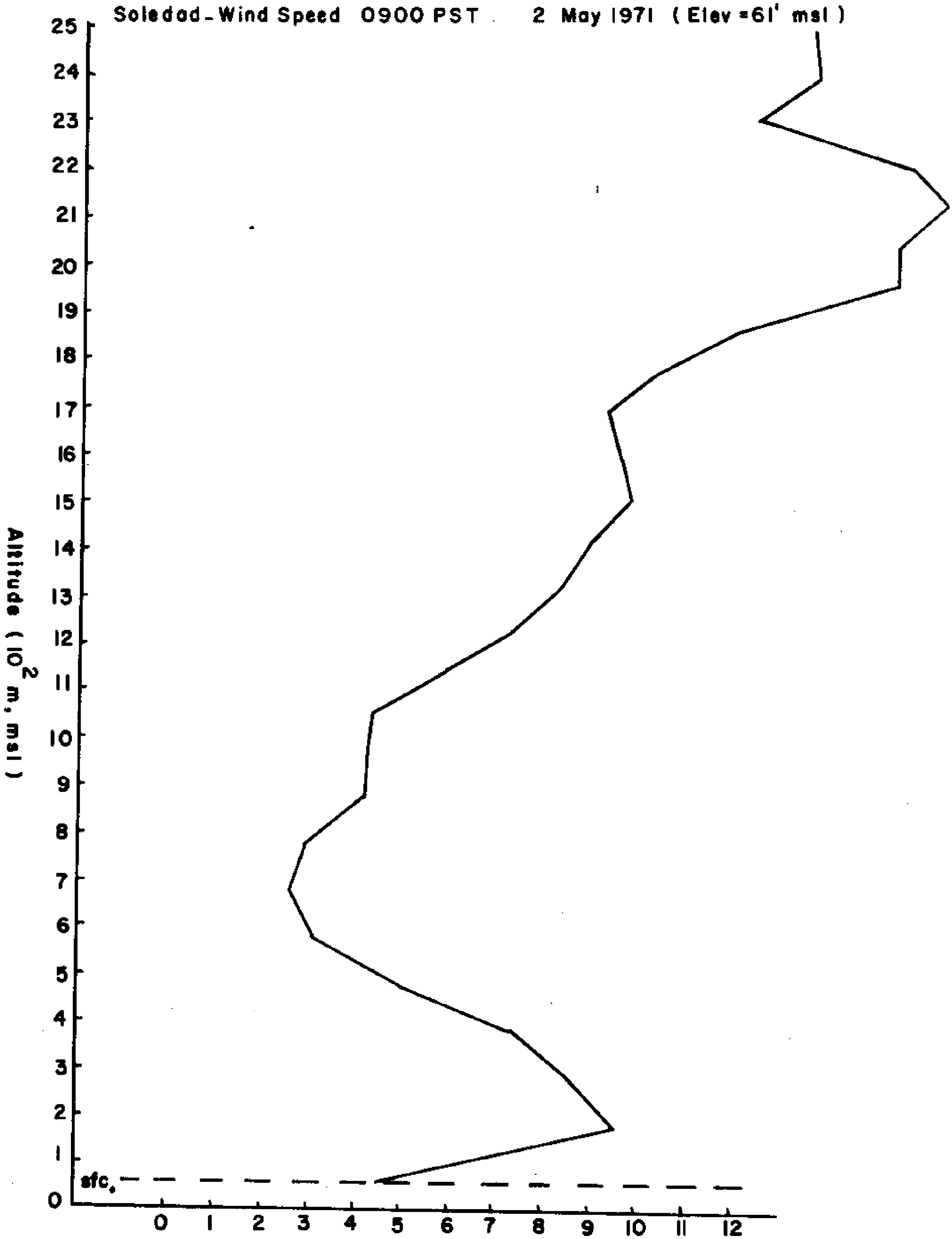
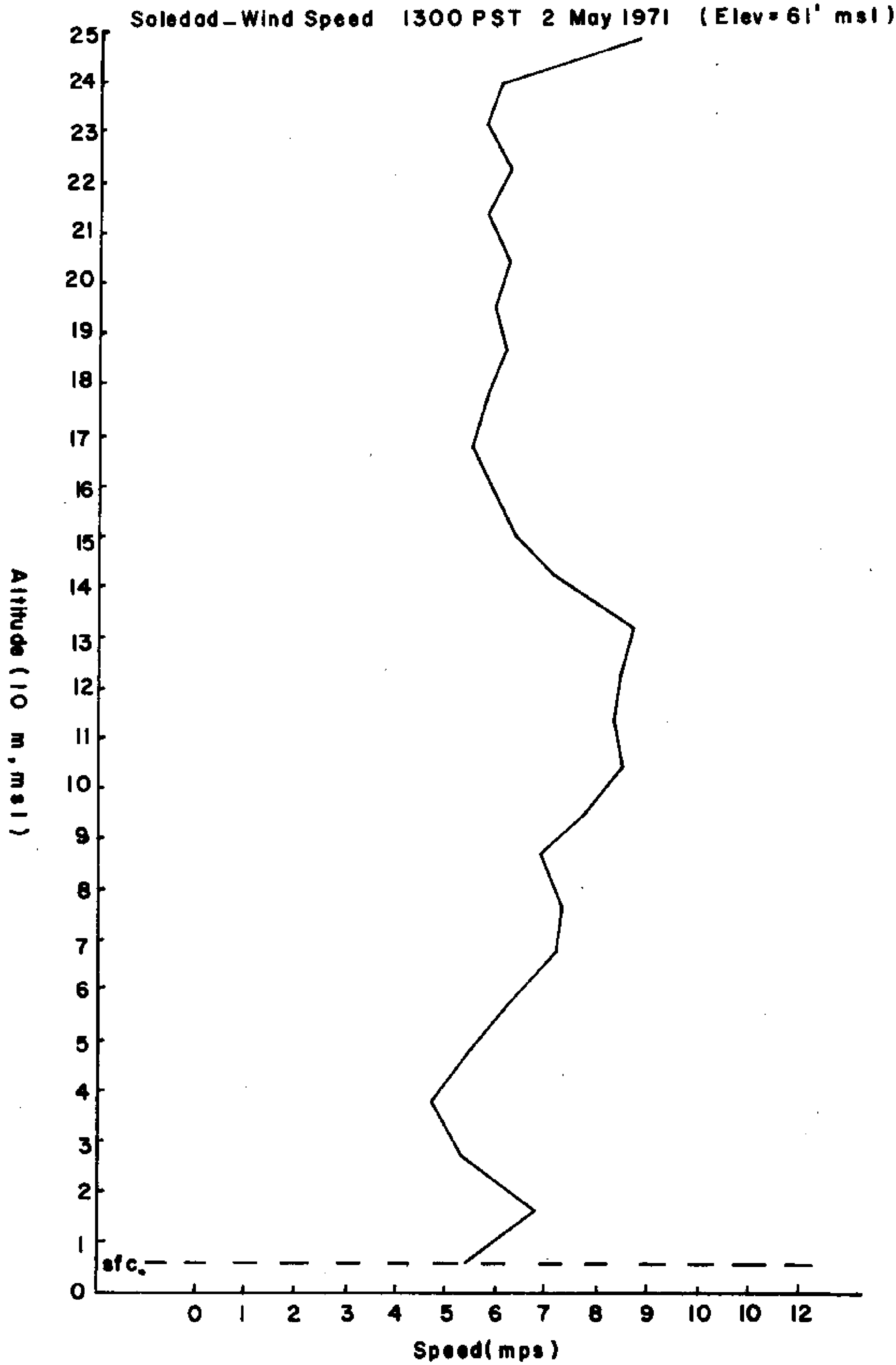
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
sfc.
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)

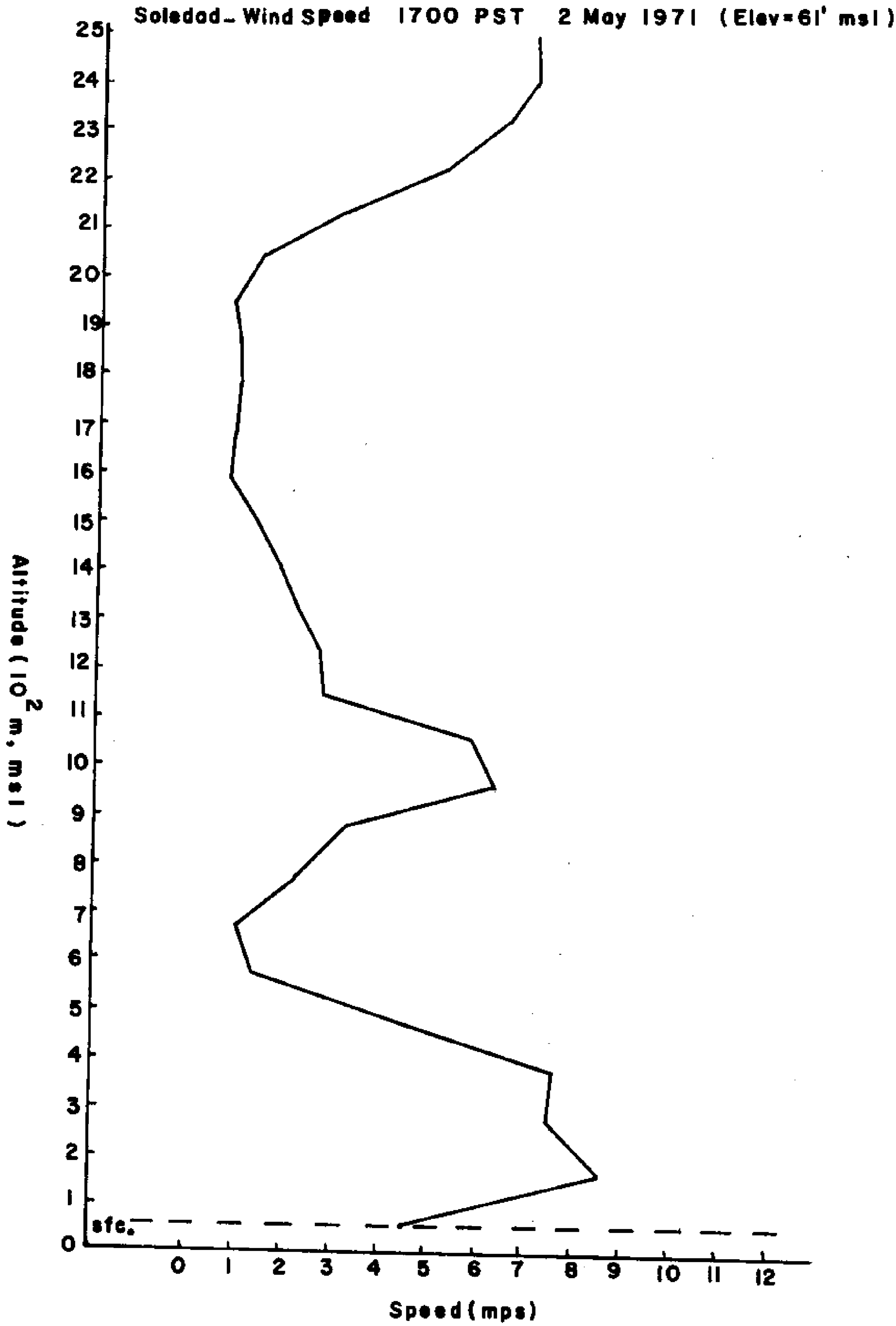

Soledad _Wind Speed 1300 PST 1 May 1971 (Elev=61' msl)
Altitudede (10^2 m, msl)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
sfc.
0 1 2 3 4 5 6 7 8 9 10 11 12
Speed (mps)

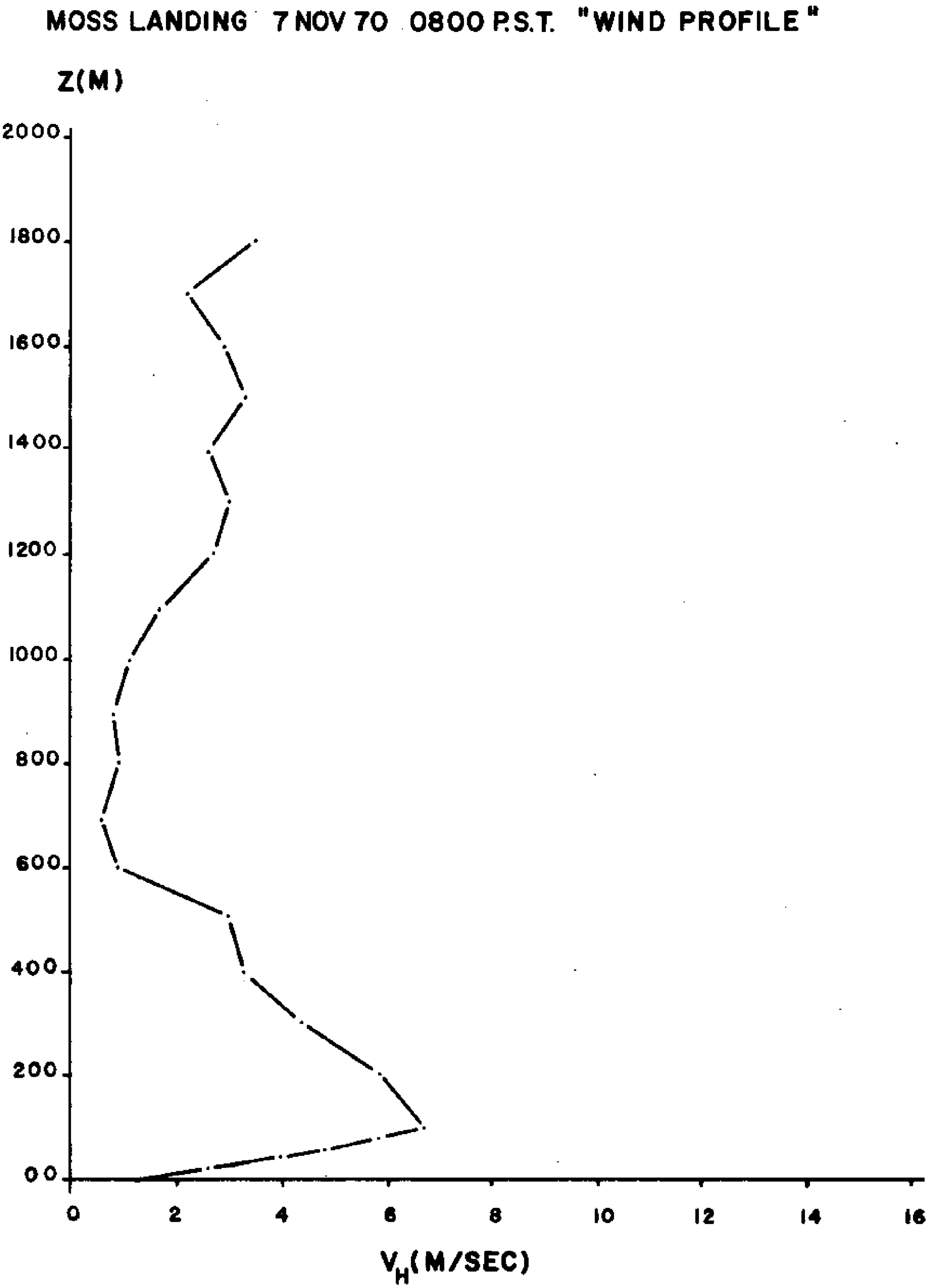
Soledad_ Wind Speed 1700 PST 1 May 1971 (Elev = 61' msl)



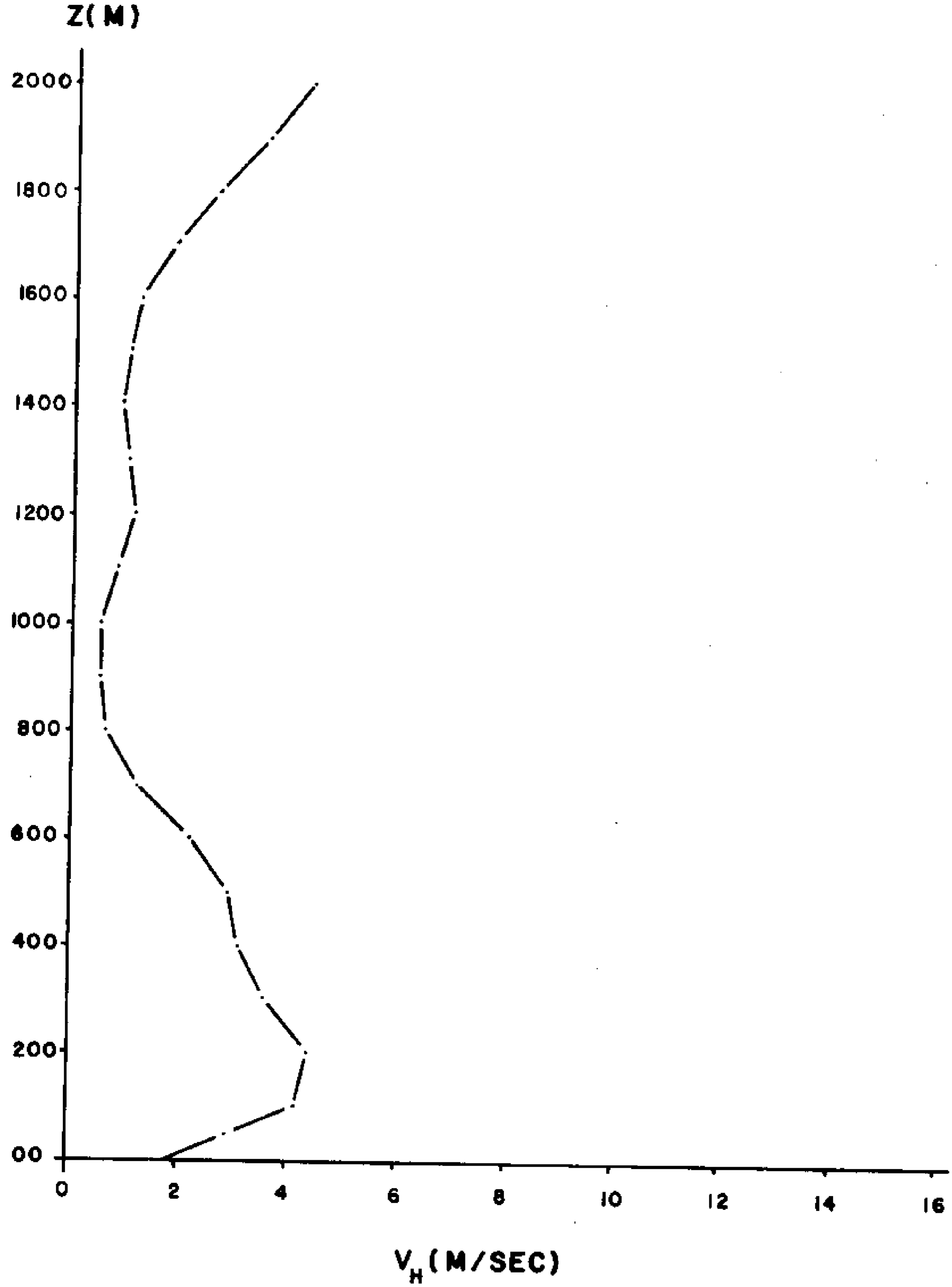

Soledad - Wind Speed 0900 PST 2 May 1971 (Elev = 61' msl)
Altitude (10^2 m, msl)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
sfc.
0
1
2
3
4
5
6
7
8
9
10
11
12
(Speed mps)

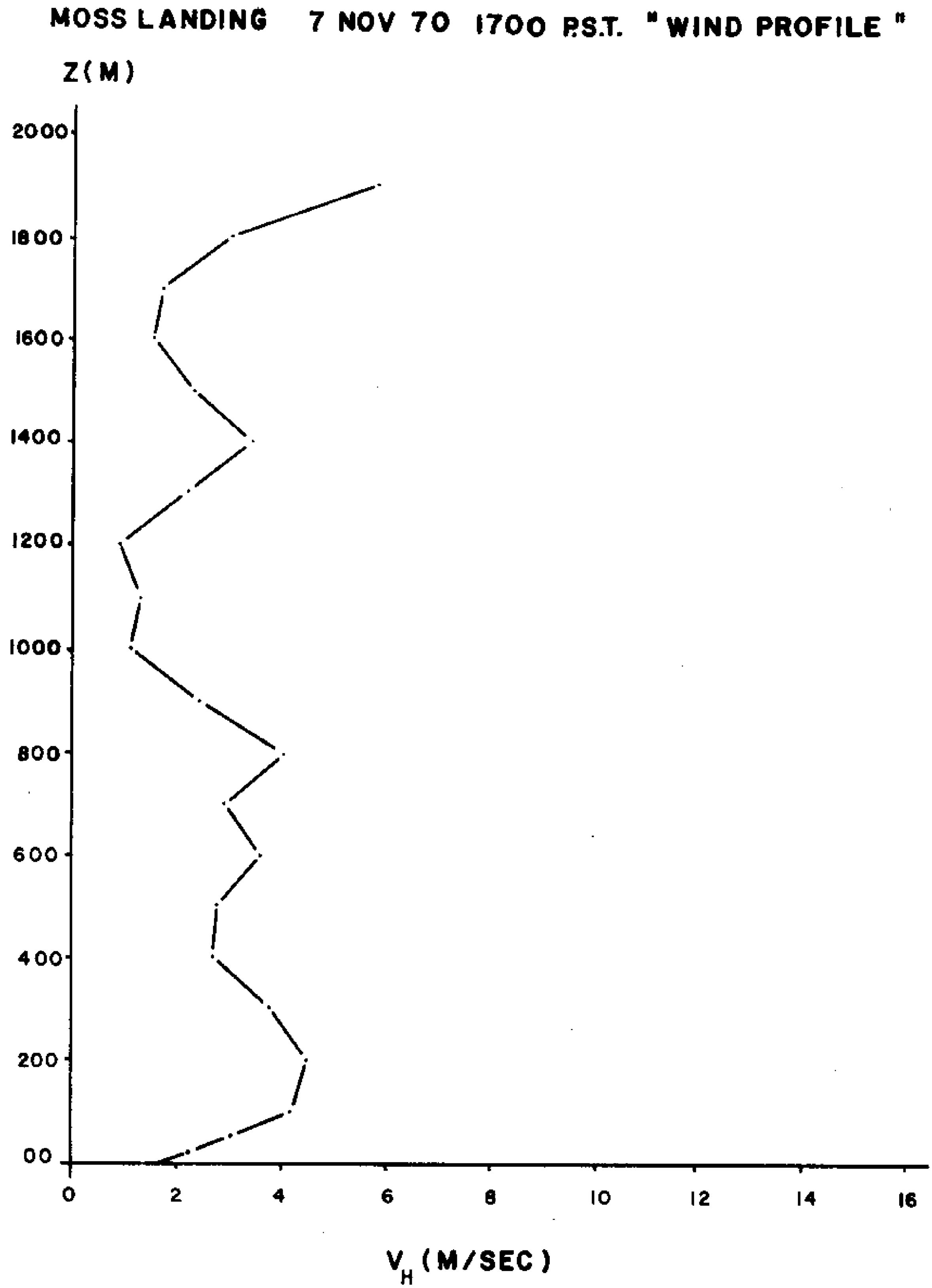

Soledad – Wind Speed 1300 PST 2 May 1971 (Elev = 61' msl)
Altitude (10 m, msl)
sfc.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
0 1 2 3 4 5 6 7 8 9 10 10 12
Speed (mps)

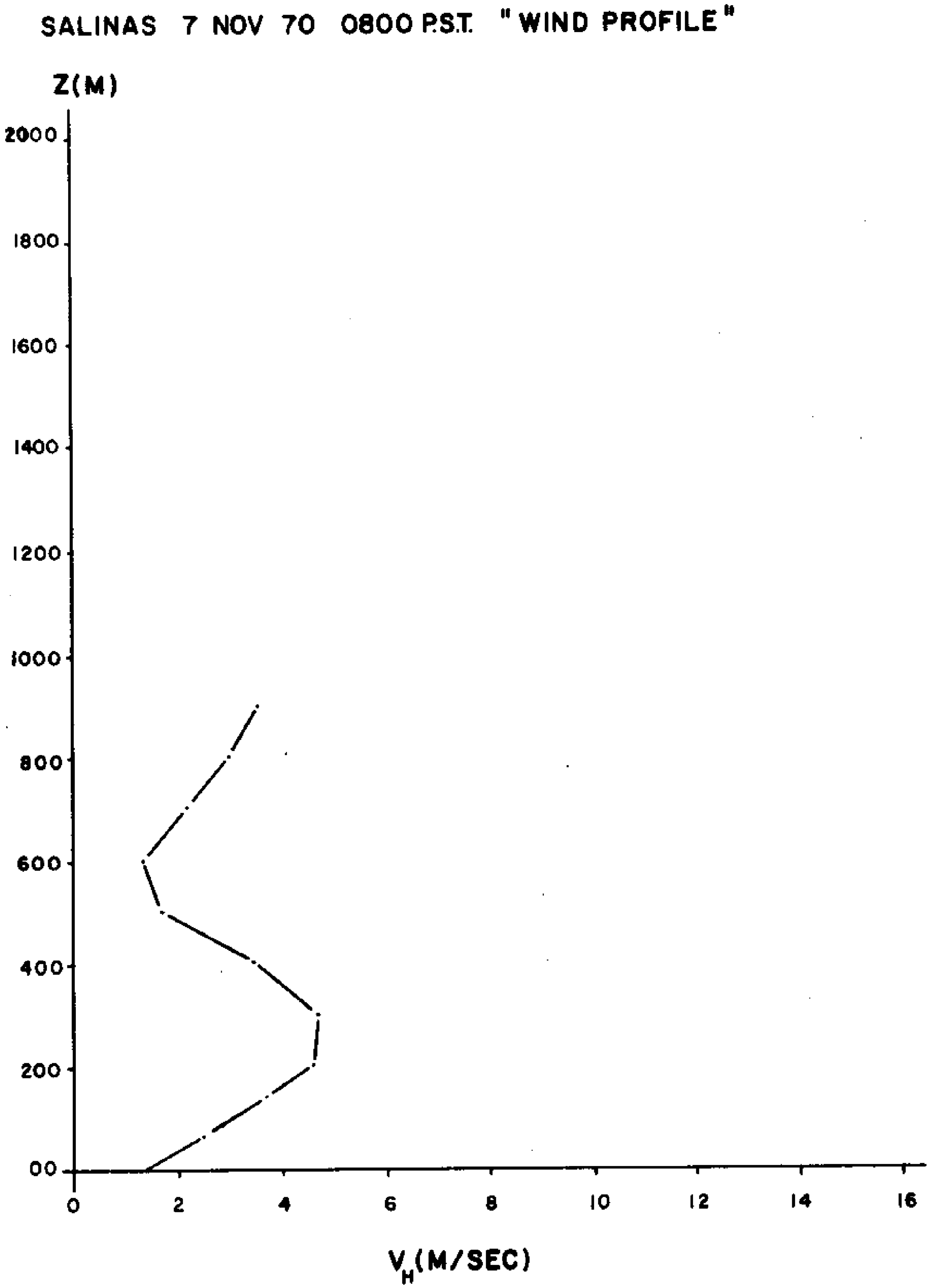

Soledad - Wind Speed 1700 PST 2 May 1971 (Elev=61' msl)
Altitude (10^2 m, msl)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
sfc.
0
1
2
3
4
5
6
7
8
9
10
11
12
Speed (mps)


MOSS LANDING 7 NOV 70 0800 P.S.T. "WIND PROFILE"
Z(M)
2000
1800
1600
1400
1200
1000
800
600
400
200
00
0
2
4
6
8
10
12
14
16
V_H(M/SEC)

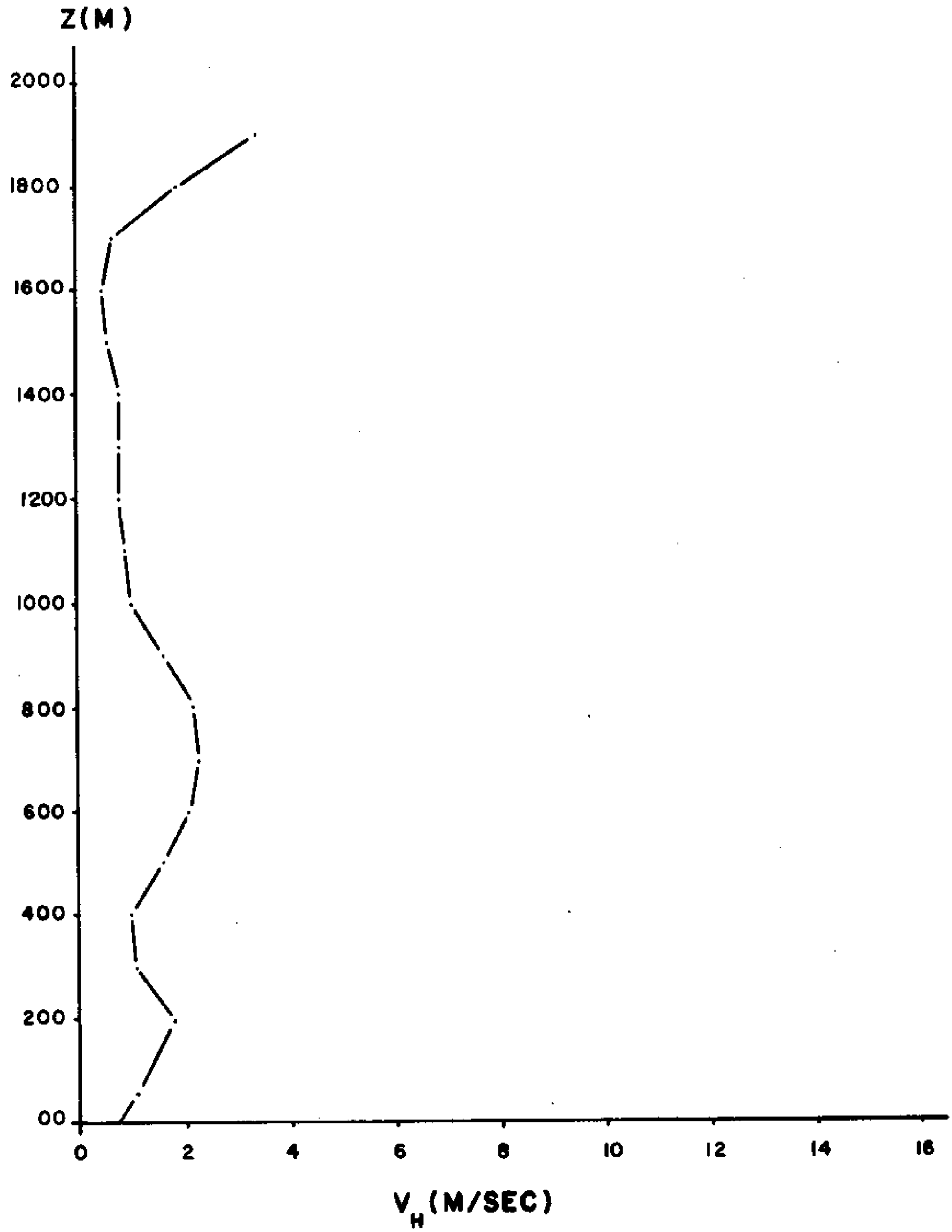
MOSS LANDING 7 NOV 70 1300 P.S.T. " WIND PROFILE "



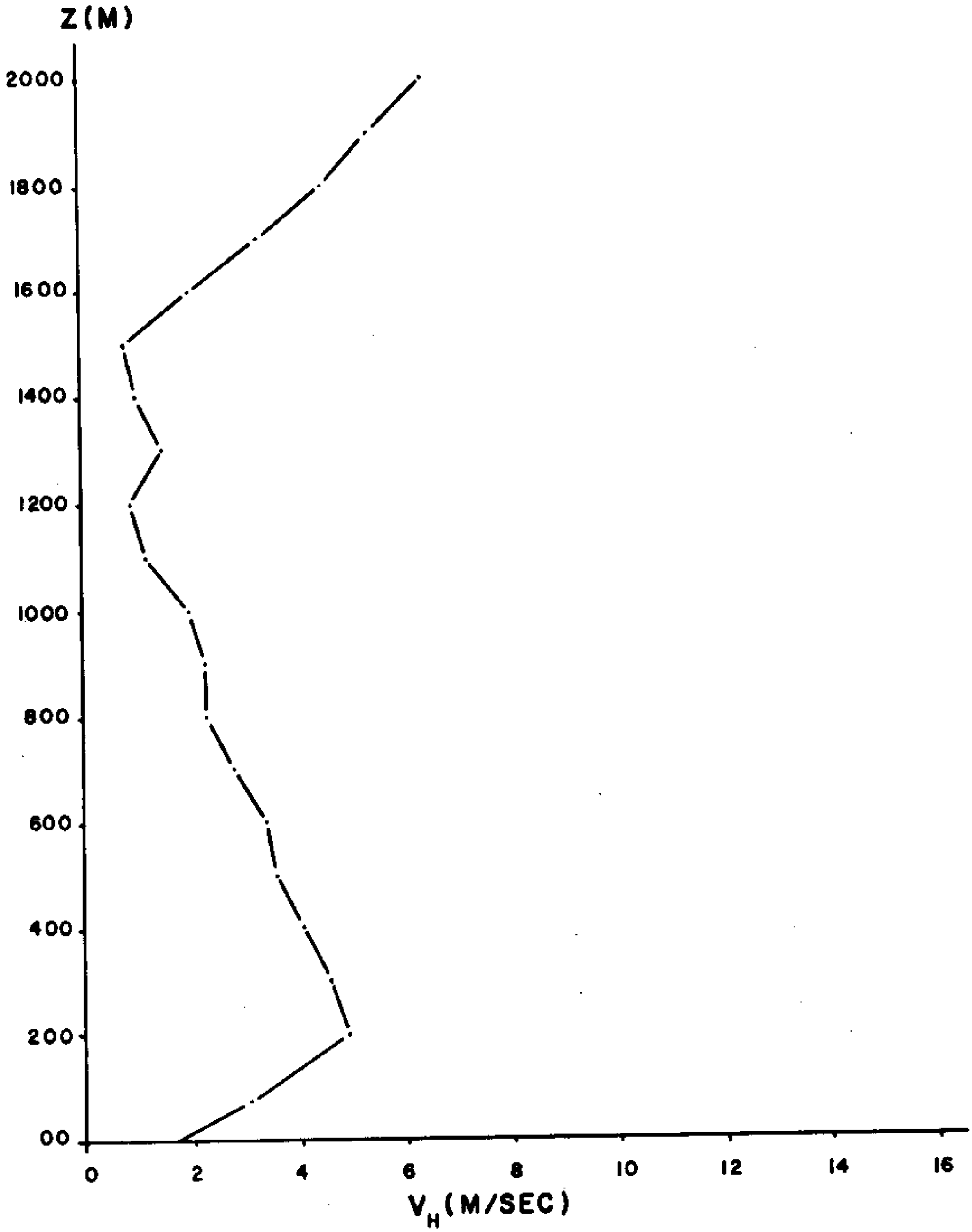

MOSS LANDING 7 NOV 70 1700 P.S.T. "WIND PROFILE"
Z(M)
2000
1800
1600
1400
1200
1000
800
600
400
200
00
0
2
4
6
8
10
12
14
16
V_H (M/SEC)


SALINAS 7 NOV 70 0800 P.S.T. "WIND PROFILE"
Z(M)
2000
1800
1600
1400
1200
1000
800
600
400
200
00
0
2
4
6
8
10
12
14
16
V_H(M/SEC)

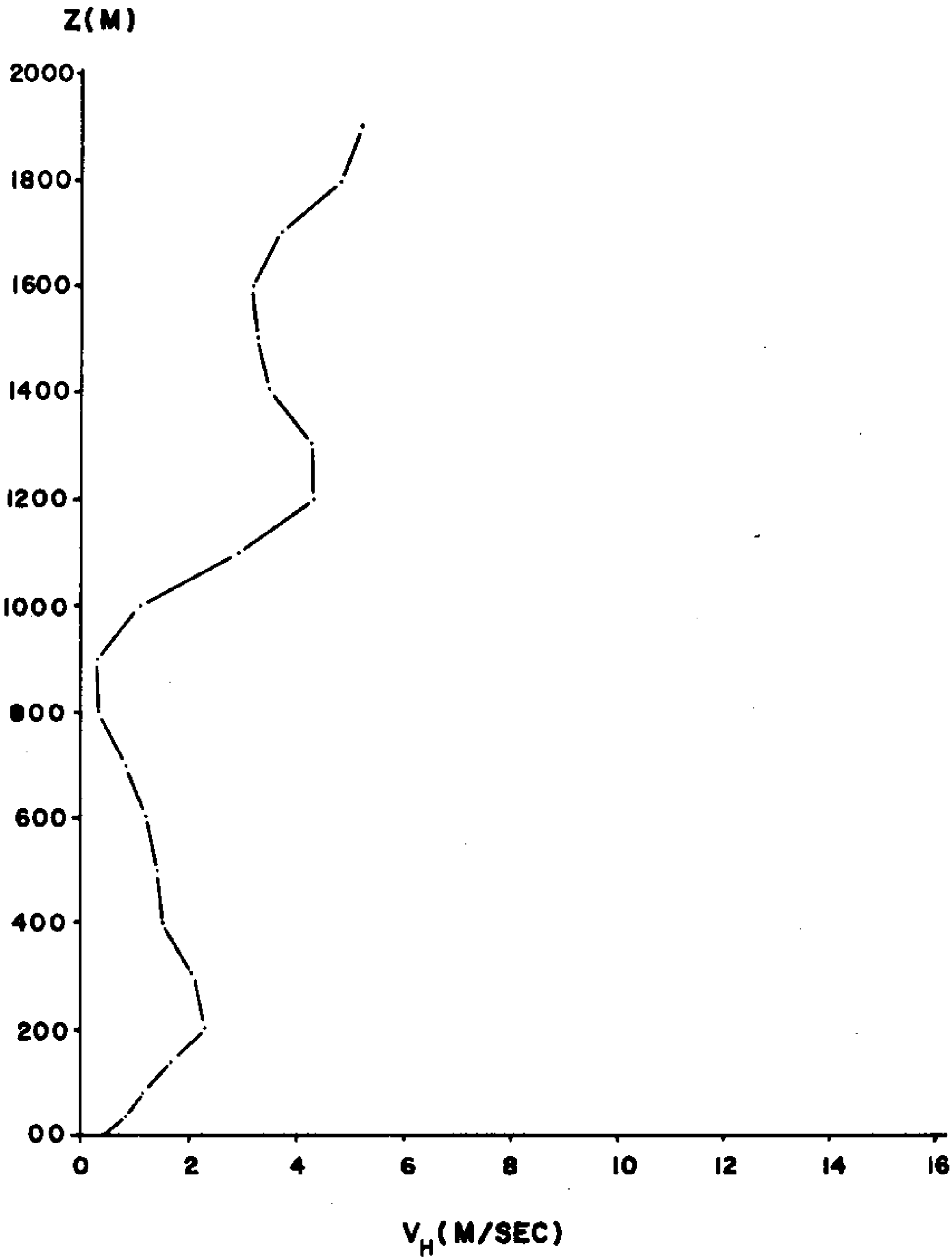
SALINAS 7 NOV 70 1200 P.S.T. "WIND PROFILE"

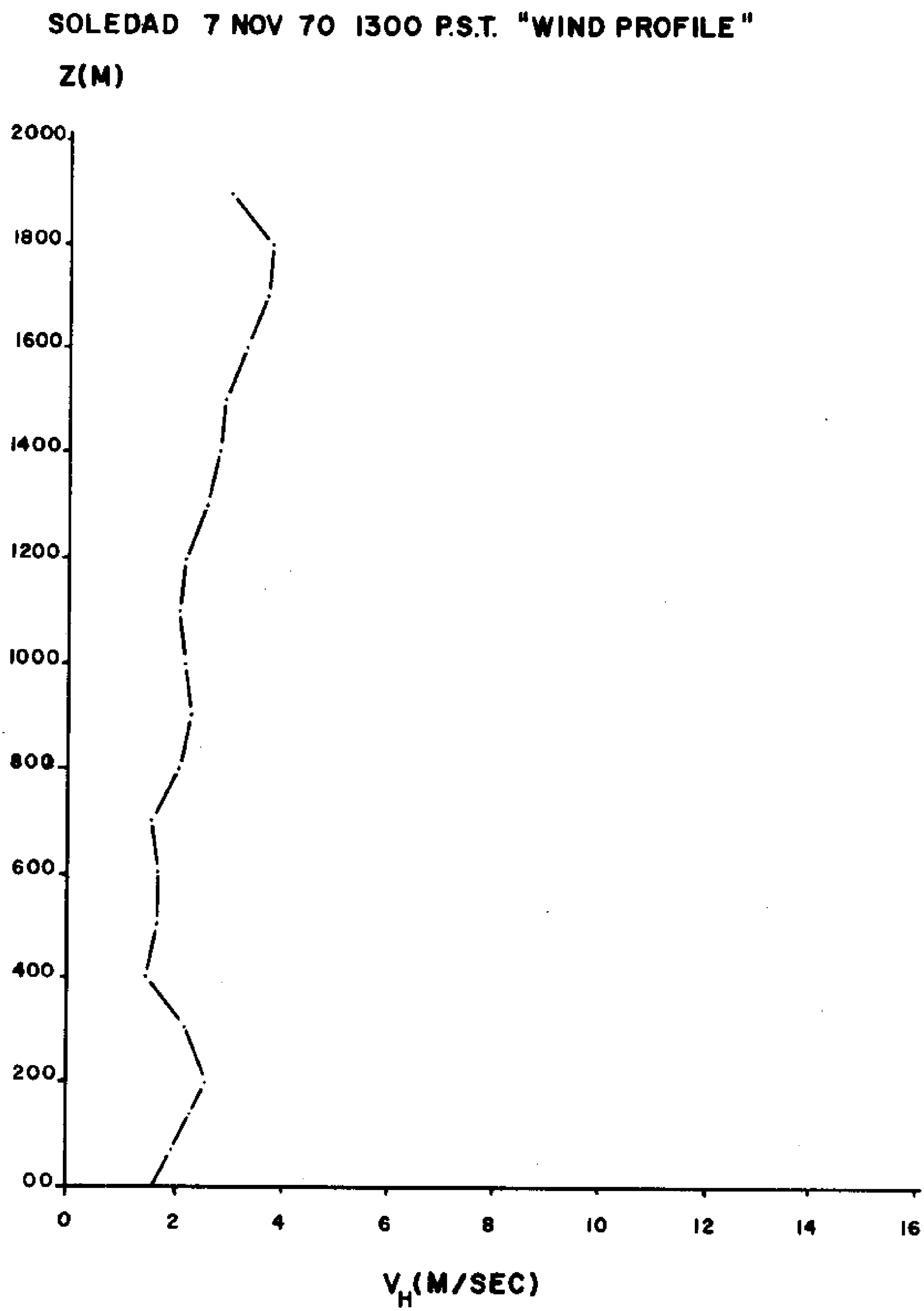


SALINAS 7 NOV 70 1700 P.S.T. "WIND PROFILE"



SOLEDAD 7 NOV 70 0800 P.S.T. "WIND PROFILE"




SOLEDAD 7 NOV 70 1300 P.S.T. "WIND PROFILE"
Z(M)
2000
1800
1600
1400
1200
1000
800
600
400
200
00
0
2
4
6
8
10
12
14
16
V_H(M/SEC)

SOLEDAD 7 NOV 70 1700 P.S.T. "WIND PROFILE"