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THE KAILUA-KONA TORNADO OF 28 JANUARY 1971

HONOLULU, HI
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March 2001

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1. INTRODUCTION

Although tornadoes in the Hawaiian Islands are relatively rare events, tornadic vortices capable of producing substantial damage do occur. One such event transpired in Kailua-Kona on the Island of Hawaii on 28 January 1971. The tornado developed in a prefrontal area associated with an intense midlatitude cyclone that affected the Hawaiian Islands on 25 – 29 January 1971. Passage of the cold front through the island chain led to a rare tornado outbreak, with four tornadoes reported. This outbreak accounted for four of the eleven tornadoes reported in Hawaii from 1963 to 1974 (Zipser 1976).

The first funnels to affect the state were observed approximately 6 miles off Barking Sands on the Island of Kauai on 25 January, where one of three funnels briefly touched the sea surface. The first tornado of the event occurred on 28 January in Whitmore Village, Wahiawa, on the Island of Oahu, where several structures were damaged. Two other tornadoes struck ranches at Honomalino Farms, South Kona, and Kainaliu, Kona, on the Island of Hawaii on 28 January, where two houses and many crops were damaged. The largest vortex of the outbreak (hereafter in this paper referred to as the Kona tornado) formed over Kailua Bay as a large tornadic waterspout and moved inland, through downtown Kailua-Kona (Fig. 1). The tornado traveled about 1.6 km inland, destroying many structures and causing damage in excess of $1.5 million.

Zipser (1976) studied the Kona tornado using video footage of the event, applying a technique called analytical photogrammetry. This technique derives tornado wind speeds from mathematical computations using measurements acquired from photographs. The characteristics of the vortex are reported in Table 1. Zipser identified the Kona tornado as an F2, concluding that despite its birth over water, the tornadic waterspout possessed many environmental and vortex characteristics of a tornado over land.

2. TORNADO CLIMATOLOGY IN HAWAII

Several studies have examined tornadoes, waterspouts, and funnel clouds in the Hawaiian Islands. Price and Sasaki (1963) studied events occurring in the years 1949 through 1960. Schroeder (1977) investigated the occurrences from 1961 to 1975, and the years 1976 through 1997 were examined by Tanabe (2000).

Tornadoes in the Hawaiian Islands are mainly associated with intense midlatitude cyclones, with most strong tornadoes forming in unstable air masses associated with winter storms. All eight "significant" tornadoes identified in Schroeder's study occurred in November, December, and January, and all were associated with major midlatitude synoptic-scale disturbances. Of these eight events, seven formed in prefrontal regions.

Funnel clouds in Hawaii are also most common in the winter. Of the 22 funnel days in 1974, 17 days were characterized by upper level troughs located to the west of the Hawaiian Islands (Schroeder 1977). Figure 2 shows the typical 300-mb pattern supportive of funnel clouds over the

Hawaiian Islands, which is very similar to the 300-mb pattern in place the day of the Kona tornado.

Price and Sasaki attempted to investigate whether the Hawaiian Islands serve as a vantage point to view tornadoes, waterspouts, and funnels, or if the island topography induces or contributes to their formation. Still a relevant question, this issue was never resolved in their study due to the lack of data.

3. SYNOPTIC CONDITIONS

The Kona tornado developed in the prefrontal region associated with a strong midlatitude cyclone. The surface features were analyzed using National Weather Service (NWS) six-hourly surface charts, while 500- and 250-mb analyses were created using NWS National Centers for Environmental Prediction (NCEP) reanalysis data. The central North Pacific exhibited a strong meridional surface pattern during this time. The upper levels were characterized by large, long wavelength troughs at lower latitudes merging with strong, high amplitude troughs in higher latitudes. A strong 250-mb jet stream was an important feature of the system.

The midlatitude cyclone's surface circulation formed at 32°N, 173°W at approximately 1800 UTC 26 January 1971, under the divergent left exit region of a jet streak (Fig. 3). The surface flow pattern was meridional (Fig. 4). A large 1030-mb high pressure system (high) was centered at 40°N, 130°W, far north of the climatological position, and another 1030-mb high was centered over the Aleutian Islands. A ridge associated with the Aleutian high extended south to 23°N, 167°E, providing low-level cold air advection to the developing storm.

The surface low pressure system (low) intensified over the next 36 hours and moved east and east-southeast, following the steering winds of the upper-level troughs. On 27 January the long wavelength troughs at 500-mb and 250-mb merged with higher amplitude troughs from the higher latitudes. This resulted in one large, high amplitude upper-level trough. The trough axes remained to the west of the Hawaiian Islands during this time, while the surface low deepened under the left exit region of a jet streak, located west of the 250-mb trough axis.

By 0600 UTC 28 January, the surface low was at its peak intensity (984 mb) at 31°N, 162°W, and the cold front was affecting the Island of Kauai. The low began to occlude after this time, moving slowly northward and losing little intensity. The cold front passed through the entire island chain in the following 24 hours. At 1800 UTC, the front was located in the Alenuihaha Channel between Maui and the Island of Hawaii. By 0000 UTC 29 January, the cold front had reached the Kona Coast of the Island of Hawaii, with the 988-mb surface low located at 34°N, 157°W (Fig. 5). Wind observations behind the front (W at 25 kts) and ahead of the front (SSW at 20 kts) suggest significant low-level vertical vorticity near the cold front.

The 500- and 250-mb patterns on 28 January (Fig. 6 and Fig. 7, respectively) showed large, high amplitude troughs in the central North Pacific with the trough axes to the west of the Hawaiian Islands. These troughs were the product of the trough mergers discussed earlier, providing upper-level support for the intense surface low. The 250-mb flow in Figure 5 is similar to the 300-mb patterns common to funnel cloud occurrences in Hawaii (Fig. 2).

4. MESOSCALE ANALYSIS & PREDICTABILITY

Because satellite data were limited in 1971, and no operational radar existed in the Hawaiian Islands, sounding data were the sole source of information for mesoscale analyses. In order to provide useful information, atmospheric soundings must be released sufficiently close in time and space to a tornado. Darkow and Fowler (1971) defined a "tornado proximity sounding" as an upper air sounding released within 1 h 45 min prior to a tornado occurring within 80 km of the upper air station. No available soundings met these criteria, since the Hilo sounding site is approximately 100-km away, and the nearest sounding was taken on 0000 UTC 29 January, 3 h 10 minutes after the event (Fig. 8). However, this sounding is considered the best available tornado proximity sounding, since it represents prefrontal conditions sufficiently close to Kailua-Kona. This sounding site has been criticized for its lack of representation of the undisturbed flow near the islands, but in the south to southwest flow of this event, this sounding is adequate.

Zipser (1976) describes the 0000 UTC 29 January Hilo sounding as showing many characteristics of a Type II tornadic air mass common to the coastal Gulf of Mexico region of the United States (Miller 1972). A Type II air mass is equatorial and moist to great heights, and the lapse rate is typically conditionally unstable (Fig. 9). Winds in a Type II air mass normally decrease with height, although more intense tornadoes occur when the low- and mid-level winds are significant. Wind speeds at 850 and 500 mb are usually no greater than 65 kts and 55 kts, respectively, and the median wind direction veers approximately 30 degrees between these levels. Under these conditions, short-lived, isolated tornadoes are most common.

The 0000 UTC 29 January Hilo sounding (Fig. 8) shows many characteristics of the Type II air mass. The low- and mid-levels were conditionally unstable, and the atmosphere was relatively moist up to 25,000 feet. The trade wind inversion was absent, due to the nearby low- and mid-level troughs. Unlike a typical Type II air mass, wind speeds increased with height. The atmosphere was moderately sheared with a strong jet stream located over the islands. The presence of a major midlatitude disturbance over the Hawaiian Islands is apparent in the Hilo sounding, while it also displays traits of a Type II air mass.

Most stability indices represented neutral to modest instability (Table 2). The moist, conditionally unstable atmosphere near the front did not allow for very unstable conditions. The cold front induced synoptic scale forcing, and topography may have played a role in the creation of vorticity and as a trigger for convection. A better index for predicting severe weather in these conditions may be the severe weather threat (SWEAT) index, developed at the Military Warning Center. The SWEAT index accounts for thermodynamic instability and the kinematics of the wind fields at low and mid-levels. SWEAT values of 297 and 351 were computed near the event. Provided a trigger is present, SWEAT values greater than 300 indicate a potential for severe weather, and SWEAT values greater than 400 suggest tornadic potential. The trigger for the Kona tornado was most likely cold frontal forcing.

Moderate vertical wind shear existed on 0000 UTC 29 January. The hodograph in Figure 10 depicts a jet between 700 and 600 mb, with wind speeds increasing with height to the jet stream between 300 and 250 mb. This hodograph is similar to a hodograph produced by Chisholm and Renick (1972) for multicell storms in the plains of southern Canada (Fig. 11), suggesting that this wind profile is capable of producing severe weather. The wind shear in the lowest 5 km was 3.1×10^{-3} s^{-1}, considered to be moderate and partially attributed to the very light surface wind speeds. Identical calculations were computed (Table 2) for the 1200 UTC 28 January sounding (Fig 12), considered to be very similar to the 0000 UTC 29 January sounding taken at Hilo. Higher wind speeds near the surface contributed to a lower vertical wind shear of 2.1×10^{-3} s^{-1}, but the higher wind speeds may have been caused by a nighttime drainage flow.

Midlatitude cyclones affect the Hawaiian Islands nearly each year, although a storm of this intensity is uncommon, and most do not produce tornadoes. The information obtained from the mesoscale analysis might provide clues to predicting potential tornadic events. Evaluation of the atmospheric soundings, in particular the use of the SWEAT index, can provide useful information. Schroeder's study noted that although SWEAT values observed in the Hawaiian Islands near tornadic events are lower than those in Miller's study, values at Hilo on tornado days were in the top 1% of those for that station from September 1974 to December 1976. Vertical wind shear can also reach moderate levels and should be considered a tornado prediction tool. The use of operational Doppler radar in the Hawaiian Islands today provides an excellent source of mesoscale information not available in 1971. An important factor still misunderstood is the effect of topography on tornado formation. Although the mechanical and thermal effects of topography on atmospheric flow is well known and must be considered in sounding interpretation, it is unknown how it influences tornado formation in Hawaii.

5. SUMMARY

The Kona tornado and tornado outbreak of 28 January 1971 were rare events produced by an intense midlatitude cyclone affecting the Hawaiian Islands. The meridional surface synoptic pattern indicated an intense (984 mb) surface low approximately 1100-km north-northeast of the islands, with strong cold air advection from the central North Pacific. At 500 and 250 mb, strong troughs provided the necessary support to the developing storm, including the effects of jet stream dynamics on the surface circulation.

The Kona tornado, classified as an F2, is common of most "substantial" tornadoes in the Hawaiian Islands forming in the prefrontal region of an associated midlatitude cyclone. The environment was conditionally unstable, while the cold front provided forcing in the moderately sheared environment. The SWEAT index, which considers thermodynamics and kinematics, may be a good indicator of tornadic potential. SWEAT values of 297 and 351were recorded near the time of the Kona tornado.

The lack of satellite and radar data limited the ability to monitor and forecast these events in 1971, although use of these data supplies critical information today. The effects of the local topography on the tornadic activity cannot be ignored, although its contributions cannot be quantified in this case.

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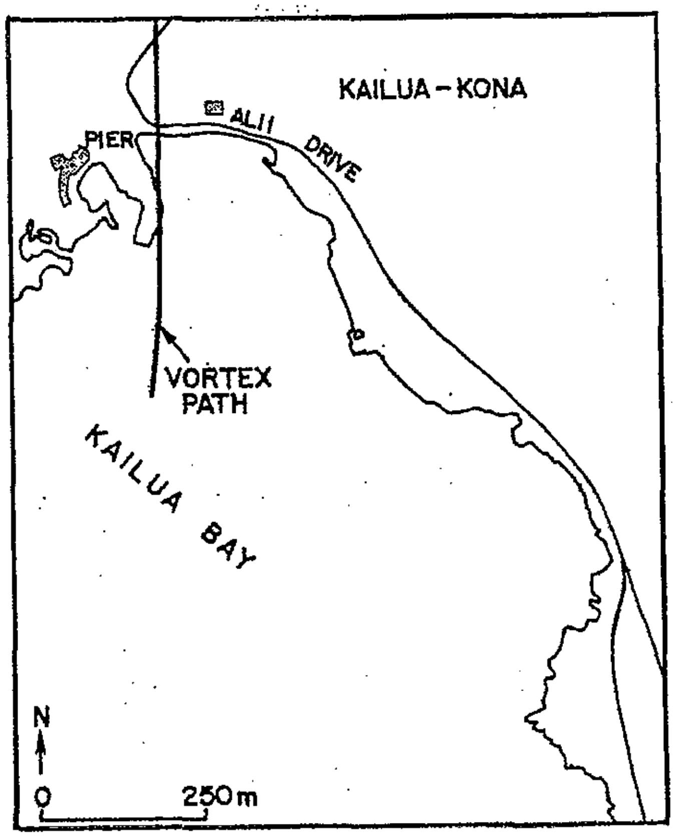

Figure 1. Path of the tornadic waterspout occurring on 28 January 1971 (from Zipser 1976).

QUANTITY	MAGNITUDE
V_t (typical)	25 - 55 m s^{-1}
V_t (max)	56 m s^{-1}
w (max)	25 m s^{-1}
V (travel)	13.9 m s^{-1}
r	49.5 m s^{-1}

Table 1. Summary of the photogrammetric results for the Kailua-Kona tornadic waterspout (from Zipser 1976).

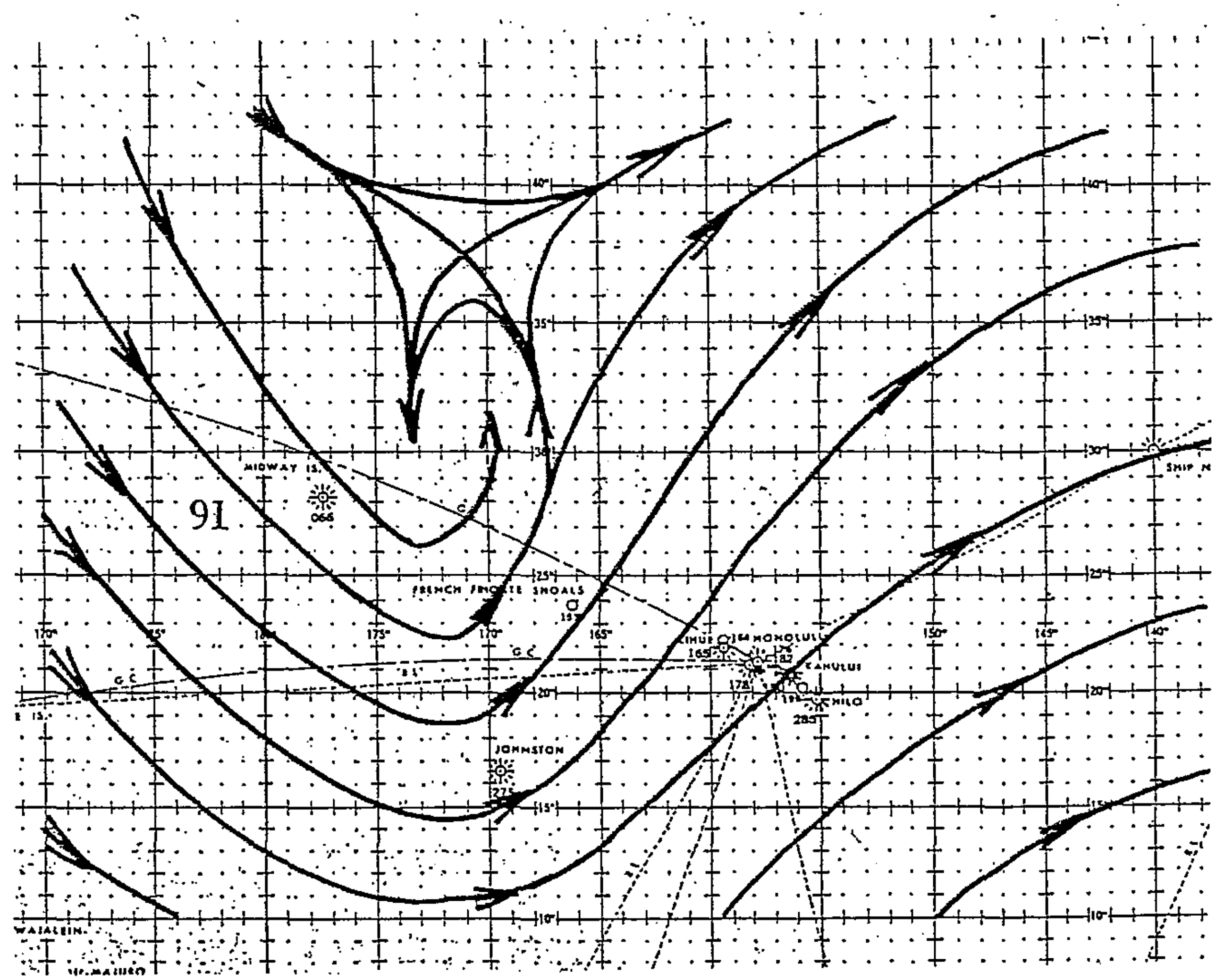

Figure 2. A typical 300-mb streamline field supportive of funnel cloud development over the Hawaiian Islands (from Schroeder 1977).

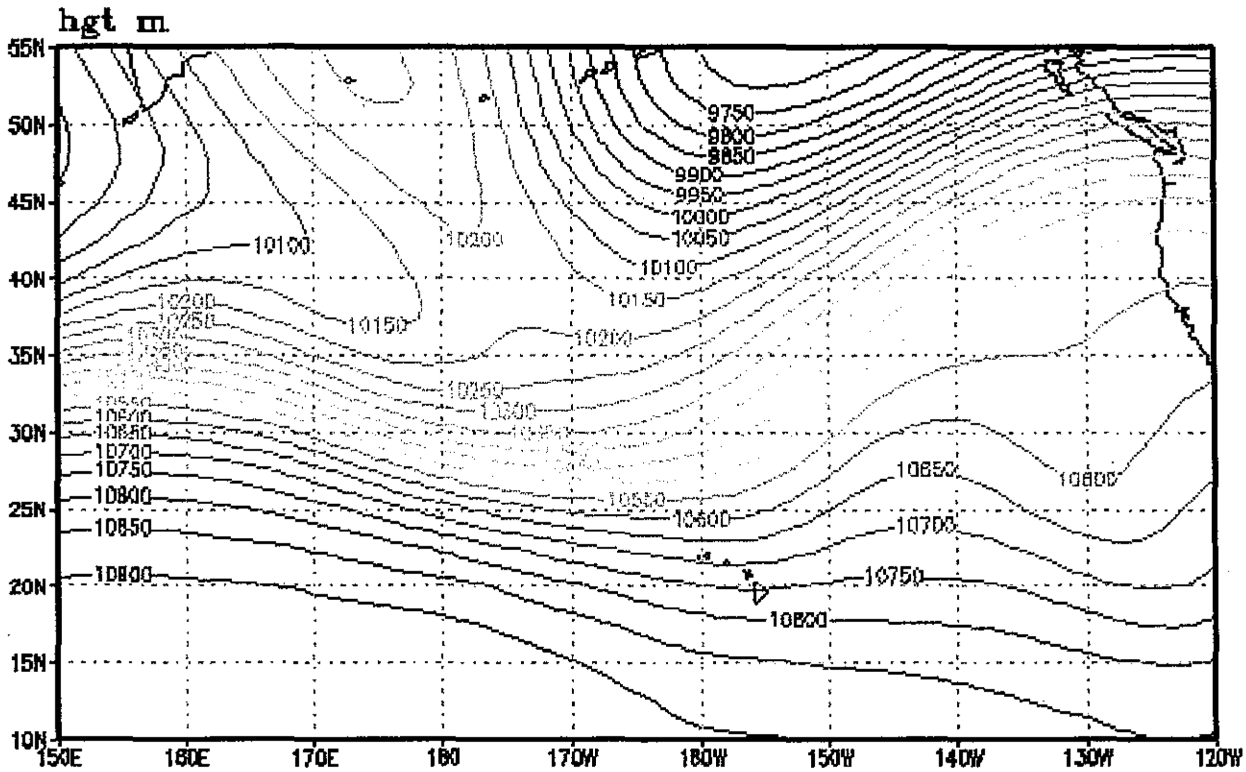

Figure 3. Daily averaged 250-mb geopotential height field over the North Pacific on 26 January 1971.

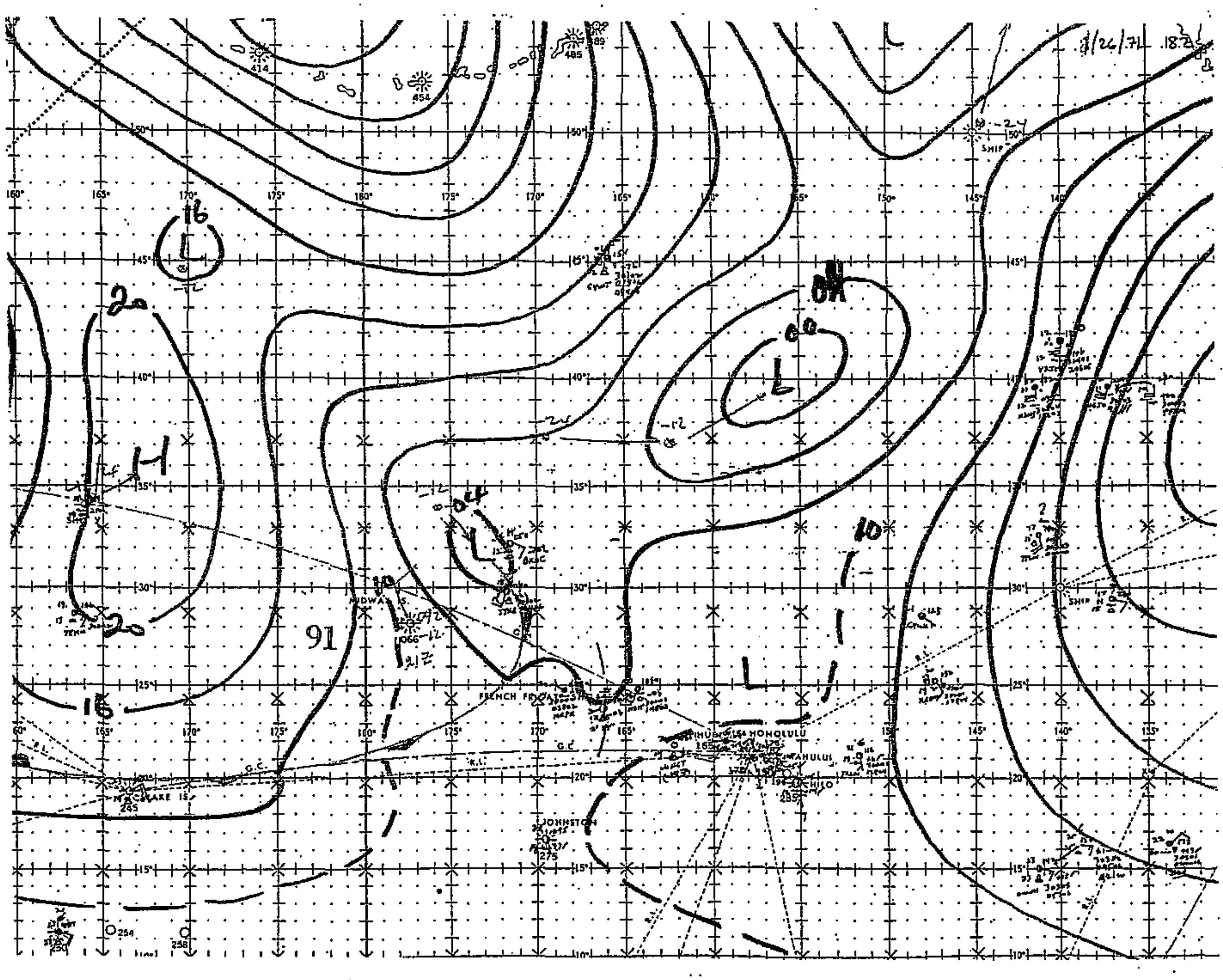

Figure 4. Mean sea level analysis for the North Pacific at 1800 UTC 26 January 1971.

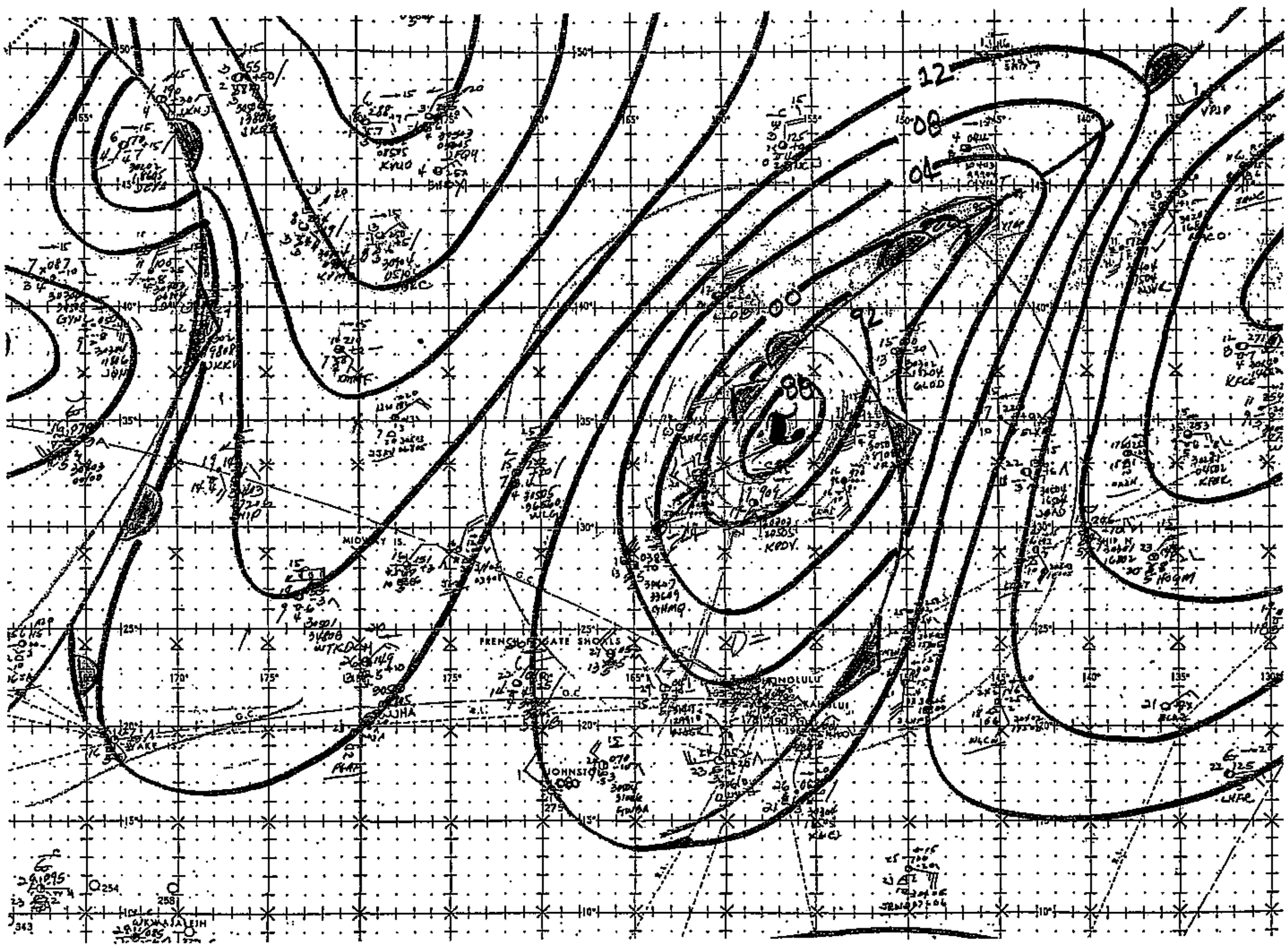

Figure 5. Mean sea level analysis for the North Pacific at 0000 UTC 29 January 1971.

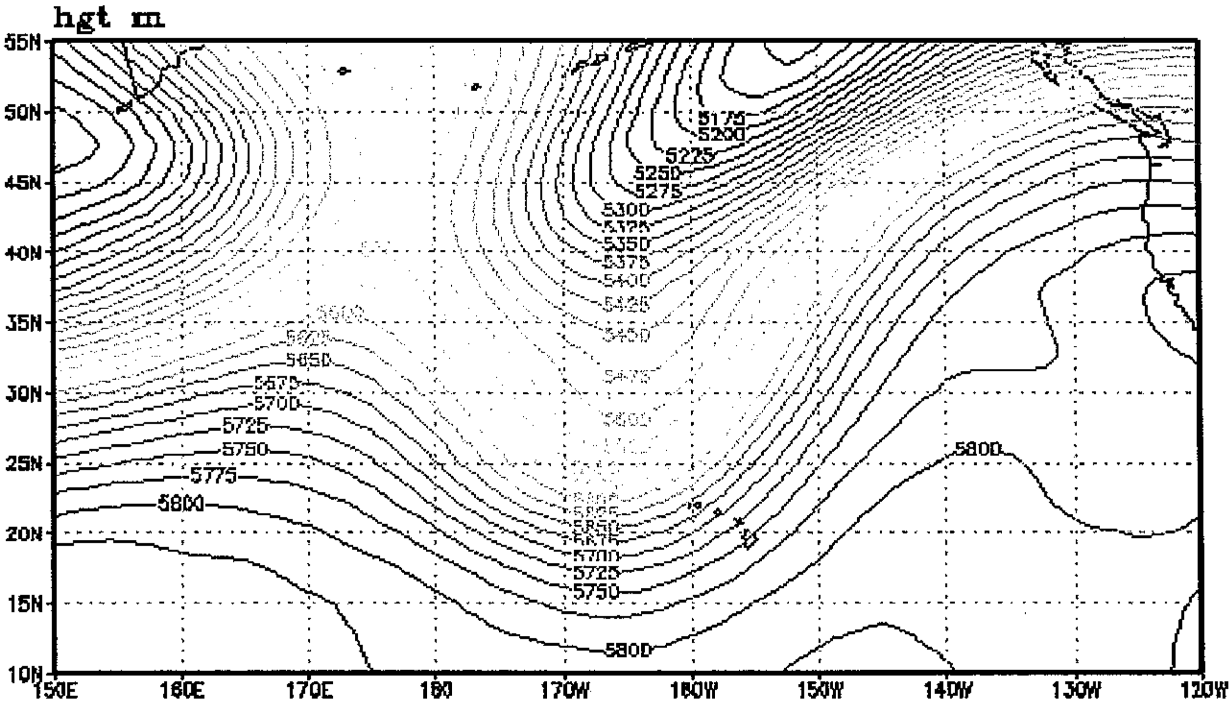

Figure 6. Daily averaged 500-mb geopotential height field over the North Pacific on 28 January 1971.

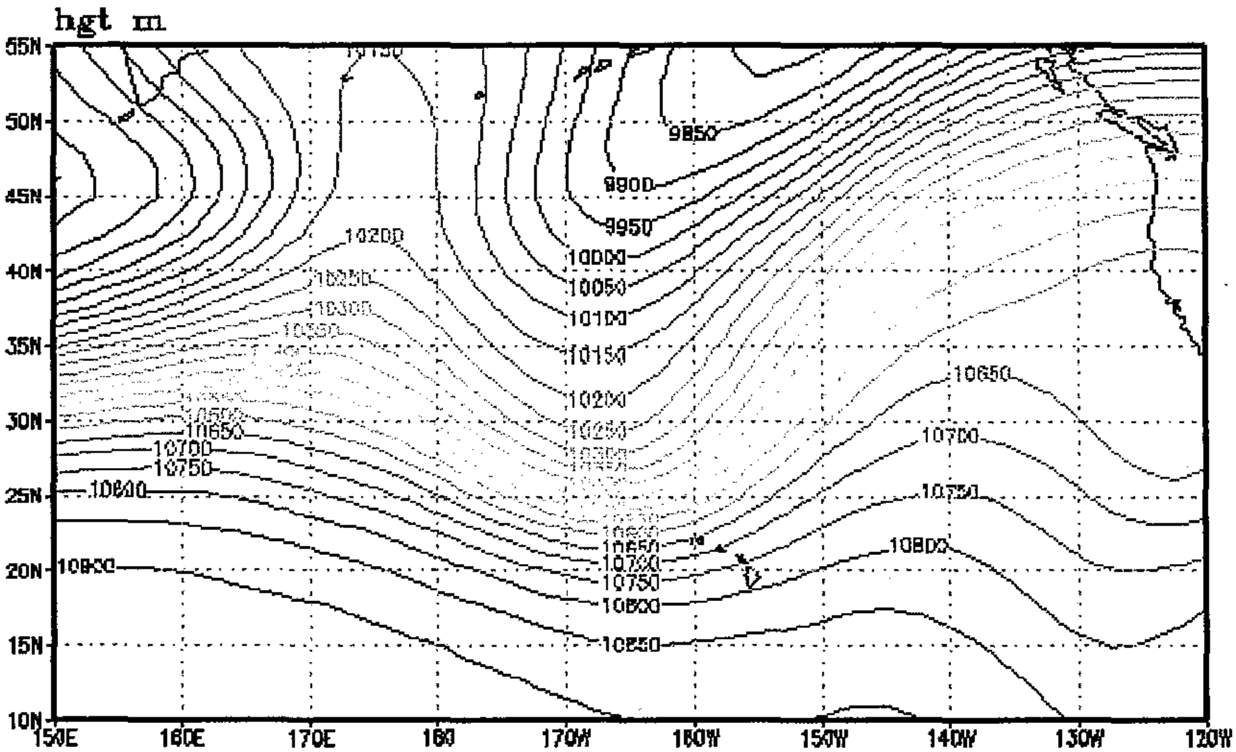

Figure 7. Daily averaged 250-mb geopotential height field over the North Pacific on 28 January 1971.

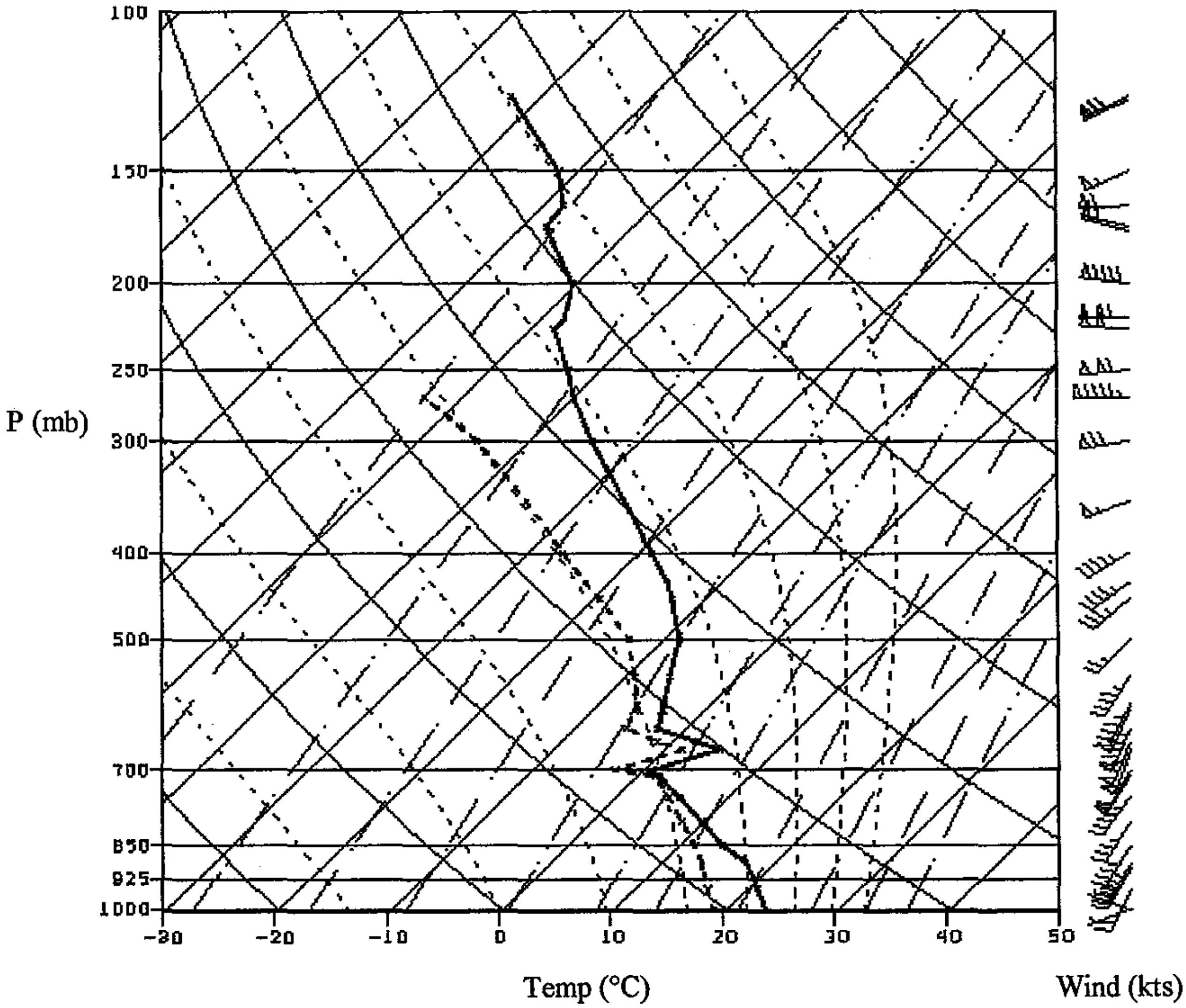

Figure 8. Hilo souding at 0000 UTC 29 January 1971.

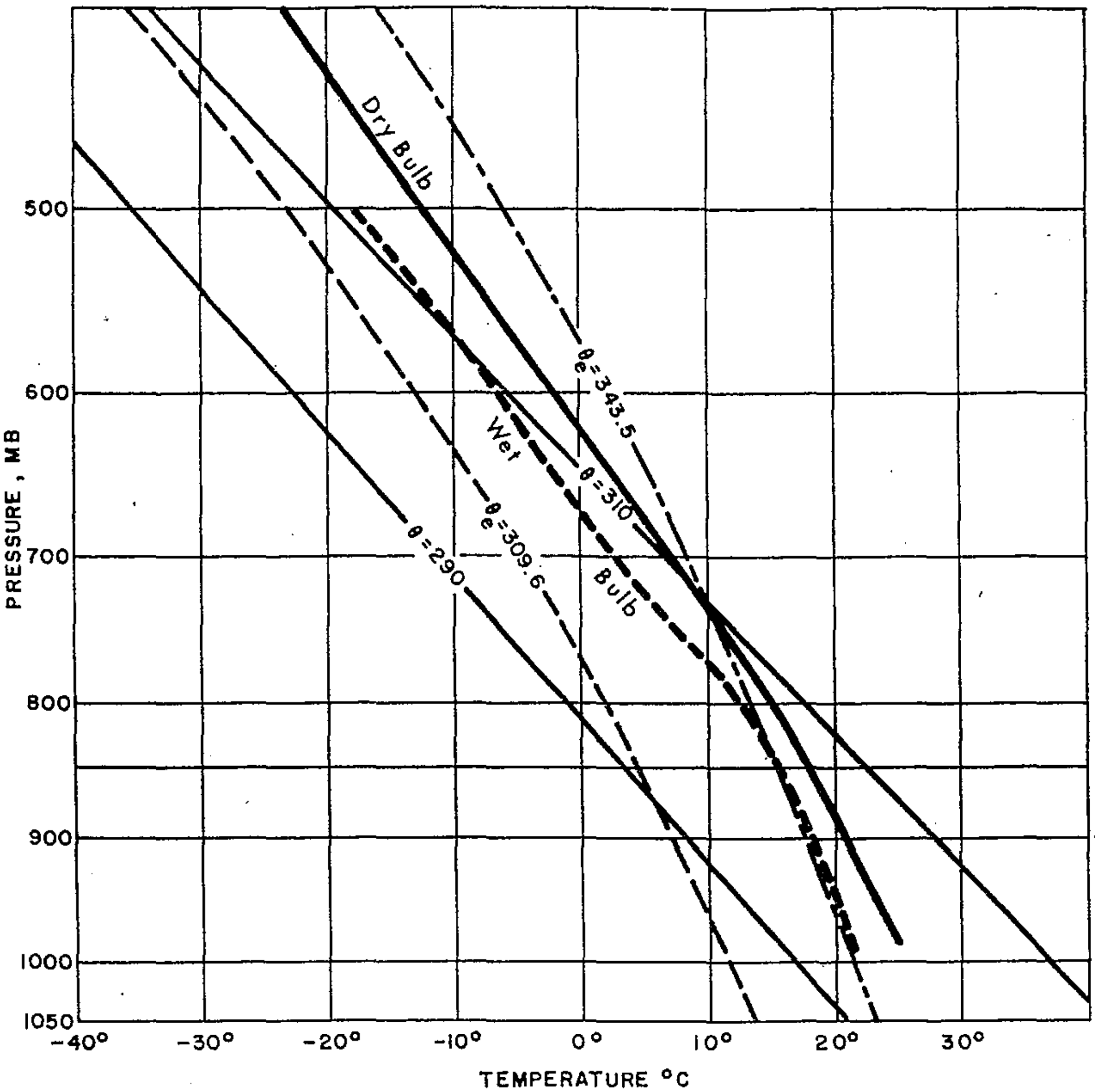

Figure 9. Mean sounding of Type II tornado air mass (from Miller 1972).

INDEX	0000 UTC 28 January	1200 UTC 29 January
SWEAT	297.0	351.0
CAPE	353.0	150.0
LI	6.7	4.4
BRCH	3.9	1.5
TOTL	42.5	49.0
SHOW	2.5	-1.2
KI	30.7	37.6

Table 2. Stability indices derived from the Hilo sounding at 0000 UTC 29 January 1971 and 1200 UTC 28 January 1971.

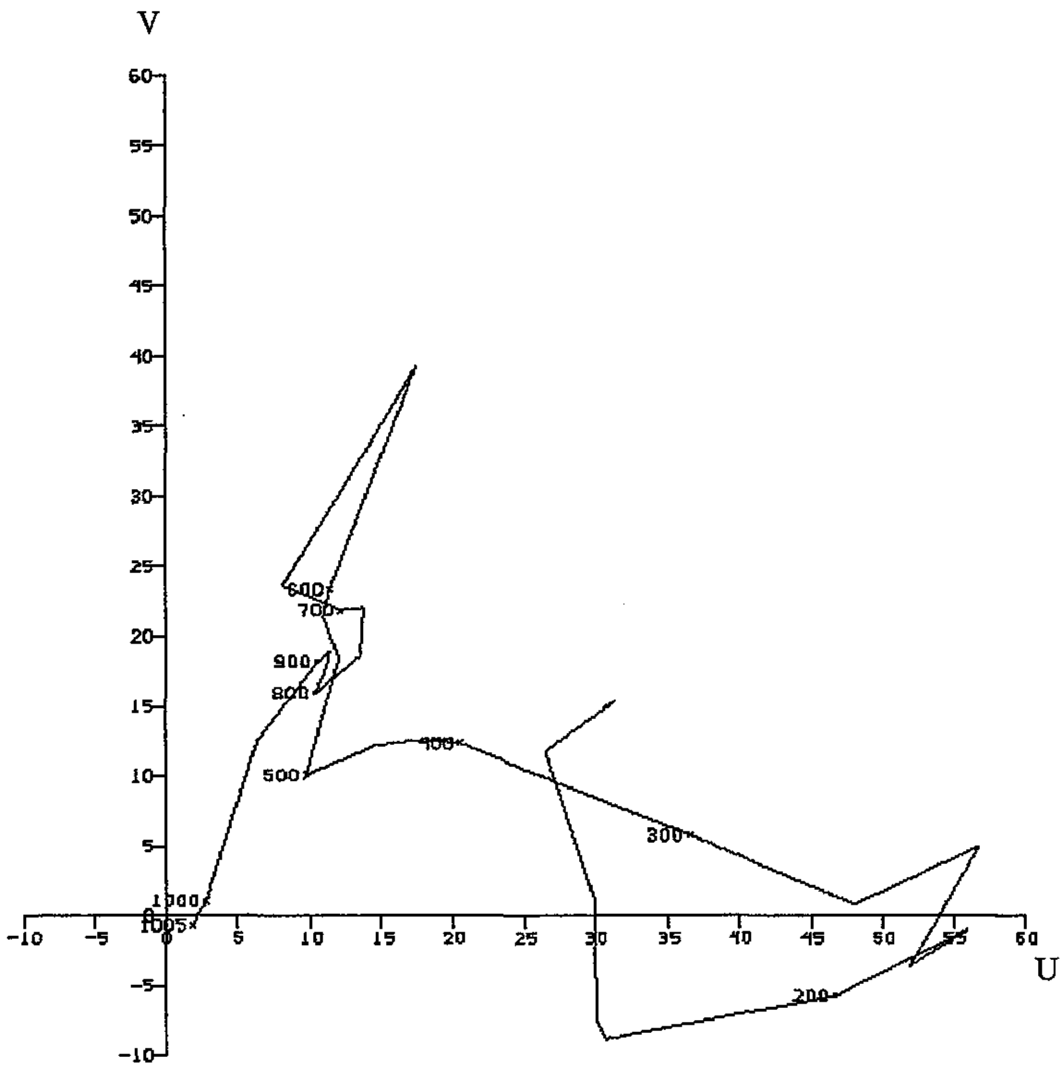

Figure 10. Hodograph (m s^{-1}) for the 0000 UTC 29 January 1971 Hilo sounding (labeled every 100 mb).

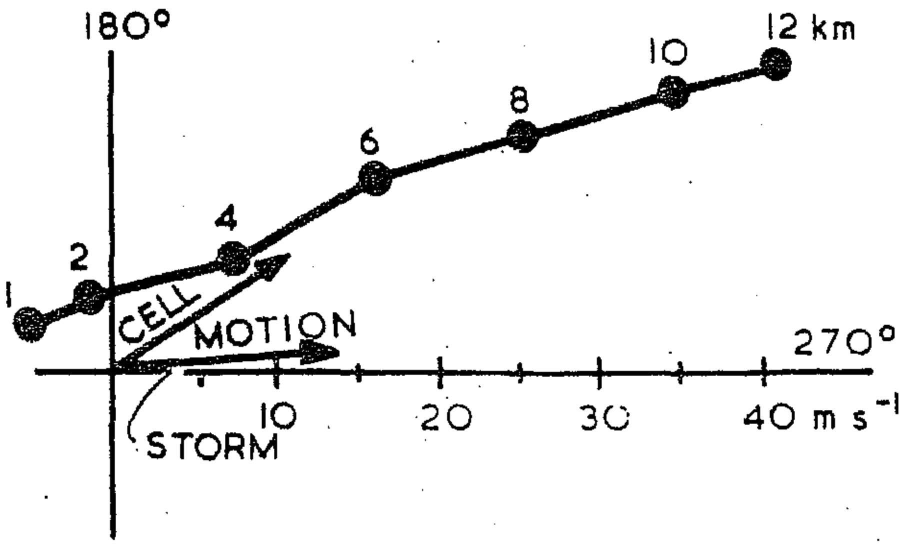

Figure 11. Typical hodograph representing the environmental conditions accompanying a well-organized multicell thunderstorm (from Chisholm and Resnick 1972).

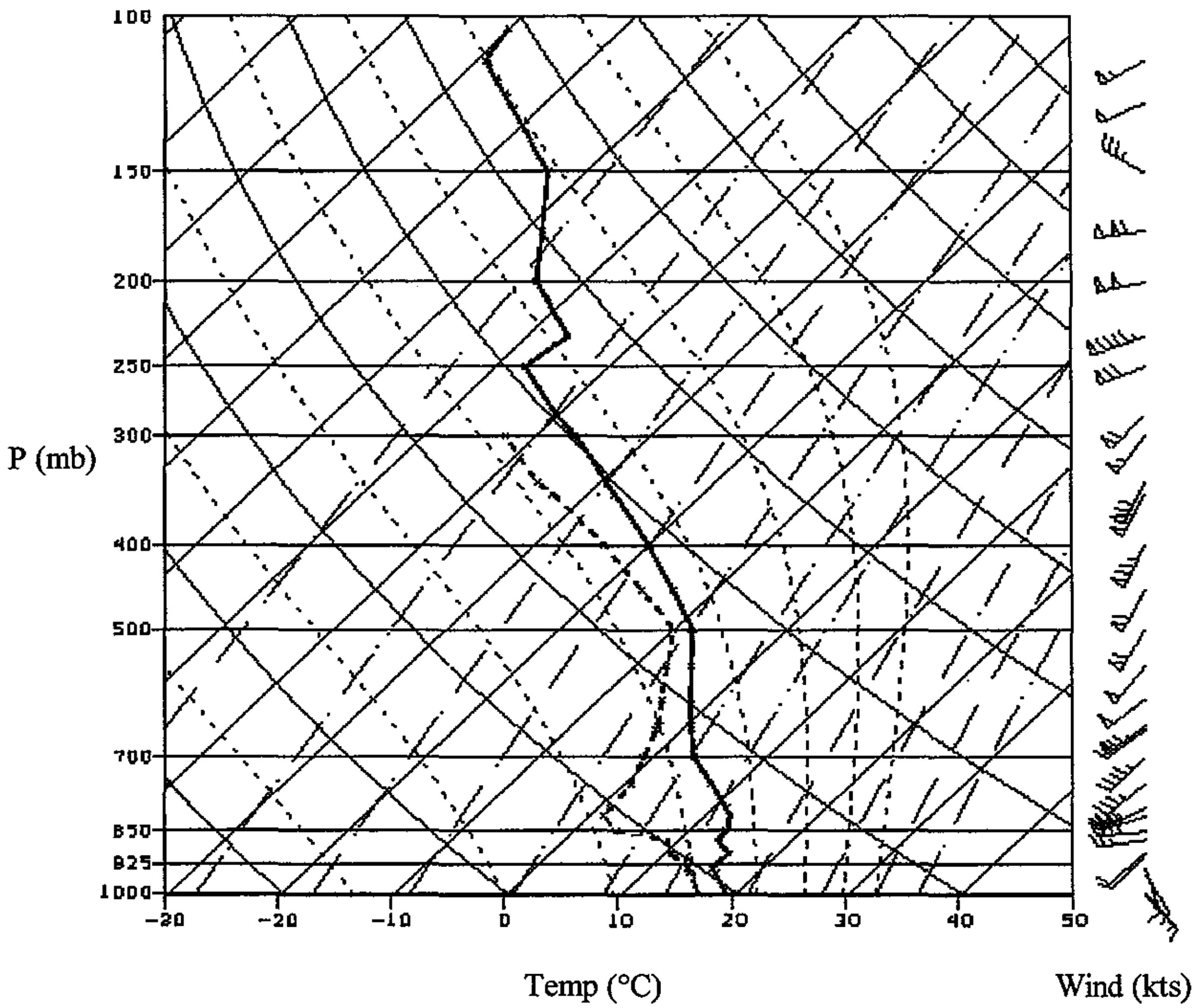

Figure 12. Hilo sounding at 1200 UTC 28 January 1971.