

gations be carried out to determine the amount of residual air which should be left inside the pressure elements in order to obtain a compensation pressure of about 600 mb. This work is now being done at the Weather Bureau and the results will appear shortly. If this work gives satisfactory results, it is planned to recompensate the elements now in use and then to omit the temperature correction

since it will, in general, be small in comparison to other uncertainties present.

The authors desire to acknowledge the helpful suggestions of Dr. W. G. Brombacher, in charge of the Aeronautic Instrument Section, United States Bureau of Standards, where these tests were carried out.

BATTLE OF THE CHINOOK WIND AT HAVRE, MONT.

By FRANK A. MATH

[Weather Bureau office, Havre, Mont., January 1934]

Apparently Havre, Mont., was on the battle front between cold polar air and warm Pacific air during most of December 1933. During the first week the weather was generally fair and mild, and the ground bare of snow. From the night of December 9 to December 12 a spell of cloudy weather with light-to-heavy snowfall prevailed. The temperatures were below normal, ranging between 3° and 11° F., and the winds generally from the east, while the ground in the surrounding country became covered with freshly-fallen snow from 6 to 9 inches deep. The 12th to the 16th had much below-normal temperature and more or less overcast skies and light snow flurries. The lowest temperature registered was -13° on the 15th. However, on December 16, with clear sky, falling temperature and dry, cold air moving from the northeast, suddenly at 7:19 p.m., almost like a shot from a cannon, a southwest chinook wind struck the station. The temperature jumped from -9° to 18° almost instantly. The thermometer and the thermograph moved upward 27° in 5 minutes. The wind velocity increased from 5 to 25 and 30 miles per hour, blowing and whirling the fresh snow about the streets in a boisterous, blinding manner, while some exposed places were swept clean, others were packed with heavy drifts. The temperature continued to rise steadily during the next 36 hours, reaching 23° at midnight of the 16th and a maximum of 44° about 11 p.m. of the 17th. It continued in the 40's until 4 a.m. of the 18th when a cold wave swept over the station and forced the mercury down to zero. The sharpest fall, 40° in 2 hours, was from 43° at 4 a.m. to 3° at 6 a.m.

During the period of rising temperature, from the night of the 16th until the morning of the 18th, the wind was blowing strongly from the southwest, averaging 23 miles per hour during the entire 17th, with a maximum of 35 miles per hour. This forceful wind packed the snow so hard in drifted areas that transportation was difficult. Automobiles were stalled for hours along the highway, and trains were many hours late. Drifting stopped about 9 a.m. of the 17th and by late afternoon the snow had softened and thawing begun. Water was running off the roofs all night and pools were standing in the streets. The sky was partly cloudy to cloudy, but no precipitation fell.

The morning map of December 16 showed that Havre lay in a trough of quiet polar air, but conditions changed rapidly during the next 24 hours. As the map of the 17th indicates an intense low centered off the north Pacific coast and reached inland to Alberta, with high pressure over the Plateau—a typical chinook map for this section. This explains Havre's strong chinook on the night of the 16th-17th.

During the 33 hours following 4 a.m. of the 18th moderate to fresh easterly winds caused a westward surface drift of cold polar air (from a high-pressure area that moved over from Alberta and Manitoba) which underran warm Pacific air and kept the temperatures at Havre

down between zero and 19° F. Then at 6:55 p.m. of the 19th the drift from the east gave way to a northerly wind and the full force of a west-southwest chinook struck at 7:40 p.m. The velocities ranged from 20 to 33 miles per hour during the next 2 hours with a temperature rise to 41° by 8:15 p.m., a jump of 27° in 1 hour and 15 minutes. A dash of rain fell between 7:30 and 8 p.m. but otherwise the sky was mostly clear. The chinook continued less than 2 hours, but thawing was in progress with water in the streets. Shortly before 10 p.m. a sharp increase in atmospheric pressure brought a cold northwest wind, attended by a corresponding fall in temperature from 38° at 10 p.m. to 7° at midnight and -1° by 5 a.m. the next day (December 20). This cold polar air coming down from a Saskatchewan high, held until 7:30 p.m., when a wind controlled by a Plateau high and a low over Washington caused another chinook from the southwest, blowing from 25 to 35 miles per hour and bringing a rise in temperature even greater than that on the preceding date. This rise was from 14° at 7 p.m. to 48° at 8:30 p.m., or 34° in 1½ hours. The daily range in temperature for the 20th was 51°, from -1° to 50°. The remaining snow dwindled rapidly and water from melting ran in the streets in the early morning.

This chinook, however, lasted only 11 hours. The center of the Washington low in its eastward drift passed slightly north of Havre between midnight and 2 a.m. The pressure rose slowly from 3 to 6 a.m., then rapidly, 0.3 inch in about 4 hours, to 10 a.m., accompanied by decreasing wind which veered from southwest through west, northwest, north, to northeast in 30 minutes. The temperature fell 23° in 2 hours to a minimum of 22° at 9 a.m.

Following this, conditions were about normal for the season for 15 hours, but in the meantime a strong wind developed aloft, as indicated by the 4 p.m. pilot-balloon observation, 29 miles per hour southwest at 1,500 feet above the ground. That started another chinook at this station about 10 p.m., December 21. A strong 26 mile-per-hour wind, accompanied by a temperature rise of 24° in 1½ hours to 48°, drove into our midst to the bewilderment of the inhabitants. This was the fourth chinook of Pacific air in a period of 5 days. It held sway for 11 hours, thawing and melting the snow and ice as usual. The accompanying fourth wave of diminished air pressure passed rapidly eastward and at its rear the pressure rose rapidly again, 0.2 inch in 2 hours, bringing the cold polar air back over this station where it continued with sub-zero temperatures for 4 days, reaching a low of -18° on December 26.

"All was quiet" in north-central Montana for 6 days when another chinook began at 1 p.m., December 29, with a rise in temperature of 27° in 2½ hours, to 51° at 3:30 p.m., and a southwest wind that increased to 28 miles per hour. It was followed in 18 hours by a shift of wind through northwest to northeast accompanied by a sharp

fall in temperature, 31° in 2 hours, from 6 to 8 a.m., December 30 to -5° at 11 p.m. (See table 1.)

As a result of the alternate thawing and freezing there was, in the vicinity of Havre, much bare ground and the remaining snow cover during the early part of December was reduced to a mass of snow and ice from one quarter of an inch to several inches in thickness. (See fig. 1.) This condition was unfavorable for winter-sown grains and the ice prevented livestock from grazing, making feeding necessary. Roads were slippery, as were sidewalks and streets.

While these conflicts of the air masses were going on in north-central Montana, western Montana, northern Idaho, and the area westward to the Pacific coast received unprecedented rains, resulting in floods which washed out bridges and roads, destroyed homes, and delayed trans-

This conflict between warm and cold winds seems to have prevailed over central Montana throughout most of the month of December 1933 as indicated by the charts published in the Weekly Weather and Crop Bulletin, issued by the Weather Bureau at Washington, D.C. The chart showing departures of mean temperature from the normal for the week ending 8 a.m. December 12, 1933, shows minus values for Havre and the plains of northeastern Montana, while the southern and western portions of Montana had plus departures, 6° or more, in the extreme west. The chart for the week ending December 19 shows a much steeper gradient with the minus area including all of eastern Montana, -12° near Havre, and plus 3° in the southwestern mountainous section of the State. For the week ending December 26 the northeast portion of Montana continues in the area of minus

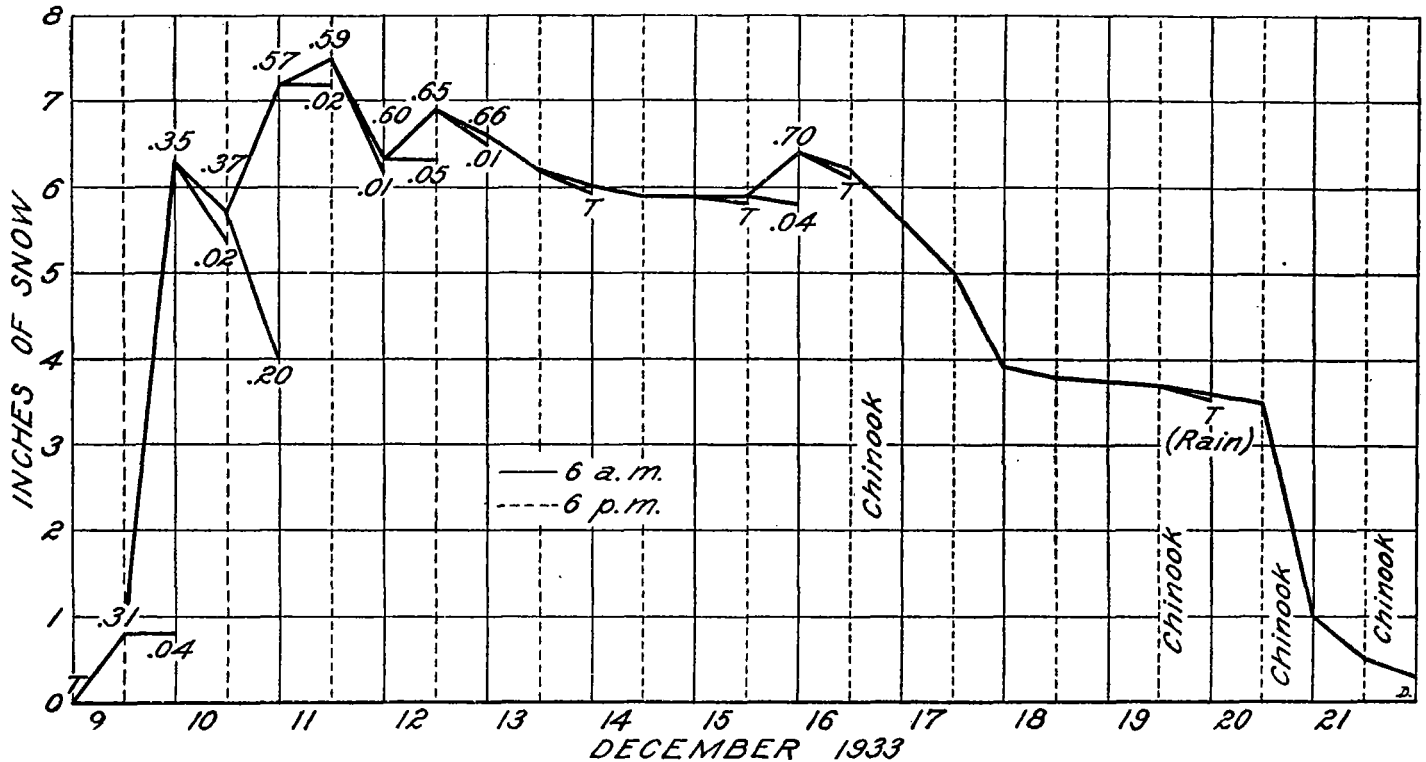


FIGURE 1.—Snow graph, Dec. 9-22, 1933, for Havre, Mont. (Total depth of snow and 12-hour snowfall indicated by lines. Figures above line are accumulated water content of snow. Figures below line are the additional new 12-hour amounts.)

portation; and the country to the east, in North Dakota and northern Minnesota, experienced abnormally cold weather.

TABLE 1.—Chinooks, December 1933, Havre, Mont.

Date	Duration	Temperature rise	Maximum temperature	Temperature fall	Minimum temperature	Maximum wind	Weather
1933	Hrs.	°F.	°F.	°F.	°F.	m. p. h.	
Dec. 5-6...	27	27, 4 hours.	48	22, 12 hours.	19	33 SW.	Cloudy on rise, snow on fall.
Dec. 7....	5	16, 2 hours.	37	20, 8 hours.	17	18 SW.	Clear.
Dec. 18-18.	33	27, 5 min.	44	40, 2 hours.	0	35 SW.	Clear to cloudy.
Dec. 19....	2	27, 75 min.	41	40, 6 hours.	-1	33 SW.	Trace, rain.
Dec. 20-21	12	34, 1½ hrs.	50	23, 2 hours.	22	38 SW.	P.C. to cloudy.
Dec. 21-22	10	24, 1½ hrs.	49	31, 6 hours.	8	26 SW.	P.C. on rise, snow on fall.
Dec. 29-30.	18	27, 2½ hrs.	51	31, 2 hours.	-5	28 W.	Clear on rise, snow on fall.

NOTE.—Temperatures in degrees Fahrenheit; wind from 4-cup anemometer corrected to true velocity.

departures, 9° in the extreme corner, while large plus departures are shown in the southwest, up to 12°. Again, the chart for the week ending January 2, 1934, shows a large minus departure in the northeast and a correspondingly large plus departure in the southwest part of the State.

The charts of December 19 and January 2 show the battleline diagonally in a northwest-southeast direction through central Montana, following the general direction of the Continental Divide. The weather described for Havre is an example of what was experienced at other points near this "battleline" which surged back and forth from the foothills to about 250 miles out on the plains.

A somewhat similar period of chinook conditions at Havre, with sudden rises and falls in temperature, occurred during March 7, 8, and 9, 1900. (See MONTHLY WEATHER REVIEW, vol. 28, April 1900, p. 161.)

The thermograph and barograph records for the most interesting week, December 15-22, 1933, are given in figures 2 and 3, respectively.

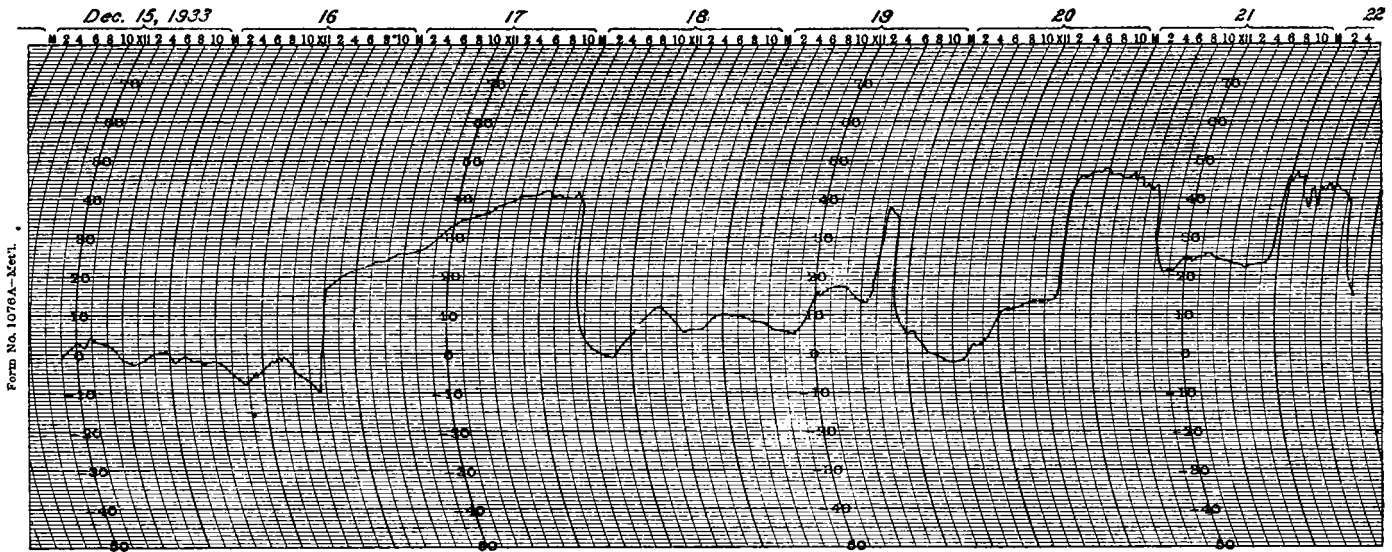


FIGURE 2.—Thermograph trace, Dec. 15-22, 1933, Havre, Mont.

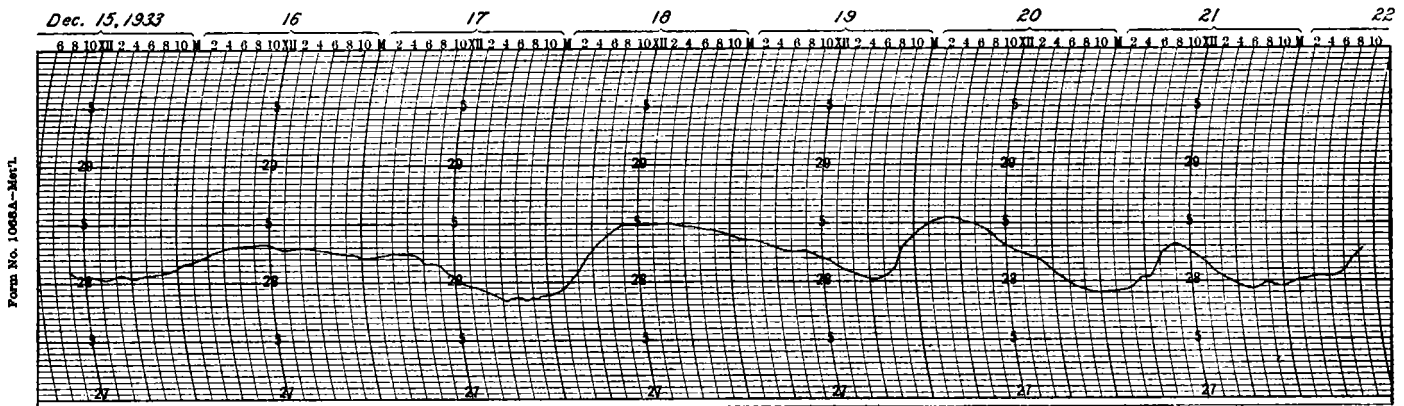


FIGURE 3.—Barograph trace, Dec. 15-22, 1933, Havre, Mont.

TABLE 2.—Wind aloft (indicated by pilot balloons) at Havre, Mont.

Date	Time	Elevations, feet above sea level										Wind velocities in miles per hour								Surface weather
		Surface 2,500 feet		3,000 feet		4,000 feet		5,000 feet		6,000 feet		7,000 feet		8,000 feet		10,000 feet		12,000 feet		
		Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	
1933																				
Dec. 16...	4 a.m.	W.	5	NW.	5	WNW.	6	W.	14	WNW.	24	WNW.	24	WNW.	47	WNW.	39	W.	39	Colder.
	4 p.m.	ENE.	5	WSW.	12	WSW.	36	W.	47	W.	54	W.	60	WNW.	47	WNW.	43	W.	46	Chinook, at 7:30 p.m.
Dec. 17...	4 a.m.	SW.	21	SW.	38	WSW.	51	W.	42	W.	47	WNW.	47	WNW.	47	W.	46	---	---	Chinook wind.
	4 p.m.	SW.	28	SW.	47	SW.	66	WSW.	55	WSW.	46	WSW.	47	W.	53	---	---	---	---	Do.
Dec. 18...	4 a.m.	W.	20	WNW.	19	WSW.	33	WSW.	67	WSW.	74	W.	70	W.	72	---	---	---	---	Cold wave coming in.
	4 p.m.	ENE.	18	E.	21	ESE.	14	SW.	17	SW.	42	WSW.	45	WSW.	36	---	---	---	---	Cold weather.
Dec. 19...	4 a.m.	ENE.	11	ENE.	7	SW.	12	SW.	36	SW.	43	WSW.	43	WSW.	43	WSW.	36	WSW.	40	Do.
	4 p.m.	ENE.	9	S.	15	SW.	43	SW.	51	WSW.	65	WSW.	65	WSW.	65	---	---	---	---	Chinook, 8 p.m. to 10 p.m.
Dec. 20...	4 a.m.	NW.	7	NW.	8	WNW.	18	WNW.	31	WNW.	38	WNW.	42	WNW.	62	---	---	---	---	Cold weather.
	4 p.m.	S.	6	SW.	12	SW.	46	WSW.	59	WSW.	65	---	---	---	---	---	---	---	---	Chinook, 11 p.m.
Dec. 21...	4 a.m.	SW.	34	WSW.	44	WSW.	63	W.	82	W.	92	W.	97	---	---	---	---	---	---	Strong chinook ended 7 a.m.
	4 p.m.	ENE.	14	E.	5	SW.	29	SW.	45	WSW.	56	WSW.	66	W.	74	W.	82	---	---	Cold weather.
Dec. 22...	4 a.m.	SW.	18	WSW.	36	W.	57	W.	73	W.	70	W.	72	W.	71	---	---	---	---	Chinook ended 7:40 a.m.
	4 p.m.	NE.	13	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	Snow and cold.
Dec. 23...	4 a.m.	ENE.	2	SE.	6	WSW.	33	WSW.	46	WSW.	42	WSW.	36	WSW.	38	W.	34	---	---	Normal.
	4 p.m.	W.	8	WSW.	26	WSW.	58	WSW.	72	W.	54	W.	58	W.	69	---	---	---	---	Chinook.

It is interesting to note the winds aloft, as indicated by pilot-balloon observations at 4 p.m., several hours in advance of the occurrence of five of the chinooks. In all cases they were preceded by a shallow layer of cold, heavy surface air from the east. On December 16 the surface wind was ENE, 5 miles per hour, at 4:05 p.m., and veered

to SW. within 400 feet above the ground. The southwest wind arrived at 7:30 p.m.

On December 19 the surface wind at 4 p.m. was NE. 9 miles per hour, and veered to SW., 42 miles per hour, at 1,500 feet above the surface. The southwest wind set in at 7:45 p.m.

On December 20 the wind at 4 p.m. was S., 6 miles per hour at the surface, but increased rapidly with altitude to 68 miles per hour at 3,800 feet. However, the light surface wind shifted to N. from 5 to 7:30 p.m., when the strong southwest wind began.

On December 21 the wind was ENE., 14 miles per hour, at the surface, SW., 29 miles per hour, at 1,500 feet ele-

vation, and 82 miles per hour at 7,400 feet above the ground. The strong southwest wind set in at 11:30 p.m. On December 29 at 4 a.m. the wind was ENE., 2 miles per hour at the surface; WSW., 33 miles per hour at 1,500 feet elevation, and W. at the surface at about 1:30 p.m. The temperature and humidity of these winds aloft would be interesting.

THE JANUARY 1934 COLD WAVE ON MOUNT WASHINGTON, N.H.

By SALVATORE PAGLIUCA

[Mount Washington Observatory, Gorham, N.H., Feb. 15, 1934]

The cold wave of January 29, 1934, hit Mount Washington with extreme severity. The preceding day, January 28, was characterized by relatively mild conditions,

further shift in wind to the NW. With a temperature of 5° below zero at midnight, a total drop of 20° had occurred in the previous 4 hours. (See fig. 1.)

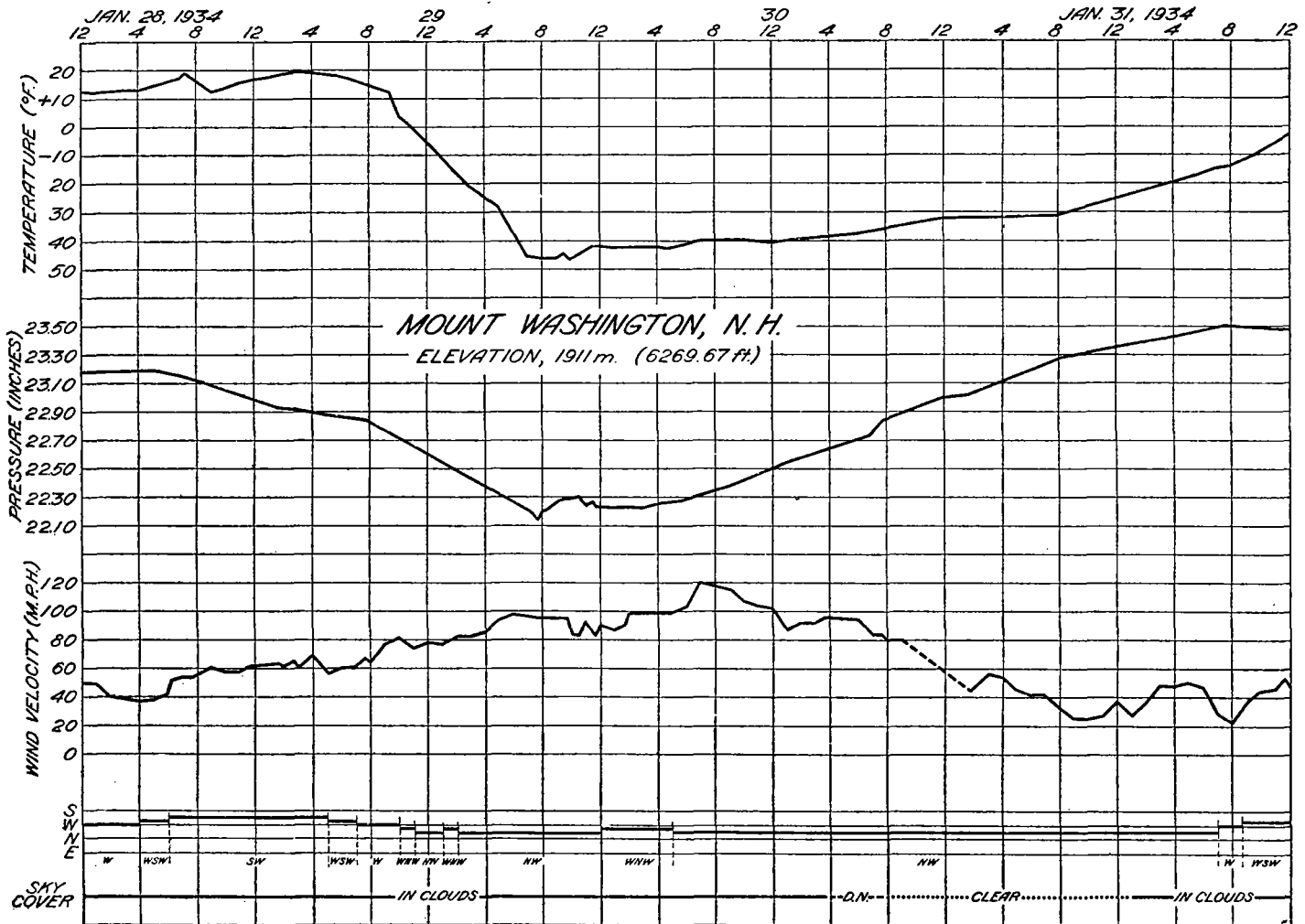


FIGURE 1.—The cold wave of Jan. 28-30, 1934, on Mount Washington, N.H. (1,911 meters or 6,270 feet above m.s.l.) Drawn by Wendell Stephenson, Mount Washington Observatory.

the temperature having risen during the day to a maximum of 22.6° F., with a 54- to 63-mi/hr wind of prevailing SW. direction. It snowed all day, with a total precipitation of 0.19 inch from 8 a.m. to 8 p.m. Also the summit was in dense, rime-forming fog all day.

The pressure was unusually low and steadily falling, as the center of a low-pressure area moving eastward passed slightly north of Mount Washington.

Shortly after 3 p.m. the temperature took a downward trend followed by gradual shifts in wind direction to the WSW., W., and WNW. The wind steadily increased to an average velocity of 80 mi/hr at 10 p.m., when a major drop in temperature took place, shortly followed by a

From 3 a.m. to 7 a.m. January 29, the temperature dropped 25° more to 45.5° below zero. From 7 a.m. to 10 a.m. the temperature was oscillating about -46°, with a minimum of -46.5°, read at 10 a.m. A pressure of 22.187 inches (reduced to sea level, 29.35 inches) was noted on the mercurial barometer at 7:40 a.m., but barograph traces indicate that at 7:15 a.m. the pressure was nearly 22.15 inches.

The wind which had been averaging 80 to 95 mi/hr, increased in velocity and gustiness to nearly 100 mi/hr early in the afternoon, reaching a maximum of 120 mi/hr at 7 p.m. The wind direction was WNW. from 12 noon to 5 p.m. when it shifted again to NW.