

WIND DIRECTION DURING SNOWFALL AT CENTRAL SIERRA SNOW LABORATORY

By

Arnold Court^{1/}

Winds are predominantly southwesterly when snow falls at the Central Sierra Snow Laboratory near Donner Pass. Between precipitation periods, however, the valley of Castle Creek, in which the laboratory is situated, has a typical mountain-valley wind regime, with northeast winds blowing down-valley in the night and morning, southwest winds blowing up-valley in the afternoon and evening.

These are the conclusions from analysis of the wind and precipitation records for the first three months of 1957, the first winter's operation of the laboratory by the California Forest and Range Experiment Station. These conclusions are corroborated in a general way by a study of the records for 1947-48, when the laboratory was operated by the Corps of Engineers and Weather Bureau.

The Study

How the wind blows during periods of snowfall is important in understanding the manner in which snow accumulates among trees and in open areas, and on slopes of varying inclination and orientation. Such understanding is essential to any program of managing the snow to increase its depth, delay its melt, or otherwise increase or alter its yield of water. Research into the possibility of such management of California's snowpack was begun in 1956 by the Experiment Station in cooperation with the State Department of Water Resources. As a part of this research, the Central Sierra Snow Laboratory, just west of Donner Summit on U. S. Highway 40 in the Sierra Nevada, was reactivated. (The laboratory had been established in 1946 by the Corps of Engineers and Weather Bureau, and operated until 1953.)

Reactivation included installation of precipitation and wind instruments in almost the same locations formerly used. Precipitation is measured by a weighing rain gauge north of the laboratory headquarters. Wind direction and speed are obtained from instruments 46 feet above the ground on a stripped tree south of the headquarters; the earlier wind instruments had been mounted in the top of a tree (now dead), 52 feet above the ground. Wind and precipitation instruments were less than 100 feet apart.

Results

Out of a total precipitation of 33.19 inches during January, February, and March 1957, more than two-thirds fell during hours when the wind was from the southwest. An additional one-fourth came with winds from the two adjacent sectors, south and west (Table 1; Figure 1C).

Less than 2 percent of the precipitation came during hours when the wind movement was less than 1 mile, and hence classed as calm.

To show that winds during precipitation differ substantially from those when no precipitation falls, wind roses for the two conditions were compiled (Table 1; Figure 1A and B).

When no precipitation was falling, air movement was still strongly from the southwest (44 percent of all non-precipitation movement), but northeast winds were also substantial (29 percent), in contrast to their negligible occurrence during precipitation. This tendency toward two predominant directions characterizes the usual mountain-valley breeze circulation, established during stable weather conditions. During the night and morning, cooled air drains down the valley from the northeast; during the afternoon and evening, sun-warmed air flows up the valley, from the southwest. The total wind movement (miles) from these two predominant directions, by 6-hour periods, for the 3 months, when no precipitation fell, was:

Wind direction:	<u>00-06</u>	<u>06-12</u>	<u>12-18</u>	<u>18-24</u>	<u>Total</u>
Northeast	563	429	104	410	1,506
Southeast	360	549	964	466	2,339

^{1/} Meteorologist, California Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture. The Station is maintained at Berkeley in cooperation with the University of California.

Thus the winter wind regime in Castle Creek in 1957 appears to have two distinct patterns: NE-SW diurnal alternation during fair weather, and a SW persistence during storms.

Table 1.--Directional distribution of precipitation amounts and of wind movement during and without precipitation, at Central Sierra Snow Laboratory, 1957^{a/}

MONTH	: N	: NE	: E	: SE	: S	: SW	: W	: NW	: CALM	: TOT.
<u>PRECIPITATION (Inches)</u>										
JAN.	.00	.13	.11	.00	2.97	5.80	.23	.77	.53	10.54
FEB.	.04	.15	.04	.03	2.65	8.09	1.34	.00	.02	12.36
MAR.	.00	.03	.01	.00	1.06	8.67	.47	.01	.04	10.29
TOTAL	.04	.31	.16	.03	6.68	22.56	2.04	.78	.59	33.19
<u>WIND MOVEMENT DURING PRECIPITATION (Miles)</u>										
JAN.	0	46	67	0	205	656	46	7	--	1027
FEB.	15	60	26	3	269	1118	79	0	--	1570
MAR.	0	7	4	0	171	1499	83	3	--	1767
TOTAL	15	113	97	3	645	3273	208	10	(b/)	4364
<u>WIND MOVEMENT WITHOUT PRECIPITATION (Miles)</u>										
JAN.	93	687	165	13	187	942	107	30	--	2224
FEB.	33	544	192	17	191	540	25	10	--	1552
MAR.	12	275	75	36	123	857	72	39	--	1485
TOTAL	138	1506	432	66	501	2339	204	79	(c/)	5261

a/ Wind records missing for January 13, 1957, when 1.20 inches of precipitation fell, and wind directions missing for March 22-25, when only 0.02 inches fell; these amounts were not used in the analysis.

b/ Total hours calm with precipitation: 11

c/ Total hours calm without precipitation: 17

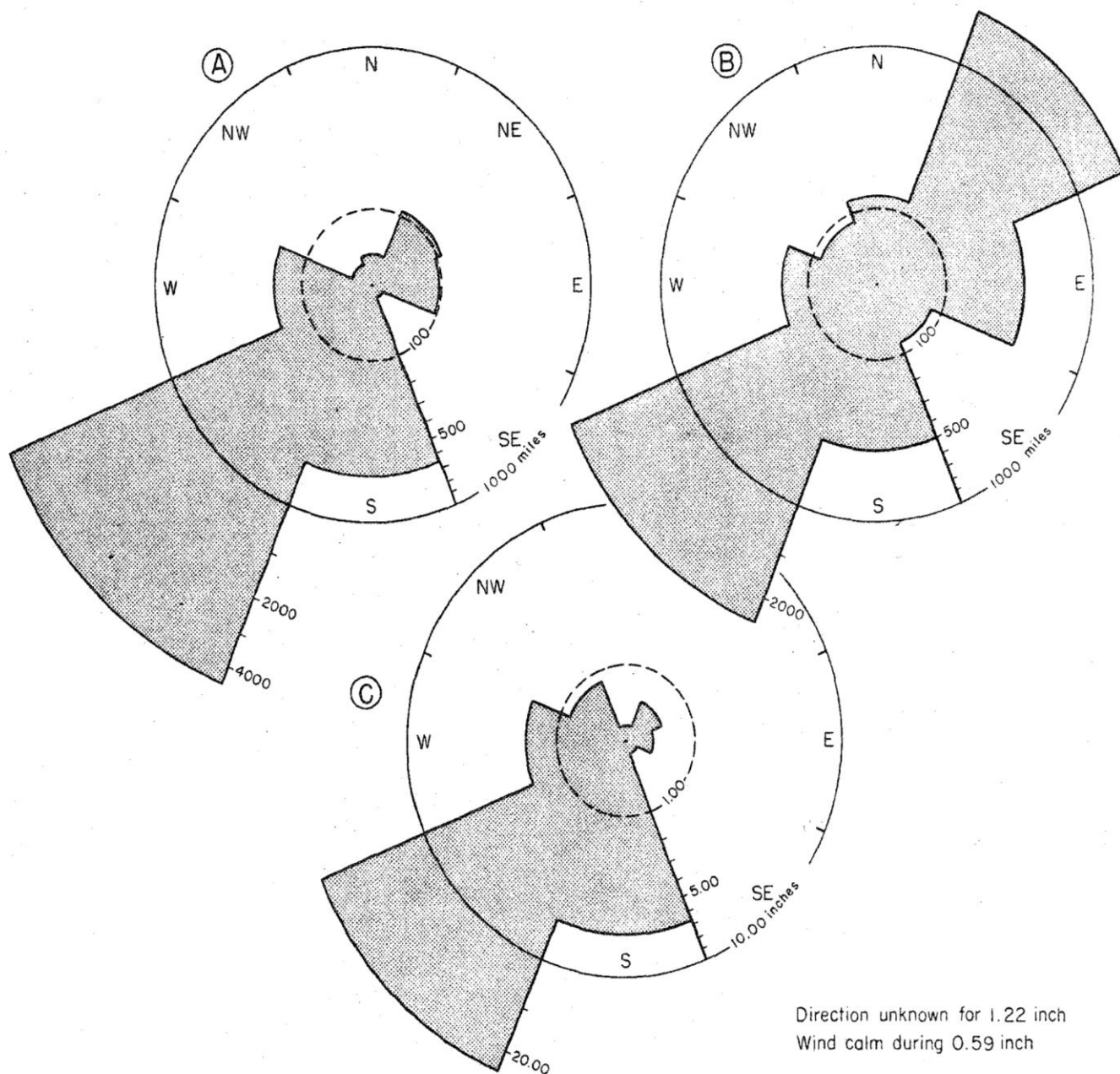


Figure 1.--Total wind movement, by directions, during periods with (A) and without precipitation (B) and total precipitation (C) by wind directions, January through March, 1957, Central Sierra Snow Laboratory. (Calm during 0.59 inches of precipitation, 28 hours; 3 $\frac{1}{4}$ days of wind and 1.22 inches of precipitation were omitted.)

Corroboration

Wind behavior in the valley of Castle Creek during early 1957 was generally similar to that observed there a decade earlier. The Hydrometeorological Logs published for the Central Sierra Snow Laboratory contain hourly wind directions for two seasons, 1946-47 and 1947-48. Directions reported for the first season appeared to be questionable; later, Mr. Glenn Castle of the Corps of Engineers, who helped direct the instrumental installations of the Cooperative Snow Investigations, remarked that at some time during the first year the wiring of the windvane had been found to be incorrect, but the date of this discovery, and the nature of the error, had not been placed on file. Consequently the entire year's record was not used in the analysis.

The preliminary study of the 1947-48 wind directions during precipitation was based on storms, rather than on all periods of precipitation. Storms were defined as periods of generally continuous precipitation totalling at least 0.9 inch, so as to include all major storms; these produced 87 percent of the total winter precipitation, most of which falls as snow. Storms were chosen as the unit to determine whether significant differences existed between the wind patterns of various storms, but no such differences were found.

Hourly precipitation values were available from one of several weighing raingages on platforms kept at least 5 feet above the ground or snow surface. On the few occasions during which the record of the main gage was incomplete, precipitation amounts were interpolated from one of the adjacent gages. During only 13 of the 676 hours of precipitation was the wind recorded as calm; precipitation during these hours was credited to the wind direction that had prevailed during the preceding hour.

The total amounts and intensities of precipitation, in cent-inches (hundredths of an inch), that fell when the wind was from various directions during the 1947-48 winter were:

Item:	<u>N</u>	<u>NE</u>	<u>E</u>	<u>SE</u>	<u>S</u>	<u>SW</u>	<u>W</u>	<u>NW</u>	<u>Storm</u>	<u>Nonstorm</u>	<u>Total</u>
Centinches	28	14	9	404	3,088	697	59	1	4,300	574	4,874
Cin/hour	1.4	2.0	1.3	8.4	6.9	5.3	5.9	1.0	6.4	2.9	5.5

Besides bringing some 72 percent of the 1947-48 storm precipitation, southerly winds brought generally greater precipitation intensities than winds from other directions.

These 1947-48 data indicate a predominant south wind during precipitation; the 1957 data, for almost the same instrument exposure, indicate a predominant southwest wind. Whether this difference is instrumental, reflecting an error in windvane orientation, or is real, indicating that basically different storm conditions prevailed in the two years, cannot be determined until further observations are made.

In the general vicinity of Castle Creek, the Cooperative Snow Investigations staff concluded:

"Prevailing winds are predominantly from the southwest quadrant ... during storm periods. This is shown by a frequency distribution of hourly wind directions during storm periods for the 1949-50 water year, as measured at Donner Summit Airways Station, ^{2/} which is approximately 2 miles from the laboratory area. During the year, wind direction was tabulated hourly during every period of precipitation and the amounts of precipitation also noted. Results show that 96 percent of the time during which precipitation occurred, the winds were from the quadrant SSW through W, and 98 percent of the precipitation occurred with winds from this quadrant."^{3/}

The local topography at the airways station tends to deflect south winds to be slightly more westerly than at Castle Creek.

Plans for Further Study

At neither the Snow Laboratory nor Donner Summit site are the winds fully representative of the true airflow of the Sierra Nevada. To obtain information on this undisturbed air movement,

-
- 2/ The Donner Summit Airways Station was operated from December 1929 until February 1952 at a site 7,189 feet above sea level, on the north side of Donner Pass.
 - 3/ C. E. Hildrebrand and T. H. Pagenhart, "Determination of Annual Precipitation, Central Sierra Snow Laboratory." Snow Investigations Research Note No. 21, North Pacific Division, Corps of Engineers, Dept. of the Army, 22 Sep 1954. 22 pp. Ref. to p. 9.

wind instruments were installed early in 1957 on the summit of Mt. Lincoln, 8,383 feet above sea level, on the south side of Donner Pass. Instrumental difficulties, especially icing, prevented a usable record during the early months; if these can be overcome, this installation will provide further valuable information on wind movement in the central Sierra Nevada.

In addition, a continuous recorder has been attached to the wind instruments at the Blue Canyon Airways Station of the Weather Bureau, 18 miles west of the laboratory. Records from this location, on a mesa-like hill exposed to winds from all directions, together with those from Mt. Lincoln, will be used for further studies of wind behavior during snowfall in the central Sierra Nevada.

Acknowledgments. Assistance in tabulation and computation was provided by C. O. Johanneson, L. G. Richards, T. H. Pagenhart, Don Rogers and Joenne Cannon.

NEW METEOROLOGICAL AND SNOW STUDIES IN THE CENTRAL SIERRA

By

Kenneth J. Walsh^{1/}

A major phase of "Operation Wet Blanket"^{2/} is the initiation of new meteorological and snow physics studies in the Central Sierra Nevada. To carry out these new studies, the Forest Service has reactivated the Central Sierra Snow Laboratory near Soda Springs, operated from 1946 to 1953 by the Corps of Engineers and the U. S. Weather Bureau. Reactivation has involved resumption of many of the basic measurements of snow and weather as well as several new ones.

Our meteorological and snow physics studies in the Central Sierra Nevada are not as intensive as those made at the peak of the Engineers' activity at the Central Sierra Snow Laboratory, but they are more extensive. We have set up five meteorological and snow stations. Periodic measurements at one or more stations include incoming and outgoing short wave and long wave radiation, barometric pressure, wind, temperature, relative humidity, snow fall, and snow characteristics. Two of the sites are in the Castle Creek Basin, two in the Onion Creek Basin 6 miles to the south, and one at Blue Canyon, 15 miles to the west. Continuous measurements of the physical elements which affect snow management will provide a necessary base for evaluation of short-term studies of snow physics and long-term studies of snow accumulation and melt and evaporative losses.

Mt. Lincoln Studies

The most spectacular—and also most difficult—of our new studies in the central Sierra is that of wind and temperature on the summit of Mt. Lincoln. This is a flat-topped, well-exposed peak, 8,300 feet above sea level on the crest of the Sierra Nevada about 2 miles south of Donner Pass; it is situated just at the head of our Onion Creek experimental watersheds. The recent installation of a chair lift by the Sugar Bowl Corporation makes Mt. Lincoln the highest mountain peak in the Sierra that is accessible throughout the winter.

Through the generous cooperation of the Sugar Bowl management, we were able to install a recording anemometer and wind direction indicator on the top of the upper tower of the chair lift. A standard instrument shelter, with hygrothermograph, psychrometer, and maximum and minimum thermometers, is anchored nearby. The wind speed and direction recorder and a barograph are installed in a nearby Ski Patrol shelter hut.

No electric power is available on this mountain-top site to keep the anemometer or the wind vane free from snow and ice. During storms in February and March 1957 solid ice more than a foot

- 1/ Meteorologist, California Forest and Range Experiment Station, U. S. Dept. of Agriculture, Forest Service; the Station is maintained at Berkeley in cooperation with the University of California.
- 2/ Snow management research conducted by the California Forest and Range Experiment Station in cooperation with the State of California, Department of Water Resources.