THE AVALANCHE WARNING PROGRAM IN COLORADO [1/]

By

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Introduction

As the fourth winter of formal operation draws to a close, Colorado's Avalanche Warning Program is operating smoothly. This joint venture between the USDA Forest Service (FS) and the National Weather Service (NWS) operates around the clock from November through May. Warnings originate from the Forest Service's Rocky Mountain Forest and Range Experiment Station at Fort Collins, and are issued intermittently as dangerous avalanche conditions warrant. Primarily the warnings are intended for backcountry travelers, but are used to alert all mountain travelers and residents as the degree of danger dictates.

Avalanche problems affect 140,000 km^2 of Colorado's high mountainous area from 37° N. to 41° N. latitude and 105° W. to 109° W. longitude (Fig. 1). Frequent periods of pleasant weather, the ski slopes, large resort centers, excellent alpine touring, and an extensive network of mountain highways lure thousands of recreationists into avalanche terrain. Unfortunately, many people who play, work, and live in the mountains are unaware of the hazards that lie quietly beneath the beautiful snow surfaces, especially on steep slopes. Between 1951 and 1976, 88 avalanches killed 52 people--half of them were either climbers or skiers and a fourth of them were motorists, truckers, or highway employees. Damaged were 69 vehicles, which included 2 buses and 5 tractors or bulldozers; 21 structures; and numerous telephone and power lines (Table 1).

Pilot tests for the avalanche warning program began in 1962 with only a few selected sites; in 1973, the Statewide system was initiated. Principal components include a network of reporting stations in the mountains, the Avalanche Warning Center (AWC) at Fort Collins, and a teletype network for disseminating public warnings.

The Reporting Network

The reporting network is a composite of government and private cooperators who report weather, snow, and avalanche conditions from 58 sites scattered throughout Colorado's high mountains (Fig. 1). Density of reporting stations depends on differences in regional snowfall, availability of observers with adequate communication facilities, and presence of line power needed for instrumentation. Contributing observers have diverse backgrounds; most are local volunteers, but a few are on contract for special services, and one is a full-time FS employee who reports data from four stations.

To make optimum use of available information, FS works with numerous organizations who collect and transmit pertinent data. Primary cooperators include:

- National Weather Service
- Bureau of Reclamation
- Colorado State University
- Colorado Amateur Radio Weather Network
- Colorado Department of Highways
- Colorado State Patrol
- Colorado Ski Country U.S.A.
- Federal Aviation Agency
- National Park Service
- Soil Conservation Service - Snow Survey Section
- Camp Bird Mine
- Urad-Henderson Mines
- University of Colorado

1/ Presented at the 45th Western Snow Conference, Albuquerque, New Mexico, April 1977. Mention of trade or company names in this paper is for the benefit of the reader, and does not constitute endorsement by the U.S. Department of Agriculture.

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Table 1. Avalanche accidents in Colorado that resulted in fatalities and/or damage, 1951 through 1976

Year and date	Location	Fatalities	Damage
1951			
7 Feb	Berthoud Pass		Telephone poles/lines
23 Apr	Monarch Pass	2 motorists	1 vehicle
20 Dec	Loveland Pass		5 vehicles
24 Dec	Arapaho Basin		Power lines
30 Dec	Wolf Creek Pass	2 truckers	1 vehicle
30 Dec	Berthoud Pass		3 vehicles
30 Dec	Red Mt Pass		1 vehicle
31 Dec	Loveland Pass		1 vehicle
1952			
11 Jan	Cunningham Gulch		1 mining mill
7 Apr	Battle Mt		1 vehicle
1953			
24 Nov	Loveland Pass		1 vehicle
1954-----None			
1955			
10 Feb	Red Mt Pass		1 vehicle(bus)
1956			
25 Jan	Red Mt Pass		1 vehicle
1957			
8 Jan	Red Mt Pass		1 vehicle
26 Jan	Wolf Creek Pass		2 vehicles
27 Jan	Red Mt Pass		1 vehicle
27 Jan	Red Mt Pass		Telephone lines
27 Jan	Wolf Creek Pass		1 residence; 2 vehicles; 2 bulldozers
27 Jan	Wolf Creek Pass		7 vehicles
24 Feb	St Mary's Lake	1 climber	
8 Apr	Berthoud Pass	1 photographer; 1 hwy employee	2 vehicles
10 Apr	Berthoud Pass		Power lines; telephone lines
1958			
14 Feb	Red Mt Pass		Power lines; telephone poles/lines
14 Feb	Camp Bird Mine	3 miners; 1 hwy employee	
30 Mar	Loveland Pass		1 vehicle
1959			
3 Feb	Aspen	1 lift skier	
1960			
13 Feb	Berthoud Pass	1 ski tourer	
19 Mar	La Plata Peak	1 climber	
1961			
23 Feb	Aspen	1 lift skier	
4 Mar	Red Mt Pass		1 vehicle
24 Nov	Arapaho Basin	1 lift skier	
1962			
7 Jan	Loveland Pass		1 vehicle
9 Jan	Loveland Pass		1 vehicle
21 Jan	Twin Lakes	7 residents	3 residences; 2 cabins; 1 trailerhouse; 1 barn; 7 vehicles; 2 tractors; power and telephone lines
1963			
3 Mar	Red Mt Pass	3 motorists	1 vehicle
1964			
31 Jan	Homestake Lake	1 construction worker	
1 Feb	Urad Mine		1 power line; 1 misc.structure
2 Feb	Arapaho Basin		1 sewer plant; power lines
21 Mar	Urad Mine		1 vehicle
1964 (continued)			
22 Mar	Loveland Pass		1 vehicle
24 Mar	Fremont Pass		5 telephone poles/lines
30 Mar	Gladstone		Telephone lines
1 Apr	Gunnison	1 construction worker	
20 Dec	Geneva Basin	1 lift skier	
1966-----None			
1967			
7 Jan	Loveland Pass	2 climbers	
26 Nov	Arapaho Basin	1 lift skier	
19 Dec	Red Mt Pass		1 vehicle
1968			
23 Feb	Telluride (mine)		1 snowshed; 1 crusher bldg
24 Feb	Leadville	1 snowmobiler	
1969			
30 Jan	Redcliff		1 residence
7 May	Leadville Lead Mine		1 construction trailer
8 May	Jones Pass		1 mine bldg
27 Dec	Urad Mine		1 misc. mine structure
1970			
2 Mar	Red Mt Pass	1 snowplow driver	1 bulldozer
10 Apr	Red Mt Pass		1 vehicle
26 Apr	Red Mt Pass		1 vehicle
1971			
16 Mar	Aspen	1 ski tourer	
17 Oct	Pole Creek Mt	1 hunter	
26 Dec	Red Mt Pass		Power lines
27 Dec	Silverton		1 bridge
27 Dec	Gladstone		1 mine bldg
1972			
20 Aug	Mitchell Lake Glacier	1 climber	
8 Dec	Aspen	1 lift skier	
13 Dec	Steamboat Springs	1 lift skier	
1973			
29 Mar	Telluride		1 mine bldg
26 Apr	Eisenhower Tunnel		1 construction bldg
30 Apr	Camp Bird Mine		1 vehicle
13 May	Arrastra Bulch		1 mine water system
13 Oct	Rocky Mt Natl Park	2 climbers	
28 Dec	Berthoud Pass		1 vehicle
29 Dec	Eisenhower Tunnel		3 vehicles
30 Dec	Wolf Creek Pass		1 misc.structure
1974			
1 Jan	Aspen		1 snowcat
5 Jan	Red Mt Pass		1 vehicle
9 Jan	Camp Bird Mine		1 mine water system
23 Nov	Arapaho Basin	1 lift skier	
15 Dec	Monarch Pass	1 ski tourer	
21 Dec	Guanella Pass	1 ski tourer	
28 Dec	Aspen	1 lift skier	
1975			
9 Jan	Crested Butte	1 lift skier	
14 Jan	Monarch Pass	2 ski tourers	
15 Jan	Ashcroft	1 ski tourer	
25 Apr	Red Mt Pass		1 vehicle
1976			
17 Jan	Berthoud Pass	1 ski tourer	
9 Feb	McClure Pass		1 vehicle
9 Feb	Red Mt Pass		5 vehicles(1 bus)
29 Mar	Mt Nast	1 worker	
4 July	Rocky Mt Natl Park	1 climber	

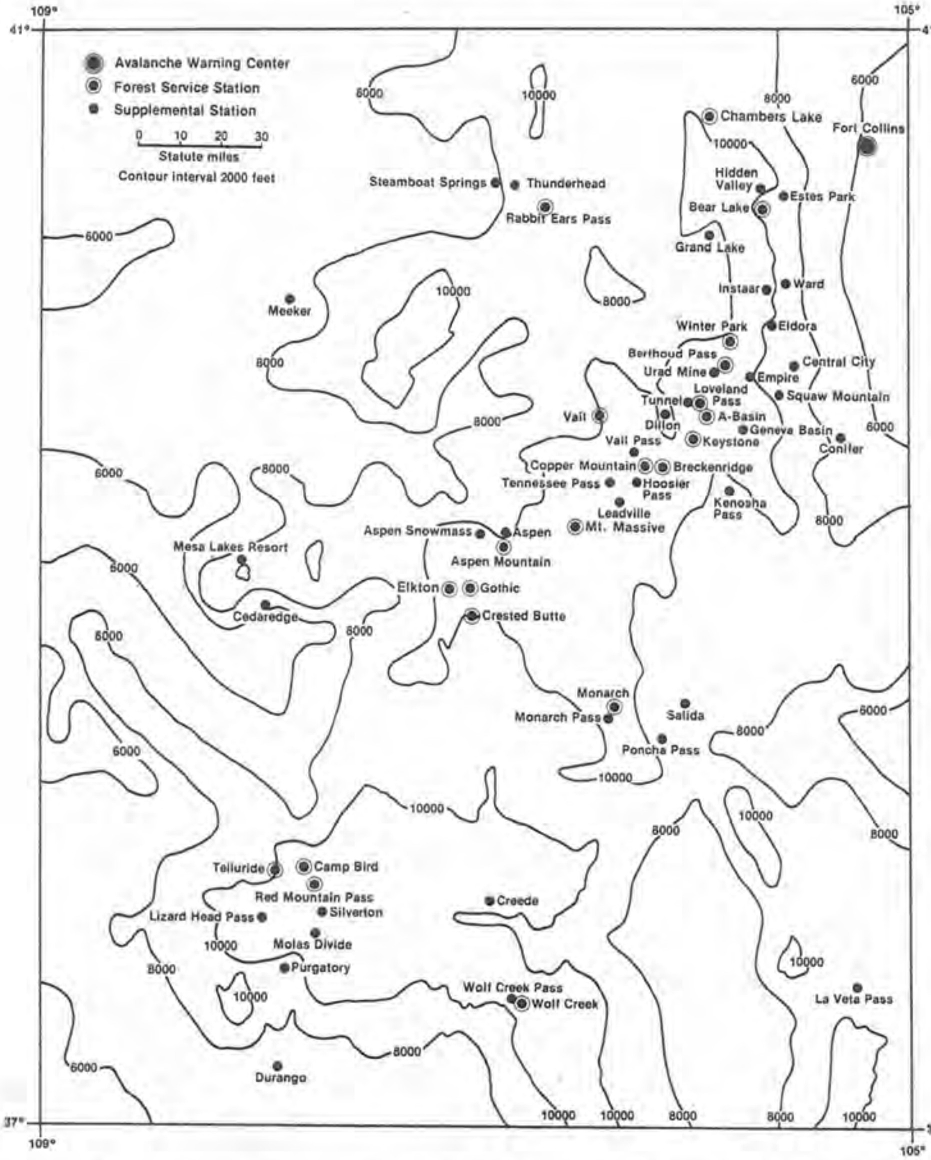
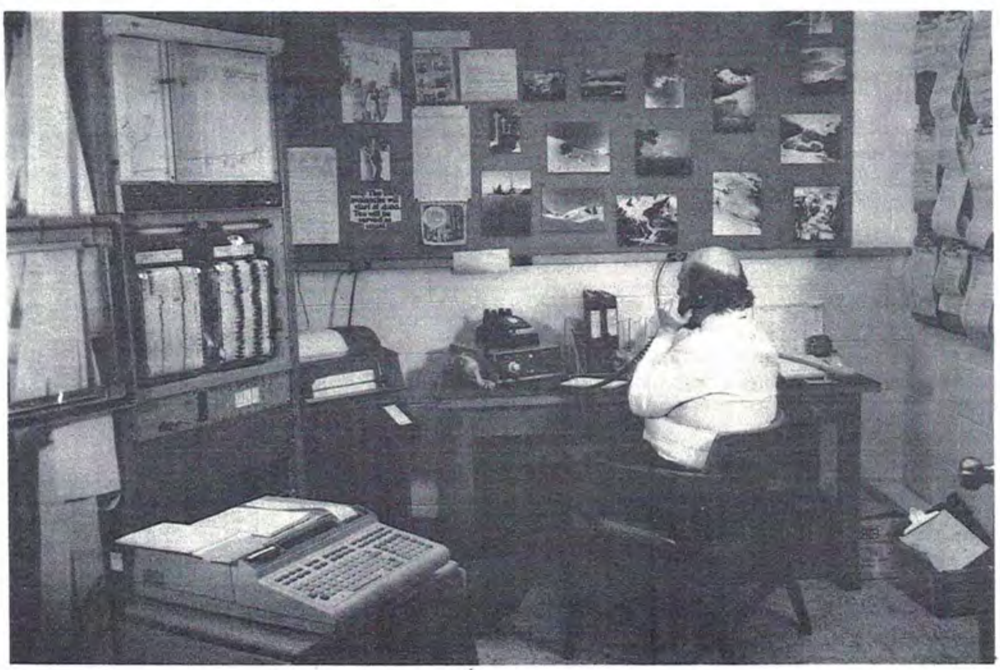


Figure 1. Weather, snow, and avalanche reporting stations for Colorado's Avalanche Warning Program during winter 1976-77.

The primary stations established by FS are the heart of the reporting system, with backup by the supplemental stations that have been established by cooperating organizations but who are willing to supply data for the AWC system. The AWC personnel are FS employees experienced in avalanche forecasting; they train the FS station observers and choose the sites where the FS instruments are located. Precipitation and temperature data are recorded at wind-sheltered clearings near, but below, timberline; wind data are telemetered from exposed ridgecrests to pass or valley locations accessible to observers. Data on windspeed, wind direction, blowing snow particle size, and particle frequency are telemetered continuously to the AWC from Colorado Mines Peak, 95 km southwest of Fort Collins (Figs. 2 and 3).

Figure 2. Project scientist, calibrating snow particle counter at the telemetry site on Colorado Mines Peak. Sensor is 50 cm aboveground; top of blowing snow layer is slightly above sensor. Windspeed and direction sensors are 10 m aboveground and 3804 m above sea level. Northward view shows Berthoud Pass highway, Fraser River valley, and west flank of Colorado's Front Range.

Figure 3. Project scientist, taking AWC message from reporting station. The Avalanche Warning Center (AWC) at Fort Collins, Colorado, shows: (Left) real-time telemetered display of data from Colorado Mines Peak; (Left of center) National Weather Service (NWS) teletype; and (Center) Code-a-Phone.



FS observers transmit additional data to the AWC each morning between 0500 and 1000 Mountain Standard time, which include: (1) station name, (2) time of observation, (3) name of observer, (4) present weather, (5) maximum temperature, (6) minimum temperature, (7) current temperature, (8) snow depth on the ground, (9) height of the 24-h snowfall, (10) water equivalent of new snow, (11) windspeed and wind direction, (12) descriptive information on fresh avalanches, (13) observer's estimate of avalanche danger, and (14) observer's opinion on the need to issue a warning. When avalanche danger increases, observers report to AWC several times a day.

Network observers and AWC personnel periodically gather data on snow structure from selected sites near avalanche starting zones. These data include: (1) snow strength profiles taken with a ram penetrometer, (2) vertical temperature and density profiles, (3) layer structure, (4) grain type and size, (5) degree of intergranular bonding, and (6) an estimate of snow wetness.

Supplemental station reports are received daily at the AWC via NWS teletype and warning center phones; these reports pertain mainly to present weather and road conditions, but include reports on avalanches that cross highways. Although these stations generally have less elaborate instrumentation than FS stations, they play a vital role in providing data from remote sites not covered by FS stations, and often provide key information on storms and avalanche activity during the night when most FS stations are unattended.

Activities at the AWC

All data on mountain weather, snow, and avalanche conditions are analyzed by FS specialists at AWC who share forecast and warning duties 7 days a week, and log the data received by telephone, teletype, and Code-a-Phone. Primary responsibilities of the AWC personnel include: (1) forecasting mountain weather, (2) evaluating present snow stability, (3) advising the public on mountain snow conditions, (4) issuing avalanche warnings, and (5) terminating warnings when avalanche conditions return to normal. Because mountain weather forecasts are all important to avalanche potential, a separate discussion of this is warranted.

Forecasting Mountain Weather: From the beginning, AWC personnel have used NWS and FAA weather forecasts; however, neither product is sufficiently detailed for making snow stability assessments. In 1975, J. O. (Owen) Rhea, a research associate at Colorado State University's Department of Atmospheric Sciences, developed an orographic precipitation model while doing contract research with the Rocky Mountain Station's Mountain Snow and Avalanche Research Project at Fort Collins (Rhea 1975, 1977a, 1977b). Rhea uses this model to generate quantitative precipitation forecasts (QPF's) for the AWC. Although initially designed as a diagnostic QPF aid in assessing season-long snowfall in mountainous regions of Colorado, the model has been successfully adapted for short-term QPF use. It operates with a 10-km grid interval, accepts wind flow from any direction, and accounts for effects from rate of rise, length of flow over elevated terrain, and shadowing from upwind barriers. Full-model runs were used to generate 36 precipitation isohyetal maps for the State's mountainous areas west of the 105th meridian. One map is available for each 10° 700-mb wind direction. Average terrain elevations for every 10-km map grid point were obtained from an original 2.5-km grid resolution. Each map contains seven isohyets, calibrated with the following assumptions: (1) 700-mb windspeed of 26 m/s, (2) 700-mb temperature of 0°C, (3) saturated airmass from 800 to 450 mb, (4) 12-h duration of moist flow, (5) precipitation efficiency of 0.25, and (6) large-scale vertical lifting component of 5 cm/s. For explanatory purposes, these isohyets are termed "reference isohyets." Precipitation efficiency and the vertical lifting components are constants.[3/] Predicted vertical profiles of windspeed, wind direction, temperature, moisture depth, and an estimate of the duration of moist flow are required model inputs. To attain QPF's, the reference isohyets are calibrated for each forecast period with a series of correction factors described by Rhea (1977b).

3/ Precipitation efficiency is adjusted downward when thin moisture layers exhibit warm cloud-top temperatures.

Model input data are accessed through an interactive terminal on the U.S. Bureau of Reclamation's Environmental Data System. The terminal is located at Colorado State University's Department of Atmospheric Sciences. Primary data retrieved are the 12-h Limited Fine Mesh (LFM) and 24-h Primitive Equation (PE) gridded field prognostic data, upper air soundings, and surface synoptic reports. Additional supportive data are available through standard facsimile products. Considerable forecast judgment is used in estimating areal extent, duration, and depth of moisture fields, and for interpreting forecasted 700-mb winds.

The reference isohyetal maps (Fig. 4) are kept at the AWC. Data needed for QPF's are entered in a Hewlett Packard 9825A computer, which generates a range of expected 12-h precipitation amounts for selected FS stations. The 12-h new-snowfall depth is then forecasted for these locations by using a new-snowfall density of 80 kg/m^3, or a snowfall-to-water-depth ratio of 12.5 to 1. Other things being equal, QPF's are highly sensitive to wind direction due to the strong orographic controls on mountain precipitation. An example of this is given in Table 2 where the QPF range varies from 0.2 to 76 mm; the converted new-snowfall amounts would vary from a trace to 95 cm. Although forecast areal precipitation amounts change with every 10° 700-mb direction increment, only 12 reference isohyetal maps -- 180°, 210° ... 150° -- are used operationally due to limitations in predicted wind direction. Sometimes two isohyetal maps are required simultaneously to handle complex wind patterns, that is, a 240° map for the mountains in southern Colorado and 270° for the northern mountains, or 090° for the eastern Front Range and 270° for the remainder of the State's mountainous area.

Table 2. Range in quantitative precipitation forecasts (QPF's)[1] at selected FS stations for four 700-mb wind directions

FS station	Predicted range in precipitation (water) by 700-mb wind-direction classes			
	180°	270°	360°	090°
	mm	mm	mm	mm
Thunderhead	0.2 - 10.2	50.8 - 63.5	0.2 - 10.2	0.2 - 10.2
Rabbit Ears Pass	0.2 - 10.2	63.8 - 76.2	10.4 - 17.8	0.2 - 10.2
Winter Park	0.2 - 10.2	18.0 - 25.4	0.2 - 10.2	38.4 - 50.5
Berthoud Pass	10.4 - 17.8	25.7 - 38.1	18.0 - 25.4	50.8 - 63.5
Loveland Pass	25.7 - 38.1	38.4 - 50.5	25.7 - 38.1	50.8 - 63.5
Arapaho Basin	25.7 - 38.1	38.4 - 50.5	25.7 - 38.1	50.8 - 63.5
Keystone	25.7 - 38.1	25.7 - 38.1	10.2 - 17.8	25.7 - 38.1
Breckenridge	25.7 - 38.1	25.7 - 38.1	25.7 - 38.1	38.4 - 50.5
Copper Mountain	18.0 - 25.4	38.4 - 50.5	38.4 - 50.5	38.4 - 50.5
Vail	0.2 - 10.2	38.4 - 50.5	10.2 - 17.8	0.2 - 10.2
Aspen Mountain	10.2 - 17.8	0.2 - 10.2	25.7 - 38.1	0.2 - 10.2
Gothic	18.0 - 25.4	38.4 - 50.5	18.0 - 25.4	0.2 - 10.2
Elkton	18.0 - 25.4	50.8 - 63.5	18.0 - 25.4	0.2 - 10.2
Crested Butte	10.2 - 17.8	38.4 - 50.5	0.2 - 10.2	0.2 - 10.2
Monarch Pass	25.7 - 38.1	63.8 - 76.2	0.2 - 10.2	38.4 - 50.5
Red Mountain Pass	38.4 - 50.5	38.4 - 50.5	50.8 - 63.5	0.2 - 10.2
Wolf Creek Pass	38.4 - 50.5	18.0 - 25.4	0.2 - 10.2	18.0 - 25.4

[1] QPF's generated using 700-mb windspeed of 26 m/s, 700-mb temperature of 0°C, a saturated airmass from 800 to 450 mb, and 12 h of moist flow.

QPF's generated by Rhea's orographic precipitation model have given AWC personnel a powerful new tool for assessing snow stability in advance, and have enabled forecasters to lengthen the forewarning period by 6 h or more. However, resolution problems in predicting vertical humidity profiles and deficiencies in PE or LFM predicted windfields occasionally cause large QPF errors.

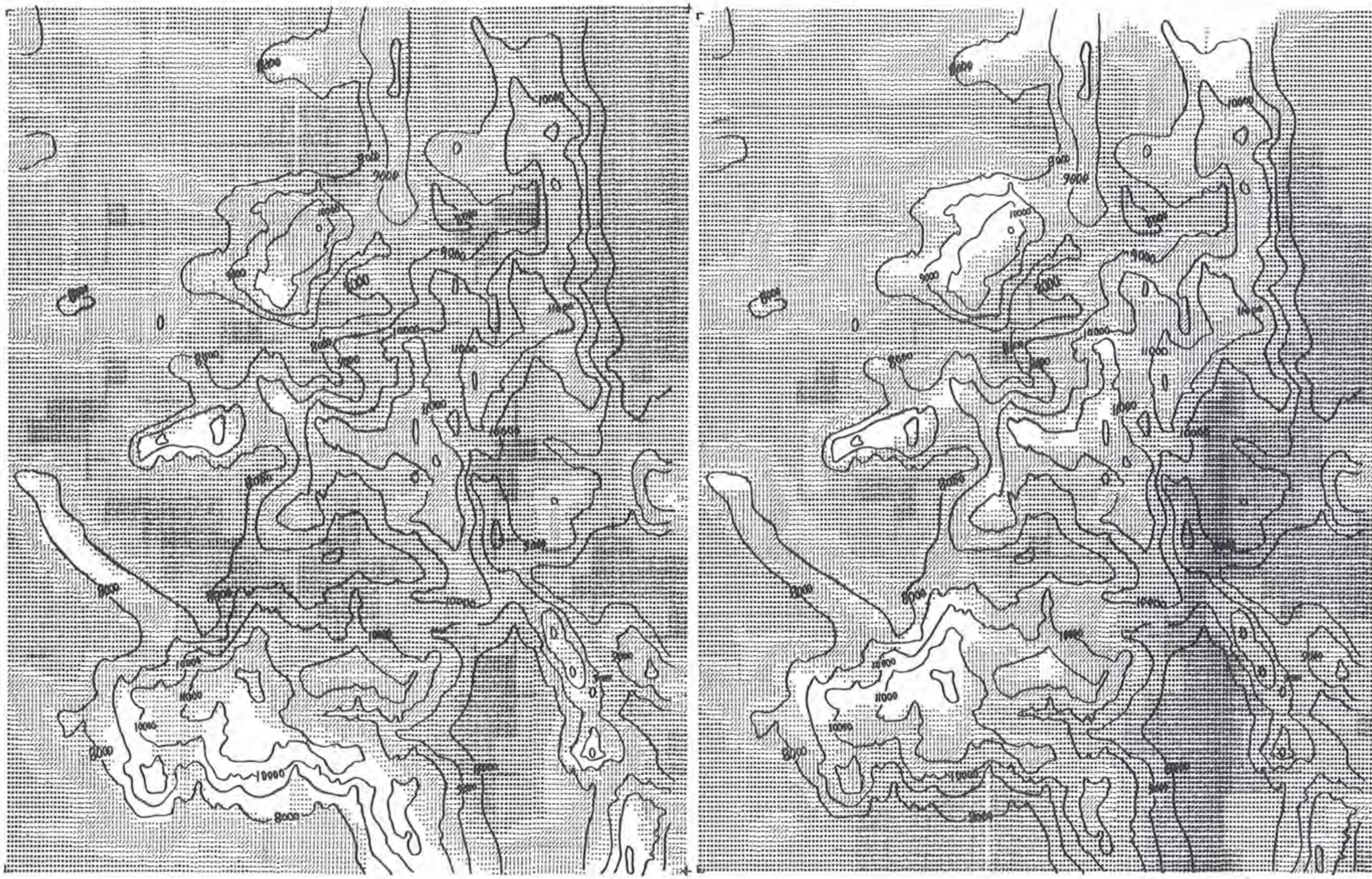


Figure 4. Examples of reference isohyetal maps used at the Avalanche Warning Center. Precipitation distribution over Colorado's mountains is shown with: (Left) 210° 700-mb windflow, and (Right) 330° 700-mb wind direction. White sections delineate areas of maximum precipitation (63.8-76.2 mm) per 12 h. Darker sections show areas of less precipitation, and exhibit strong downwind shadowing by mountain barriers.

Evaluating Conditions and Making Decisions: Avalanche warnings are usually issued when 10% or more of the avalanche paths in a specific region are expected to run naturally to the midtrack level or beyond. Warnings cover areas of 2500 km^2 or more; when avalanche conditions are localized, local authorities are notified by telephone. Data needed for warning decisions and data on snowpack stability are logged by 1000, and morning bulletins normally are issued by 1030; however, they may be issued at any hour as necessary.

Warning decisions are based on interpretation of available data, the field observer's hazard estimate, and the forecaster's experience and insight. Basic considerations include appraisals of layer stability in both old and new snow, an estimate of past, present, and future loading rates, and information on the number of people in avalanche areas. Time permitting, the AWC personnel make field checks at various avalanche areas to gather additional information not available from field observers. These field checks include making fracture line profiles at key locations, observing the nature of avalanching, evaluating the distribution of snow in avalanche paths, and noting the type of snow transport taking place. Such observations are phoned to the AWC (see Fig. 3), and the overall situation is discussed in detail. The field observations on the character of blowing snow at the Colorado Mines Peak monitor site are followed by the visual inspection of AWC strip charts and the cumulative mass flux that is computed at the AWC and displayed by an xy plotter (Fig. 5). This technique gives forecasters real-time capabilities in estimating the rate, amount, and location of snow deposition in avalanche starting zones. The quantitative measurements on blowing snow, developed by Schmidt (1971), have been used operationally in Wyoming since 1974 (Tabler, 1974); however, they are new to the AWC personnel, and the graphic presentation of cumulative mass flux (Fig. 5) has added a valuable dimension to avalanche hazard evaluation. Hopefully, additional remote blowing snow monitors can be installed in the future.

Information describing the reaction of snow to explosives, as reported by avalanche control teams, gives forecasters a working knowledge of snow stability. When such data are lacking, forecasters must rely on direct observations of snow structure in pit walls for clues to stability.

Determination of layer stability indicates the likelihood of avalanche release. Once this assessment has been made, AWC personnel estimate the amount and rate of snow deposition needed to start broad-scale avalanching. At this point, mountain-weather forecasts become crucial. As is the case in forecasting other weather-related phenomena, the borderline situations are most difficult to assess. Such situations frequently arise when the snow cover is moderately unstable, avalanche information is missing, and mountain-weather forecasts are uncertain. Constant monitoring of statewide weather and avalanche conditions are mandatory because warning situations may arise quickly and unexpectedly.

Since severe avalanche conditions seldom develop simultaneously throughout Colorado's mountains, warning areas need to be clearly delineated. Specific mountain ranges in a warning area are often named, or the warning area may be designated as an area situated north or south of a line drawn between well-known towns that are easily found on any road map. When a warning area is designated, the number of daily contacts between network stations and the AWC increases because rapidly changing snow conditions frequently dictate a shift in the size of the warning area, or a change in message content commensurate with the degree of avalanche danger.

Issuing and Terminating Warnings: Avalanche warning bulletins, prepared at the AWC, are sent by teletype on the Colorado Weather Wire through the NWS's communication network. Bulletins are aired by local VHF radio, and by recorded telephone messages at special numbers in Denver and Fort Collins. About 50 radio and television stations, major newspapers, and wire services in Colorado simultaneously receive the warning. Persons living in Wyoming and New Mexico are notified through a combination of teletype links and wire services, since many of these people come to Colorado for outdoor activities.

Message content, format, and choice of release times for maximum public exposure are crucial. Experience has demonstrated that even the most concise warning will not reach the public if it is released when media personnel are undergoing shift changes, or when media staff levels are reduced.

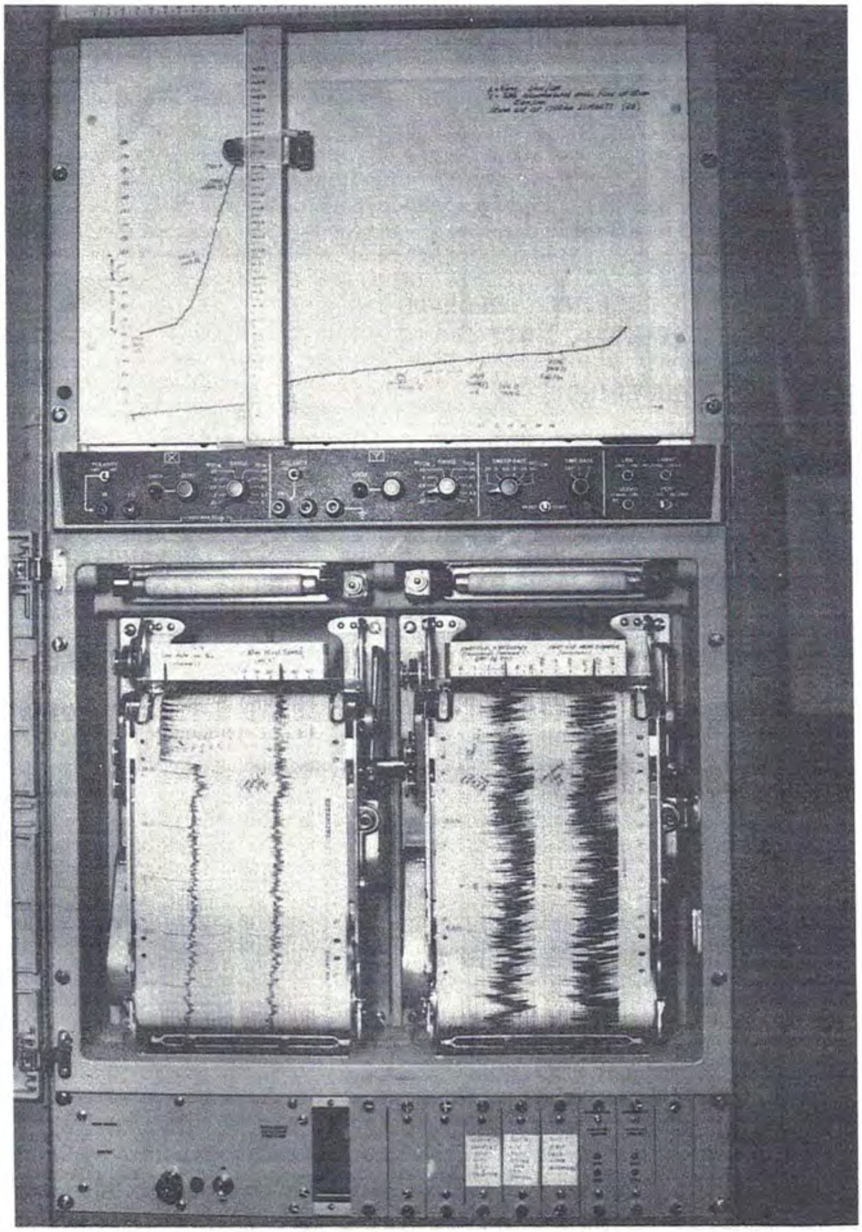


Figure 5. Instrument panels in the Avalanche Warning Center that show data from Colorado Mines Peak: (Below) wind data on strip chart recorders; (Above) xy plot of cumulative mass flux.

Saturday is probably the most difficult day of the week in this regard. Details on dissemination and message content are discussed by Judson (1975). A sample of a recent warning and its termination follows:

ZCZC

AVUS RWRC 111415

AVALANCHE WARNING BULLETIN NUMBER 1

IMMEDIATE BROADCAST REQUESTED

U.S. FOREST SERVICE FORT COLLINS COLORADO

ISSUED 7 AM MST FRIDAY MARCH 11, 1977

.....NORTHERN COLORADO MOUNTAINS.....

AN AVALANCHE WARNING IS IN EFFECT FOR THE COLORADO MOUNTAINS FROM CLIMAX NORTH ALONG THE CONTINENTAL DIVIDE TO THE WYOMING BORDER DUE TO HEAVY SNOW AND HIGH WIND. THIS WARNING IS VALID THROUGH SUNDAY MARCH 13,1977.

THE WARNING SPECIFICALLY COVERS THE FRONT RANGE, TEN MILE RANGE, GORE RANGE, AND THE PARK RANGE NORTH OF RABBIT EARS PASS. DESPITE POOR VISIBILITY, A FEW AVALANCHES WERE REPORTED LAST NIGHT.......MANY MORE ARE EXPECTED.

BACK COUNTRY TRAVELERS ARE URGED TO LIMIT TRAVEL TO FLAT OR GENTLE TERRAIN.

THE NEXT AVALANCHE WARNING BULLETIN WILL BE ISSUED AT 4 PM MST TODAY OR EARLIER IF WARRANTED.

JUDSON.....U.S.F.S. FORT COLLINS

ZCZC

AVUS RWRC 132330

AVALANCHE WARNING TERMINATION, BULLETIN NO. 5

IMMEDIATE BROADCAST REQUESTED

U.S. FOREST SERVICE FORT COLLINS COLORADO

ISSUED 430 PM MST SUNDAY MARCH 13, 1977

.....NORTHERN COLORADO MOUNTAINS.....

THE AVALANCHE WARNING FOR THE NORTHERN COLORADO MOUNTAINS IS NOW TERMINATED. NO NEW AVALANCHES HAVE BEEN REPORTED IN THE LAST 24 HOURS. THIS INDICATES A SIGNIFICANT STABILIZING OF THE MOUNTAIN SNOWPACK SINCE YESTERDAY.

LATE SATURDAY AFTERNOON WE RECEIVED REPORTS OF 35 ADDITIONAL AVALANCHES IN THE WARNING AREA, BRINGING THE TOTAL SINCE FRIDAY MORNING TO 85.

ALTHOUGH NO WARNINGS ARE NOW IN EFFECT, BACKCOUNTRY TRAVELERS SHOULD CONTINUE TO BE ALERT TO SIGNS OF UNSTABLE SNOW AND TRAVEL WITH CAUTION.

WILLIAMS.....U.S.F.S. FORT COLLINS

Assessment and Outlook

The warning program is functioning smoothly in its fourth winter of formal operation. Most of the problems encountered in its early inception have been solved. Warnings have been well received by the media, and public response has been reasonably good. Avalanche-awareness levels need to be enhanced among the public in general, and the ski mountaineering group in particular. Field reports of persons skiing in large uncontrolled avalanche paths increase as more people seek the solitude and exhilaration of skiing deep powder far removed from overcrowded ski areas. Numerous cases have been documented where skiers have pursued their sport in the most dangerous of avalanche paths, even when they knew avalanche warnings were in effect and snow conditions were unstable. Conversely, some groups have either canceled touring plans, or have turned back in response to warnings and evidence of obvious danger.

Improvements needed in the existing program include: (1) fine tuning of the orographic precipitation model, (2) implementing a more efficient system for weather-data retrieval, (3) establishing more reporting stations, (4) upgrading existing stations, (5) improving communications between field sites and the AWC, and (6) installing another toll-free telephone line for public information on snow conditions.

The Rocky Mountain Forest and Range Station is actively pursuing research on computerized avalanche danger rating models, but operational use of such models over large areas will take several years to develop. Future plans for the program include expanding the warning system to the mountainous regions of Wyoming and New Mexico.

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