# *Fire Weather Case Study* - Mann Gulch Fire, Montana
## August 5, 1949

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### *Background Information:*

The Mann Gulch Fire burned in August 1949 approximately 20 miles north-northeast of Helena, Montana (Figure 1). The fire was ignited by lightning on August 4 near the top of an east-west oriented ridge between Mann and Meriwether Gulches. It was one of ten lightning fires that started that day on the Canyon and Helena Ranger Districts of the Helena National Forest. A group of United States Forest Service smokejumpers, attached to the Missoula Smokejumper Base, initial attacked the fire the afternoon of August 5. The fire was about 50-60 acres in size when fifteen smokejumpers jumped the fire at 1600 hours. A local district fire guardsman joined them at 1700 hours. Extreme fire behavior (spotting, rapid rate of spread, and a sudden increase in fire intensity) developed around 1745 hours, overrunning the firefighters and resulting in the deaths of twelve smokejumpers and the local fire guardsman. Controversy surrounding the events of that afternoon continued for many years. A product of this incident was increased research into wildland fire behavior and the eventual development of a national fire danger rating system.


**Figure 1 – Mann Gulch Fire Location**

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### *Case Study Objective:*

Although topography and fuel conditions (Rothermel) contributed to extreme fire behavior on the Mann Gulch Fire, the intent of this report is to analyze weather conditions to determine if a “critical fire weather pattern” also contributed to the “blowup.” A “blowup” is defined as a sudden increase in fireline intensity or rate of spread of a fire sufficient to preclude direct control or to upset existing suppression plans. It is often accompanied by violent convection and may have other characteristics of extreme fire behavior. "Critical fire weather patterns" are defined as atmospheric conditions that encourage extreme fire behavior resulting in large and destructive wildland fires.

## *Weather Discussion:*

A record-setting heat wave gripped much of the Western United States, including Montana, in early August 1949. The heat wave actually began on July 30 when strong high pressure aloft pushed northward from the Desert Southwest into the Canadian Rockies. Hot, dry weather persisted for the next week. Maximum temperatures climbed well into the 90s at Helena, while minimum relative humidity dropped to as low as 12 percent.

The August 5 upper level pattern at 500 mb (approximately 18,000 ft msl) is graphically displayed in Figure 2. The 00Z chart time correlates to late afternoon, within an hour or two of the Mann Gulch blowup. For clarification purposes, the Canadian, Washington, Oregon and California coastline is shown. Just to the southeast of the low pressure center is Vancouver Island.

High pressure aloft was centered over Utah with a ridge axis through eastern Montana and central Canada. Meanwhile, a low pressure center was located near the northern tip of Vancouver Island with a trough off the Washington and Oregon coasts.

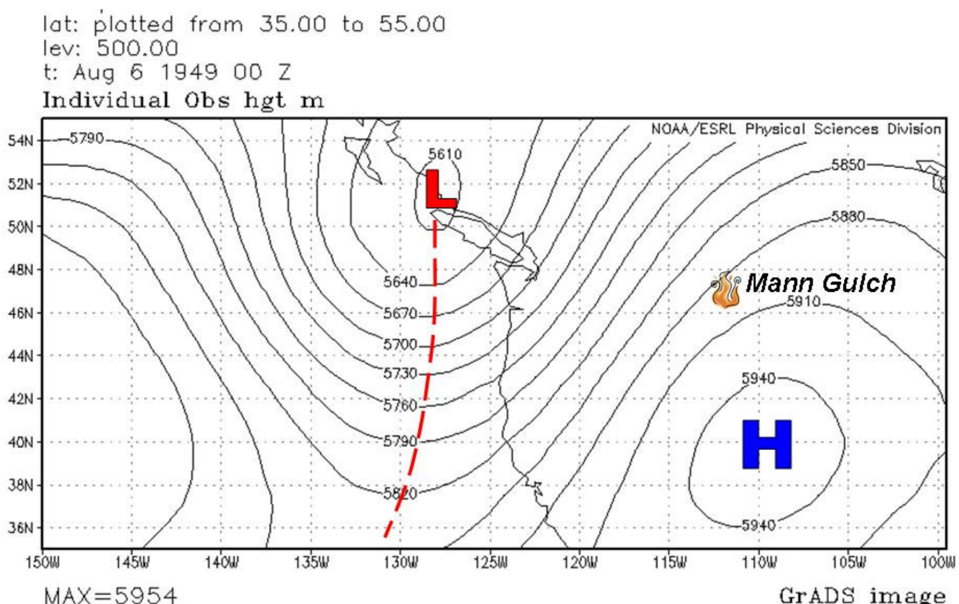


**Figure 2 - Afternoon 500MB Map August 5, 1949**

The Mann Gulch area was situated between these two pressure centers, west of the high pressure ridgeline through eastern Montana and east of the upper trough. The upper trough was advancing toward the coast, pushing the high pressure ridge east. The winds at 18,000 ft msl over the fire were from the southwest (parallel to the contour lines in figure 2). While the strongest upper level winds (jet stream) were over Washington and Oregon, upper level winds over Mann Gulch were on the increase. Cooler air aloft was also moving into Montana ahead of the upper trough.

At the same time, the surface pressure pattern (Figure 3) indicated a low pressure system (heat low) over western Idaho, with a thermal trough southward though Nevada (indicated by the dotted line). Heat lows and thermal troughs are quite common during the summer in the western United States. They form under strong high pressure aloft due to intense heating of the air near the surface. The surface wind is typically light during the morning near the thermal trough; however, the air can become very unstable during the afternoon resulting in gusty and shifting winds. Strong up and downward drafts often result in very turbulent air and erratic fire behavior. The Mann Gulch area was located just to the east of the heat low during the time of the blowup.

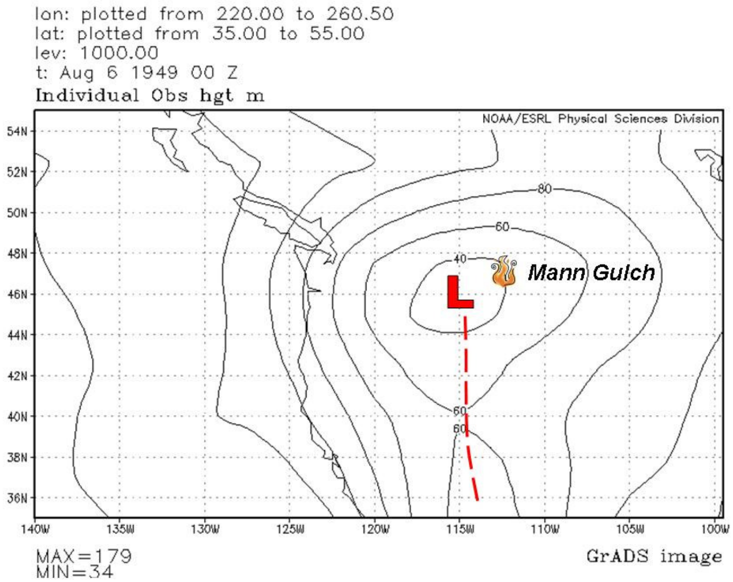


Figure 3 - Afternoon Surface Pressure Map August 5, 1949

The afternoon relative humidity pattern over the western United States (Figure 4) indicated a tongue of very dry air extending from the Great Basin into the Northern Rockies (the shaded area). Within this area, surface relative humidity ranged from 10-20 percent. The Mann Gulch area was located near the 15 percent contour line within this area.

Thus, at about the time of the Mann Gulch Fire blowup, and the resulting entrapment of the smokejumpers, the weather pattern at the fire site was dominated by: an upper level ridge of high pressure, a surface heat low (or thermal trough), and very dry air near the surface.

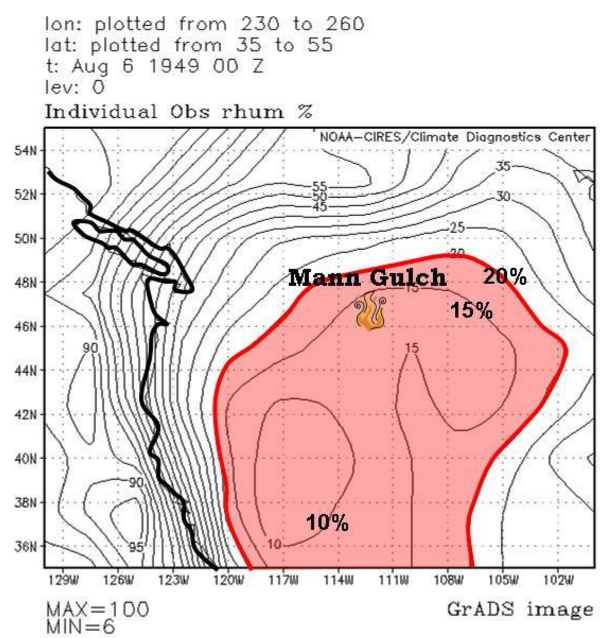


Figure 4 – Afternoon RH Map August 5, 1949

## *Critical Weather Elements:*

There are four critical weather elements common to large and destructive wildland fires: low atmospheric moisture/relative humidity, strong wind, unstable air, and drought. Low relative humidity (regional values can vary between 15 and 40% depending upon fuel model) must always be present for the development of large and intense wildland fires. In addition to low relative humidity, either strong wind or unstable air must also be present. Drought is often associated with large timber fires, but is not is not necessary for large grass fires. We will now examine how many of these elements were present during the Mann Gulch blowup.

***Low Atmospheric Moisture:***

Dry air in the lower levels of the atmosphere (i.e. low relative humidity) significantly lowers the moisture content of fuels, making them easier to ignite and carry fire. Low relative humidity also increases the probability of spotting.

Figure 5 graphs the daily maximum temperature and minimum relative humidity at Helena during August. On August 5, the high temperature was 97 degrees Fahrenheit and the minimum relative humidity (RH) was 16%. This is much warmer and drier than usual. Helena averages 85 degrees Fahrenheit, and a minimum relative humidity of 30% in early August. The 16% RH correlates well with the tongue of dry air over the Great Basin and northern Rockies displayed earlier.

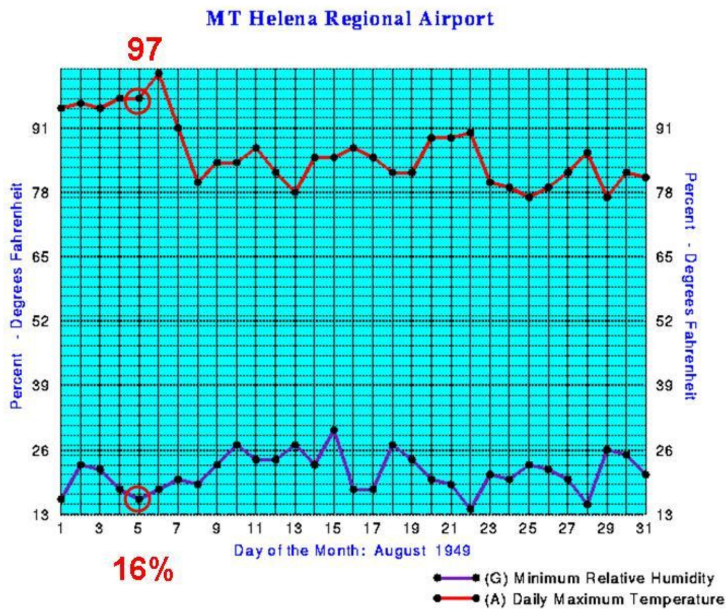


**Figure 5 – Helena MT August 1949 Temperature and RH**

**Conclusion:**
**Low atmospheric moisture was a critical element in the blowup of the Mann Gulch Fire.**

***Strong Wind:***

Extreme burning conditions have been associated with strong frontal, thunderstorm and foehn winds. Wind affects wildland fires in a number of ways. Wind: 1) supplies additional oxygen to the fire, increasing fire intensity, 2) preheats the fuels ahead of the fire, and 3) increases rate of spread by carrying heat and burning embers to new fuels. Strong wind produces wind-driven fires.

The wind at Helena was reported at 5 to 8 mi/h during the morning. At noon, the wind increased to 15 mph, the temperature jumped from 81 to 91 degrees, and the relative humidity dropped from 40% to 24%. The morning surface-based inversion had broken and cumulus clouds started to form. Then at 1530 hrs the wind switched to the south and increased to 24 mi/h. Cumulonimbus clouds (CBs) and virga were visible to the west and south of Helena. Although no thunderstorms or distant lightning were reported at Helena that afternoon, CBs and strong, gusty southerly winds at 14 to 32 mi/h continued the remainder of the afternoon and evening. Eyewitness accounts of smoke drift at the Mann Gulch fire suggests a wind shift to strong southerly winds occurred between 1615 and 1650 hours. This is consistent with the wind shift at Helena due to cumulonimbus downdraft and outflow winds. The upper level wind speed and direction would have moved the CBs at Helena into the Mann Gulch area at about 1630 hours causing the sudden increase in wind speed and a shift in direction from the south rather than the southwest. The wind at Helena continued to blow strongly from the south at 14 to 22 mi/h throughout the remainder of the afternoon and evening and this was most likely the case at Mann Gulch.

At about 1700 hours, Canyon Ferry District Ranger Robert Jansson reached the mouth of Mann Gulch by boat and attempted to walk up the gulch to reach the smokejumpers. He estimated the wind at Mann Gulch to be between 20 and 30 mi/h with gusts to 40 mi/h. Because of the orientation of the canyons and ridges, a strong southerly wind created extreme turbulence at the mouth of Mann Gulch, producing strong winds that blew up the gulch (from the southwest) toward the smokejumpers" (Rothermal, p4). Two fire weather stations in the vicinity also reported strong wind at 1700 hours: Canyon Ferry Ranger Station at 16 mi/h and Hogback at 15 mi/h.

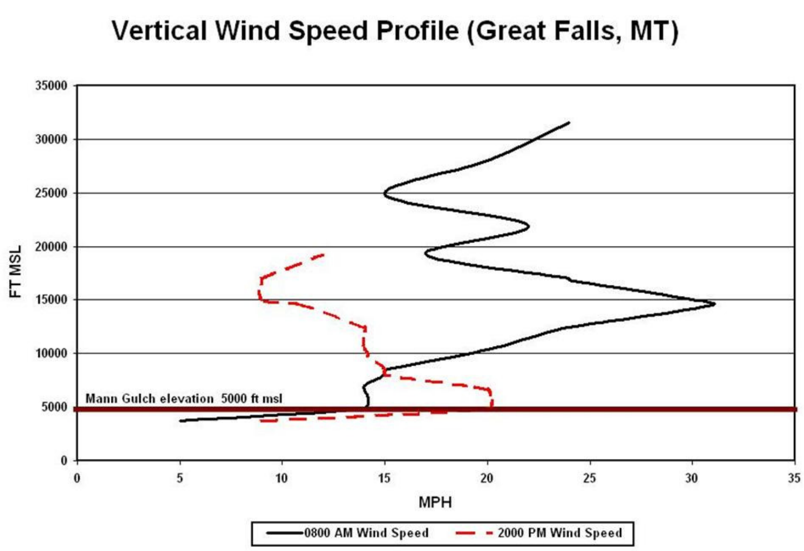


**Figure 6 – Great Falls August 5, 1949 Wind Profile**

Over the years, there have been conflicting theories as to what caused the fire to move from the ridge on the south side of Mann Gulch to the mouth of the gulch and then to the north side. One explanation is that thunderstorm downdrafts caused the fire to spot across the gulch. The other theory is that fire whirls developed on the lee (north) side of the ridge due to southerly winds down the Missouri River that caused the fire to spot on the north side. In order to determine which theory is the more plausible, the Great falls, MT upper air (radiosonde) wind, temperature and dew point data was evaluated to determine the cause of the strong wind observed at Mann Gulch. To accomplish this, two relatively new analysis programs were used: ANALYZE (Werth J.) and WINDEX (McCain). Figure 6 displays the August 5, 1949 vertical wind profile near Mann Gulch at 0800 and 2000 hours. The 0800 profile showed increasing wind aloft (south to southwesterly in direction) with a speed maximum of 30+ mi/h at 15,000 ft msl, or about 10,000 ft above the elevation of Mann Gulch. This is much stronger than the usual upper level summer wind in the northern Rockies. At 2000 hours, the strongest wind (20+ mi/h) had descended (or surfaced) to the same elevation as Mann Gulch and the vertical profile showed decreasing wind aloft. Byram (see references) described this profile of strong surface wind with decreasing wind speed aloft as one of the most dangerous for blowup fires. The strong upper level winds over the fire area during the morning surfaced later that day due to very unstable air mixing these winds downward to the surface. Southerly winds at 20 mi/h would have produced eddy winds and fire whirls strong enough to cause the spot fires north of the gulch. However, this isn't the complete story. ANALYZE and WINDEX also indicate the airmass over Mann Gulch was unstable enough for convection and the formation of CBs and possible thunderstorms with a downdraft/outflow potential of 40-50 mi/h. Although neither Helena nor eyewitness accounts from Mann Gulch mentioned thunderstorms when describing the weather that day, Helena did report CBs and downdraft winds of up to 32 mph from mid-afternoon through early evening. Thus, it is also likely that Mann Gulch received strong downdraft winds from CBs in addition to the surfacing of strong upper level winds. So both theories are correct. The strong wind that caused the fire to spot across Mann Gulch and overrun the smokejumpers was the result of both strong surfacing wind and convective downdraft/outflow wind. In any event, the topography of the area resulted in strong eddy winds and fire whirls at the mouth of Mann Gulch.

**Conclusion:**
**Strong wind was a critical element in the Mann Gulch Fire blowup.**

***Unstable Air:***

Unstable air enhances vertical motion in the atmosphere. As with wind, upward movement of air increases combustion by supplying more oxygen to the fire. It also enhances the vertical growth of the smoke column. As the height and strength of the smoke column increases, the potential for gusty surface winds, dust devils and fire whirls also increases. Spotting may become profuse all around a fire as large firebrands are lifted in the smoke column. Unstable air increases the probability of plume-dominated fires.

There are many indications that the air over Mann Gulch was very unstable that afternoon. One of the surviving smokejumpers recalled that, on the flight to Mann Gulch, "The air was so turbulent that we were all half sick and were trying to be in the stick to jump and get on the ground." (MacLean, p51) The DC-3 aircraft also encountered heavy turbulence over Mann Gulch and had to climb to a higher-than-usual altitude to drop the cargo. Ranger Jansson also reported seeing a number of vortices at the lower end of Mann Gulch at about the same time the fire spotted across to the north side of the Gulch. At 1800 hours, and at a distance farther from the fire, Jansson described the smoke column as, "One big whirl and one little whirl side by side. The little whirl came right off the big whirl."

The Haines Index is another indicator of unstable air. It combines the stability and dryness of the lower atmosphere into an index that correlates well with large fire growth. The Index ranges between 2 and 6. Values of 2 and 3 are indicative of moist, stable air. Values of 5 and 6 indicate dry, unstable air. The calculated high elevation Haines Index for the Mann Gulch Fire, using the Great Falls 0800 and 2000 hour 700 and 500 mb temperature and dew point data, was a solid 5 and a borderline 6. The Haines Index climatology for Great Falls (Werth J. and P. Werth) indicates a Haines Index of 6 occurs only 2% of the days in August. Thus, a Haines index this high is relatively rare. All indications point to a very unstable and dry airmass over Mann Gulch that day.

**Conclusion:**
**Unstable air was a critical element in the blowup of the Mann Gulch Fire.**

***Drought:***

Drought affects fuel availability by lowering the moisture content of both live and dead fuels, making them more combustible. Drought conditions are NOT a prerequisite for fires to occur and spread, but there is a close relationship between drought conditions, large wildland fires and extremely difficult fire suppression.

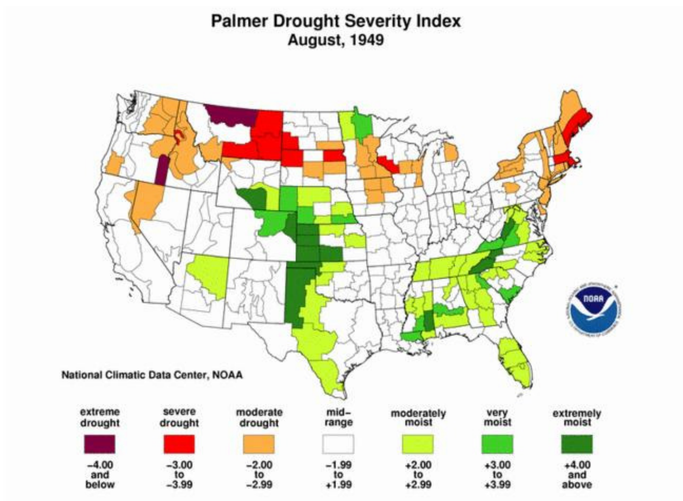


**Figure 7 – Palmer Drought Severity Index August, 1949**

The Palmer Drought Index (PDSI) has been extensively used to measure drought throughout the United States. Although primarily developed for agricultural use, the PDSI is also a good indicator of fire season severity, especially in forest fuels.

Figure 7 displays the August 1949 PDSI by climate zone. While most of eastern Montana was in severe to extreme drought, near normal conditions were indicated for the Mann Gulch area. However, the adjacent climate zone to the north indicated extreme drought.

Figure 8 displays Helena's precipitation from November 1948 through July 1949. Helena received above normal precipitation during the winter months (November through February). April was drier than usual, but May was again wet. June was a little drier than normal, but July was much drier. Thus, while the long-term PDSI did not indicate drought in this part of Montana, short-term dryness was a factor.

**Conclusion:**
**Drought may or may not have been a critical element in the blowup of the Mann Gulch Fire.**

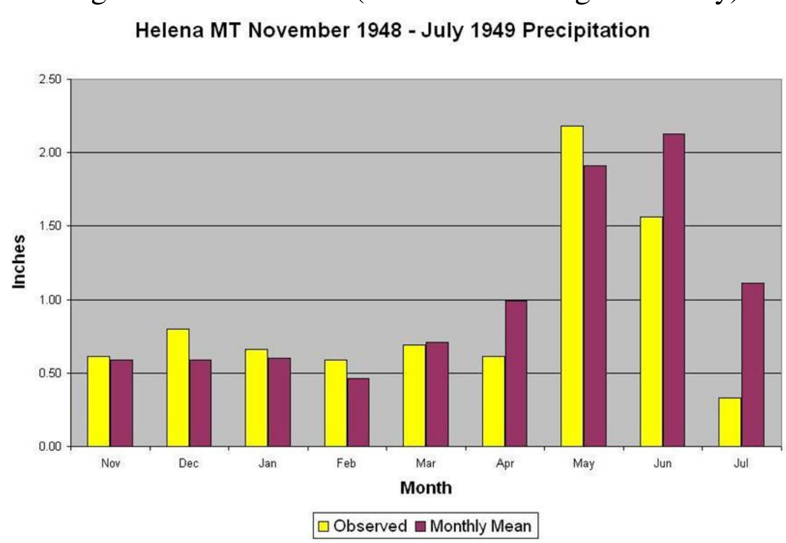


**Figure 8 – Helena MT Nov 1948 through July 1949 Precipitation**

In summary, at least three of four critical weather elements (low relative humidity, unstable air and strong wind) were present during the Mann Gulch Fire.

## *Critical Fire Weather Pattern:*

Let me define "critical fire weather pattern" one more time. It occurs when atmospheric conditions encourage extreme fire behavior resulting in large and destructive wildland fires. In this section, we will determine if, or which critical fire weather pattern significantly contributed to the Mann Gulch blowup.

The concept of critical fire weather patterns has been around for many years, but has been under-used in fire weather forecasting. While individual weather elements are highlighted in fire weather forecasts, they are seldom tied to cyclical large-scale atmospheric patterns that continually change on a daily and seasonal basis.

The first publication concerning critical fire weather patterns was "Synoptic Weather Types Associated with Critical Fire Weather" by Schroeder et al. (1964). This study covered the lower 48 states and concluded that **"periods of critical fire weather are associated with relatively few weather patterns."**

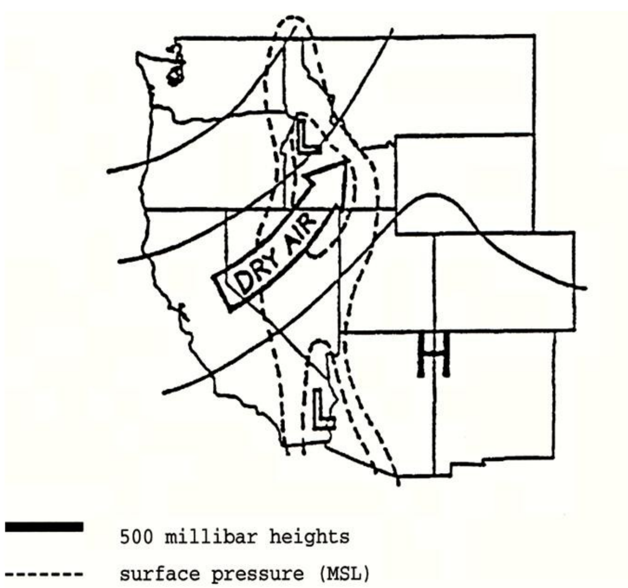


**Figure 9 – Idealized "Breakdown of the Upper Ridge" Pattern**

"Predicting Major Wildland Fire Occurrence" by Ed Brotak and William Reifsnyder (1977) detailed the relationship of central and eastern United States wildland fires to surface frontal systems and upper level troughs and ridges.

"Wildfire Behavior Associated with the Upper Ridge Breakdown" by Nicholas Nimchuk (1983) documents the relationship of the breakdown of an upper level ridge to extreme fire behavior conditions in western Canada.

Figure 9 illustrates a critical fire weather pattern: Breakdown of the Upper Ridge. There are three defining factors of this pattern: an upper level ridge at 500 mb moving off to the east, a surface thermal trough (or surface low) on the west side of the upper ridge, and dry air. The highest risk of explosive fire behavior occurs when these factors converge. This summer weather pattern typically produces hot temperatures, very low relative humidity, unstable air, strong gusty wind, and possible dry lightning. Any one of these weather elements can cause fire problems but, when combined, can frequently produce large and destructive fires.

The reconstructed upper level and surface weather maps for Mann Gulch on August 5, 1949 are markedly similar to those shown for the "Breakdown of the Upper Ridge" critical fire weather pattern. The weather elements described by survivors of the burnover and other firefighters in the vicinity are consistent with this pattern.

Thus, based on eyewitness accounts and the reconstructed weather pattern of the day, we can conclude with a high level of confidence that a "Breakdown of the Upper Ridge" critical fire weather pattern significantly contributed to the Mann Gulch Fire blowup.

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***Summary:***

Thirteen firefighters tragically perished on August 5, 1949 shortly after initial attacking the Mann Gulch Fire, 20 miles north-northeast of Helena Montana. Twelve of the fatalities were members of a group of fifteen smokejumpers. Prior to jumping the fire, one of the survivors and the jump spotter stated that the fire was relatively quiet and wasn't burning much. Yet only two hours later, with little warning, extreme fire behavior developed, trapping and overrunning the firefighters. Little did they know that their destiny was tied to a critical fire weather pattern: the "Breakdown of the Upper Ridge."

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