

Project Skyfire Lightning Research

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PROJECT SKYFIRE, conducted by the U. S. Forest Service, is a study of meteorological problems associated with lightning-caused forest fires. As part of a nationwide research effort directed toward the control and wise use of fire, the Project's goal is to obtain a better understanding of thunderstorms, lightning, and their relationships to forest fuels.

What *is* the lightning fire problem? Consider this; at this very moment some 1,800 thunderstorms are in progress over the earth's surface. During the next 20 minutes these storms will produce 60,000 cloud-to-ground lightning discharges (Fig. 1). Some of them will start fires (Fig. 2). This sequence of events occurs 9,000 times each summer in America's forests and grasslands (including Alaska and Hawaii). During the period 1946-1962, the United States experienced more than 140,000 lightning-caused fires. Eighty-five percent of them occurred in the western United States, causing severe losses of timber, wildlife, watershed, and recreation resources. We believe that the magnitude of the lightning fire problem calls for intensive research on lightning phenomena.

Project Skyfire's research program embraces four areas of study:

1. Regional study of thunderstorms and resultant forest fires.
2. Study of individual thunderstorms.
3. Characteristics and effects of individual lightning discharges.
4. Weather modification.

Let's look briefly at some of the objectives and research methods under each of these topics.

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REGIONAL STUDY OF THUNDERSTORMS AND LIGHTNING FIRES

Since 1955 we have received special thunderstorm reports from a network of forest fire lookouts located throughout the northern Rocky Mountain states. These observations tell when and where thunderstorms occur, how long they last, and how much lightning they produce.

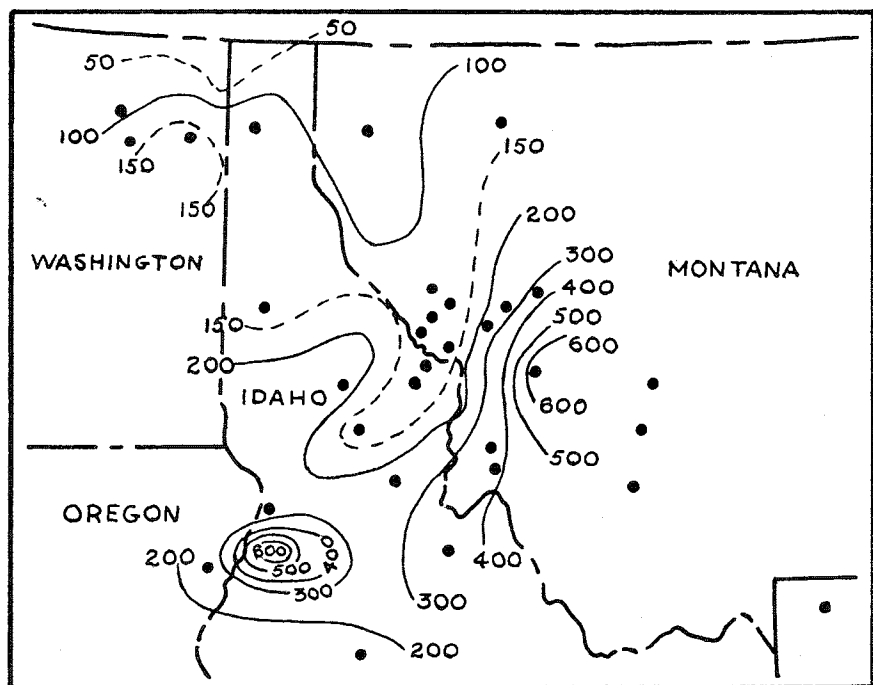


Fig. 3. Mean annual observed cloud-to-ground lightning discharges 1955-1960.

A specific example of one use of these data is this map, (Fig. 3). It shows how observed lightning discharges were distributed throughout the region in the period 1955-1960. Note the zones of high lightning occurrence near the Idaho-Oregon border and in southwestern Montana, where observers reported averages of 600 dis-

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charges per 1,000 sq. mi. per year. The map gives rise to these questions:

1. What causes these patterns of lightning occurrence?
2. Are there likewise patterns of lightning *fire* occurrence? Preliminary examination of 4,000 fire reports from the region indicates that such patterns do exist, and that some high fire zones coincide with relatively low lightning occurrence zones.
3. Is lightning a more efficient fire starter in some areas? If so, what combinations of meteorological, topographical, and fuel conditions account for this?
4. Can we develop a "natural risk" factor for incorporation into the National Fire Danger Rating System?
5. In keeping with the theme of this conference, one might well ask (although seeking the answer is not a study objective), "What ecological effects would high fire and lightning occurrence zones exert on plant and animal life in these zones?"

We expect to find answers to some of these questions as we analyze more data from the lookout network.

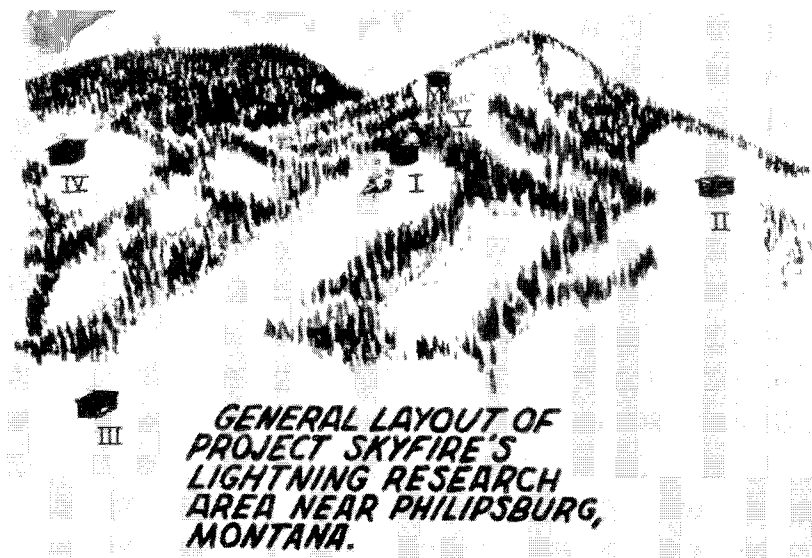


Fig. 4. Artist's sketch of Project Skyfire Research Area.

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STUDY OF INDIVIDUAL STORMS

From Figure 3, it is seen that one area of high lightning occurrence is located in southwestern Montana. This area was chosen as the field site for intensive study of individual mountain thunderstorms. The area is located in the Deerlodge National Forest near Philipsburg, Montana. An artist's sketch looking north at the research area is shown in Figure 4. The five sites were located in a prescribed geometrical pattern. The instrumentation at each site includes an electronic means of recording the type and number of lightning discharges

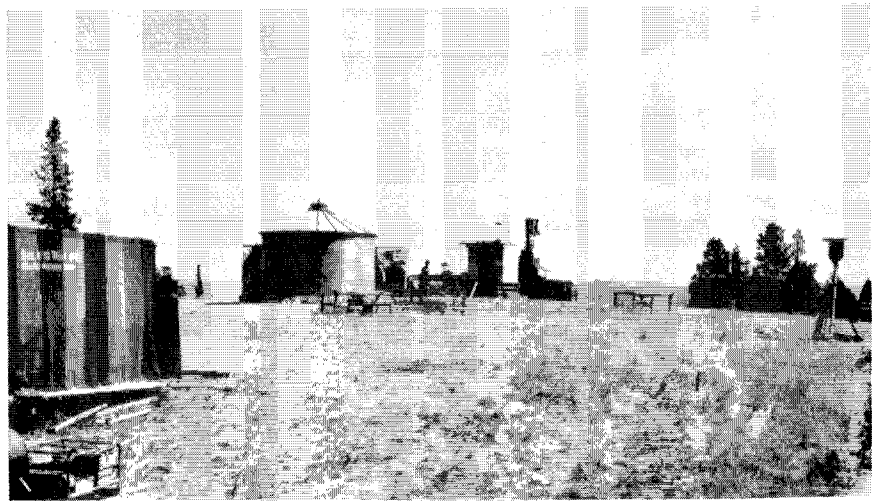


Fig. 5. Central recording system at Site I, Project Skyfire.
U. S. Forest Service Photo.

and an alidade device for visually locating them. Located at site 1 (Fig. 5), is the central recording system, located in the metal building on the left; a truck mounted radar, which is used to determine the location, height, and movement of the storms; a blue-gray trailer, in which coordination of the many observations is accomplished; a white building from which lightning frequency observations are made; and on the far right a meteorological instrument shelter.

A model of a mountain thunderstorm has been derived from observations made in the research area. This model, whose character-

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istics are a composite of many individual storms, is shown diagrammatically in Figure 6. The cloud model's base is 12,000 feet m.s.l. and its visual top extends to 36,000 feet. A single storm might have its base anywhere from 6,000 to 15,000 feet with other dimensions equally variable. The temperature at its base is very near freezing. Two items of particular interest are the height of the radar top and height of the negative charge center. This negative charge center is one of the prime operators in the creation of lightning. When a lightning discharge occurs, part of this negative electric charge will be lowered to the earth. We are now attempting to determine if electric-

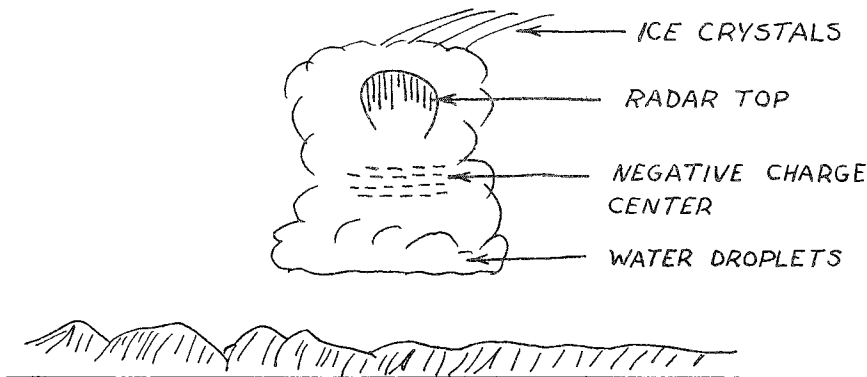


Fig. 6. Diagram of an average thunderstorm in the northern Rocky Mountains.

al properties of the thunderstorm can be adequately obtained from a radar image of the cloud. We are attempting to give an affirmative answer to the question, "Can we develop a method for determining expected fire loads some hours in advance by utilization of radar?" Both of these attempts are necessary to obtain this goal: To determine if there are measurable physical factors in a thunderstorm that are associated with its electrical activity. If so, what are they; how do we measure them; how can the knowledge of their presence best be employed?

One thunderstorm type that bears further investigation is the one characterized by high bases (17,000 feet m.s.l.), a low level of electri-

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cal activity (1-2 cloud-to-ground lightning discharges per minute), and an extreme lack of precipitation. This combination is probably an efficient fire starter.

THE CHARACTERISTICS AND EFFECTS OF INDIVIDUAL LIGHTNING DISCHARGES

Discharge Characteristics.—We have recently developed fast-response electronic instruments to record the individual electrical components of the lightning discharge. Two of our newest lightning sensors, called “field-change meters” were tested last summer. These were developed with time constants of 0.5 seconds and .005 seconds (5 milliseconds). The electrical output of these instruments is recorded on magnetic tape at a high speed and later transferred onto an oscillograph at a lower speed. This speed differential expands the scale of time a great deal and allows examination of the field changes in a more convenient manner. One type of field change associated with a cloud-to-ground discharge is shown in Figure 7. Note the

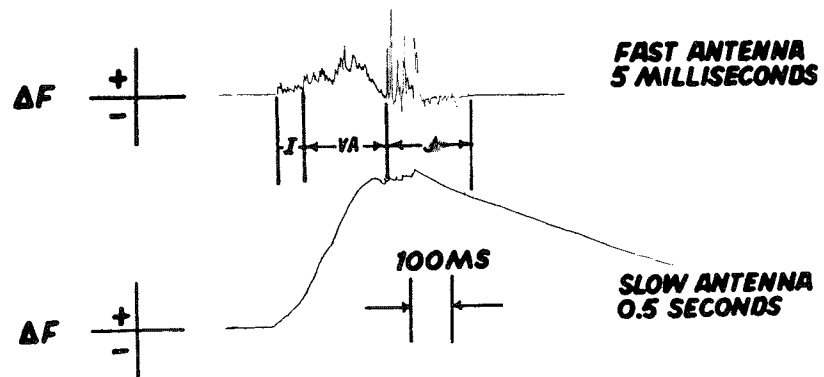


Fig. 7. Electric field change, cloud-to-cloud discharge (within field reversal distance).

greater detail given by the faster meter. Each tall “spike” represents a surge of current along the discharge channel. To the casual observer of lightning all of these spikes appear as one bright flash. In each case

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the change in the electric field, ΔF , returns to zero after the spike. The entire discharge lasted about .35 seconds (350 milliseconds).

Consider now another type of cloud-to-ground discharge, Figure 8. This event is distinctly different from the one in Figure 7, because, following the third return stroke, or spike, the value of ΔF does not return to zero for some .18 seconds (180 milliseconds). This indicates that an electrical current flowed in the discharge channel for a relatively long time. The sustained current flow could result in considerable heating of forest fuels at the discharge's ground terminal. Is this

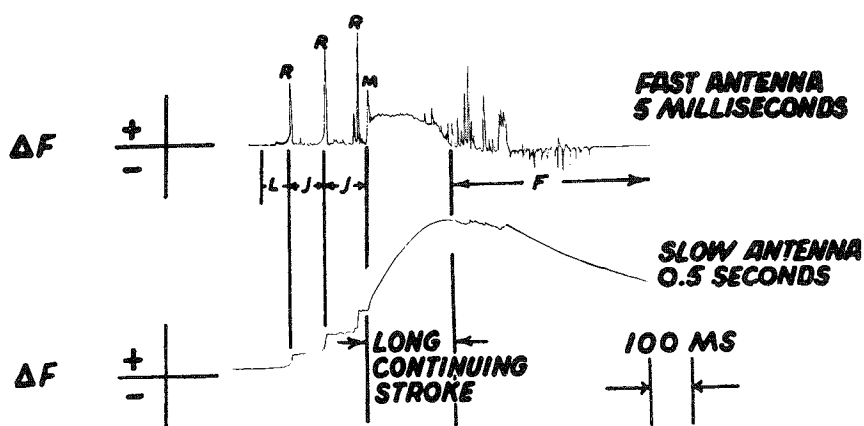


Fig. 8. Electric field change, cloud-to-ground discharge (with long-continuing stroke).

discharge a fire starter? About 25 percent of the discharges recorded last summer were of this type.

In the near future we expect to compare individual structurally damaged and fired forest fuels with the electrical properties of the lightning discharge which caused the damage or fire. The problem is to locate the ground terminal of a particular recorded discharge. New instrumentation must be developed for this purpose.

Lightning Effects on Trees.—Trees often become ground terminals for lightning discharges. More often than not, a fire-setting discharge initially ignites fine fuels near the base of a struck tree. However, it is not uncommon for the tree bole to be ignited first. Our empirical

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observations indicate that many struck trees suffer structural damage whether or not ignition occurs at all. We decided to examine this common feature—the structural damage—and in 1961 initiated a tree-by-tree search of 10,000 acres of timber in the Philipsburg area. Some 1,000 live, lightning-struck Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco glauca) trees were examined. The most common damage was a bark-depth furrow along the tree bole, but lightning gouged out deeper and wider furrows on one-fourth of the trees, causing actual loss of wood. We made damage and tree measurements on 53 of the most recently struck trees. Three interesting results are:

1. On *bark-loss* trees (Fig. 9) lightning often left a narrow strip of shredded inner-bark fibers along the scar axis, adhering to the newly exposed wood of the bole.
2. On *wood-loss* trees (Fig. 10) lightning usually removed the wood in two parallel slabs or strips. In this case, lightning rip-

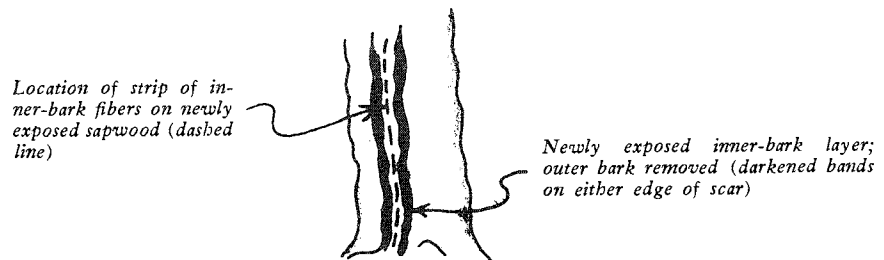


Fig. 9. Bark loss damage showing strip of shredded inner-bark fibers along scar axis.

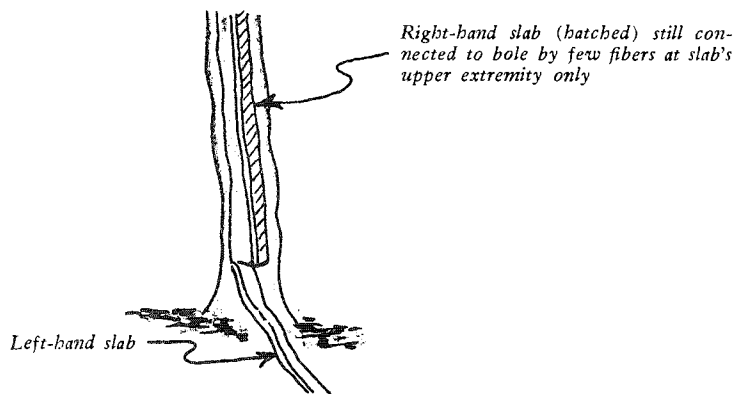


Fig. 10. Wood loss damage showing parallel slabs removed from bole.

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ped loose a pair of straight slabs, each 8 inches wide, 3 inches thick, and 44 feet long. The right-hand slab on this 90-foot high tree is attached to the bole by a few fibers at its upper extremity.

3. Average diameter (b.h., o.b.), height, volume, and age was greater on the *wood-loss* trees than on the *bark-loss* trees. This may indicate that the character of the tree, as well as that of the lightning discharge, influences the amount of damage done by lightning.

We anticipate extending this examination of structurally damaged trees to lightning-fired trees.

WEATHER MODIFICATION

If we are to modify lightning characteristics, we must first determine what parameters are at work in the cloud that cause the discharge. In order to have lightning, electrical charge must be separated within the cloud. The state of a cloud—water, ice, or a mixture of the two—determines the cloud's degree of charge separation. The billowing clouds, Figure 11, the ones with the well defined edges, are

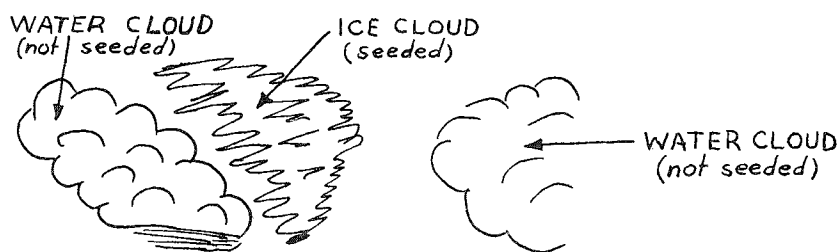


Fig. 11. Diagram of seeded and non-seeded cumulus cloud.

water clouds. The other one, with a fuzzy outline, is ice. At a later stage of the water clouds' life, some of the water droplets may freeze while others may not, thus leading to a transition of the cloud's electrical characteristics. The ice cloud will remain all ice and will dissipate. So we attempt to turn the water cloud to ice to determine how this modification may change the electrical characteristics. To do this, we

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seed the cloud with silver iodide particles using an airborne generator. Under certain conditions, these tiny particles will cause the water droplets to freeze and turn the water cloud to ice. We call this transition "glaciation."

To determine statistically if seeding actually has any influence on the cloud's electrical activity, we choose pairs of thunderstorm days and either seed all the clouds within the test area or none of them as decided by a random choice. This allows us to determine by statistical methods whether the seeding changes the lightning's frequency and characteristics. Observations of frequency and characteristics are made with the field meters and field change meters. As for results, two years of observations have yielded only a small sample-size of eighteen pairs of days. This precludes a statistical conclusion at this time. However, 38 percent less cloud-to-ground discharges were recorded on seeded days. The probability of this distribution occurring by chance is about one in four as shown by a two-sided test. Plans have been made to extend the study until valid conclusions based on a larger sample size can be reached.

CONCLUDING STATEMENT

Project Skyfire's goals are parallel to those of researchers in other branches of science. First, we must understand; we must understand the many aspects of the thunderstorm, of lightning, of forest fuels and how each influences the other. Secondly, we wish to control these interactions. If we want lightning, let us have it; if we do not want it, let us prevent it. When we have acquired these, understanding and control, the Project will have reached its goal. Our methods and results can then be combined with those of workers in prescribed fire research and with many others so that the best use, for the most people, for the longest time, can be derived from our nation's forests.