Weather and Fire Control Practices—1970

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THE DEMAND for aviation weather forecasters by the military in World War II resulted not only in the training of large numbers of forecasters, but also an upsurge of interest in meteorology and the atmospheric sciences. Many of these war-trained forecasters found their way into the civilian weather services at the end of the war. As the forestry services began to demand meteorological information in connection with their forest fire control activities, many forecasters found themselves called upon to produce specialized fire weather forecasts. Other trained meteorologists either entered or returned to the forestry profession itself, and some of these became involved in fire control activities or in forest fire research. Thus for the first time, a sizable group of professionally trained meteorologists became intimately involved in the problems of the interactions between weather and forest fires.

The decade from 1950 to 1960 saw much experimental and observational study of fire-weather relationships. In a review presented 10 years ago at the Fifth World Forestry Congress (Reifsnyder 1962), I found some two dozen post-war studies. This was a period of hypothesis development and educated speculation on fire-weather relationships.

A number of disastrous fires during this period stimulated the U.S. Forest Service to look for ways of increasing the meteorological expertise of their fire control personnel. In 1958, the Forest Service established the first of a series of national fire-behavior training courses attended by fire control supervisory personnel. Meteorology was recognized as important, and more than a third of the 5 week intensive course was devoted to basic atmospheric science. The fire weather specialist was almost nonexistent at this time. Men who had extensive training and experience in both fire and weather were very rare indeed.

The United States Weather Bureau had had a fire weather service since 1916, but development of the service was slow in early decades. By-and-large, fire weather forecasting was part-time duty for the forecasters. There were a few full-time fire weather forecasters, but they rarely had the opportunity to ply their trade at the scene of large fires in immediate cooperation with fire control personnel.

In 1961, the Weather Bureau in cooperation with the Forest Service and the Department of the Interior prepared a plan for a national fire-weather service (Svorcek 1965). Adoption of the plan resulted in immediate expansion of specialized fire weather services. Eighteen new fire weather offices were established, and an equal number of mobile forecast units were acquired. The plan was revised and updated in 1967 (ESSA Weather Bureau 1967) and is undergoing current revision. As of 1970, the Weather Bureau had 42 primary fire weather offices with one or more specialized meteorologists; 7 supplementary offices with a part-time fire weather forecaster; and 38 mobile or portable forecast units.[1] Full implementation of present plans will result in 53 primary offices and 47 mobile units by 1972.

Parallel with this development, the tempo of fire research quickened in the Forest Service research organization. Three specialized fire research laboratories were established, at Macon, Georgia; Missoula, Montana and Riverside, California. Much of the work at these laboratories has been concerned with fire behavior and weather-fire interactions. In addition, the Weather Bureau has cooperated with the Forest Service by assigning research meteorologists to the fire labora-

[1]Letter from Harry L. Swift, National Fire Weather Coordinator, Weather Bureau, 30 June 1970.

tories. Active research projects have included the development of forecasting techniques; local wind studies; lightning fire occurrence and suppression; long-range forecasting; and fire weather equipment development.

RESEARCH ACCOMPLISHMENTS OF THE PAST DECADE

Detailed Analysis of Fires and Associated Weather

The first step in understanding fire behavior and the weather variables that influence it is to obtain observations of wildfires made by experienced observers. As part of its fire research program, the U. S. Forest Service developed specialized fire behavior teams that could be rushed to major fires in order to make detailed observations and measurements of fire and weather variables. Chandler (1961) analyzed the Basin fire in the Sierra National Forest in great detail. The Hughes fire in Alaska in 1962 was recorded and analyzed by Johnson (1964). In the southeastern United States, Taylor and Williams (1966) evaluated the meteorological conditions of the Hellgate fire. Other noteworthy fire weather studies of this period include those by Countryman and others (1968); Anderson (1968); Schroeder and Taylor (1968) and Countryman, McCutchan and Ryan (1969).

Controlled burns and experimental fires provide unique opportunities for detailed study and analysis of weather-fire interactions. Project Flambeau experimental mass fires have been described by Countryman (1969); Wilson (1969) has described a single experimental mass fire in Australia. Observations on Australian wildfires have been made by McArthur, Douglas and Mitchell (1966); Bond, MacKinnon and Noar (1967); and Taylor and others (1968).

These observations have led to a number of general conclusions concerning the meteorological conditions conductive to extreme fire behavior. An unstable atmosphere to a considerable height appears to be necessary for the development of strong vertical convection and a high intensity fire. Unfortunately, however, detailed atmospheric soundings in the immediate vicinity of wildfires are lacking and so the role of atmospheric instability still remains somewhat uncertain.

Fire whirls and fire-caused tornadoes appear to require considerable vorticity or circular motion in the ambient air in addition to an unstable atmosphere and a large heat source. The upper portion of the lee side of a ridge is a favored spot for fire whirl formation (Countryman 1964; Pirsko, Sergius and Hickerson 1965). The precise relationship of low level jet winds to extreme fire behavior is still obscure, but observations appear to show a close relationship. It may be that fire convection causes the downward transfer of horizontal momentum with a consequent increase in fire intensity. Low level jets may also favor the development of cohesive convection columns in some circumstances.

Explosive flash-overs, although controlled primarily by topography, must also be related to the ambient atmospheric conditions. Here, too, the exact mechanisms are not well understood. Low turbulence conditions, perhaps coupled with local stable conditions may be necessary for the accumulation of unburned gases in topographic pockets. With a suitable admixture of atmospheric oxygen and a source of ignition, such pockets may ignite explosively.

Analysis of Historical Fires

Much has been learned through the analysis of some of the great fires of history using synoptic weather data available from climatic records. The Chicago, Peshtigo and Michigan fires of 1871, all of which burned at the same time, have been subjected to new analyses by Haines and Sando (1969) and Haines and Kuehnast (1970). They concluded that these and other major fires in the Midwest were accompanied by long periods of drought prior to the fires and a short (10 day) period of high temperatures just preceding. High solar radiation and low relative humidities were also involved.

Haines and Kuehnast observed that a well developed low level jet accompanied the fires of 1871. This jet southeast of a moist tongue in the warm sector of a low pressure area centered near Minneapolis probably produced the high winds reported in Chicago and the upper Midwest, accounting for reports of long distance spotting. The jet was also associated with the strong anticyclonic shear present in the region at the time.

An interesting analysis of the Hamburg fire storm by Ebert (1963) pointed to conditions accompanying many severe forest fires: strong insolation for several days prior to the fire; an extremely unstable atmosphere; a long drought with low relative humidities; and low surface winds permitting a tall vertical convection column to develop.

Fire Weather Climatology

Recognition of the importance of local winds in controlling fire behavior has led to a number of studies. The Santa Ana wind in southern California produces extreme fire behavior and accordingly has been studied intensively. Studies by Fosberg (1965) and Fosberg, O'Dell and Schroeder (1966) have elucidated some of the mechanisms of Santa Ana formation and action. The complex mountain and valley wind structure in this area and its effect on nighttime drying has been studied by Fosberg and Schroeder (1965).

Sea breeze circulations may also be important in determining fire behavior. The circulation pattern along the California coast has been studied by Fosberg and Schroeder (1963) and Phillips and Schroeder (1967). Movement of sea breeze fronts causes rapid changes in wind direction as well as changes in humidity and air temperature. At times, however, the wind shift may not be accompanied by humidity and temperature changes.

The effect of local circulations on relative humidity in an interior valley was studied by MacHattie (1966). He found strong evidence of the nighttime "thermal belt" but also found great variation in humidities both in space and time.

A most important study on synoptic weather types associated with critical fire weather throughout the United States was produced by Schroeder and co-workers (1964). This describes the major fire weather patterns in each of 14 regions of the United States. Presentation of typical weather map patterns enables the forecaster to be alert for them as they develop without reference to specific fire weather measurements. Because of the comprehensive, national scope of the study, the conclusions are worth quoting:

> Periods of critical fire weather are associated with synoptic patterns and types as follows:
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> a. East of the Rocky Mountains most of the high fire danger occurs around the periphery of high pressure cells, particularly in the pre-frontal and post-frontal areas.
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> b. The Atlantic and Gulf Coasts occasionally have, in addition to the above, high fire danger associated with tropical storms in the windy area beyond the rain and cloud shield.
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> c. Along the eastern slopes of the Rockies the important weather types are those producing a foehn effect, locally known as a Chinook.
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> d. In the mountain and intermountain regions, short-wave troughs moving along the jet stream cause peaks in fire danger, as do surface dryfront passages.
>
> e. Along the west coast patterns producing heat waves and patterns resulting in foehn-type wind or off shore flow are important.

Further analyses of these patterns were made by Schroeder and Chandler (1966) and Schroeder (1969). An analysis of the simultaneous flammability of wild land fuels in the United States was made by Huschke (1966) using data from the original Schroeder report.

Statistical studies of the relationship between weather variables and grass fires in Australia were made by McArthur (1966) and for forest fires in Texas by Fahnestock (1965). Gwinner (1965) found that topographic differences in fire damage were greater in polar air than in tropical air, in the Ouachita mountains in Arkansas.

Prescribed Burning Weather

Weather is, of course, critical in the scheduling of prescribed burns. Conditions must be such that burning can be done safely but with fire intensities adequate to accomplish the prescription. Several attempts have been made recently to identify quantitatively suitable weather conditions. Beaufait and Fischer (1969) have presented a scheme for identifying weather suitable for prescribed burning. Specific recommendations for burning in Minnesota have been presented by Sando (1969) and a brief climatology for nighttime burns in Georgia has been developed by Lamb (1969). Wasserman and Kanupp (1968) have also prepared a climatology for prescribed fire in the southeastern United States. Wind records in Newfoundland were analyzed by Howard, Pitcher and Nelis (1969) to determine the frequency with which winds suitable for prescribed burning occur.

A set of guidelines for weather services for slash burning in Canada have been published by Turner (1968).

National Fire Danger Rating Index

During the past decade, the U. S. Forest Service initiated the development of a national fire danger rating system. (Nelson 1964). This system is designed to replace the various regional systems that have developed over the years. A similar system has been developed for Canada (Canadian Forestry Service 1970).

Both of these systems utilize basic meteorological variables: wind, air temperature, air humidity and rainfall. These are integrated in various ways to produce indexes of fire intensity or fire spread for standard fuel types. Neither system uses direct fuel moisture measurements as did most of the older systems.

The big advantage with these systems is that fire danger indexes can be calculated from standard weather measurements such as those taken by the national weather services. This permits calculation of danger indexes for the past in areas where no specialized fire danger measurements have been taken, facilitating study of historical fires. It would also be possible to draw a country-wide synoptic chart of the fire danger index on the same basis as other weather charts are prepared. The Weather Bureau is currently preparing a daily synoptic chart of the firespread index and disseminating it on the facsimile network, on an experimental basis.[2] This chart, and others planned for the future, will enable fire control officials to keep track of day-to-day changes of fire danger on a national basis. It ought to also prove useful for urban fire services who at present have no such rating system.

[2] Letter from Merle S. Lowden dated 22 January 1971.

For application of a fire danger rating computed from measurements at a point to a wide area involves consideration of the representativeness of point meteorological measurements. A number of studies in the United States and Canada have attempted to assess this variability. Among these are works by Webb (1968), Gerrie (1969), Simard (1969), and Simard and Valenzuela (1969).

Lightning Fires

Project Skyfire personnel continued to search for ways to suppress lightning strikes that start fires (Fuquay 1962; Fuquay 1967; Fuquay and others 1967; Fuquay and Baughman 1969; Baughman and Fuquay 1970). Study of thunderstorm patterns and associated lightning fires indicated that lightning in some areas appeared to be a better fire starter than in other areas for a given apparent storm intensity. Seeding with a very high number of silver iodide freezing nuclei may reduce the number of cloud-to-ground lightning discharges, according to these studies. There is still great uncertainty as to just how charge generation and separation develops within thunderstorms, but field studies indicate considerable promise for development of techniques for reducing fires from lightning strikes.

It is interesting to note that forest fires themselves are sources of condensation and freezing nuclei (Warner and Twomey 1967; Hobbs and Radke 1969; Hobbs and Locatelli 1969). It has been suggested that extensive burning of sugar cane fields may, by over-seeding clouds, initiate a self-perpetuating cycle of drought. The diminishment of precipitation caused by such over-seeding would be conducive to natural fires which would in turn contribute to the over-seeding.

Air Pollution from Fires

With increasing national interest in the reduction of air pollution, the question of the role of smoke from natural fires and prescribed burning in polluting the atmosphere has been raised. A recent seminar on prescribed burning and the management of air quality was held by the Southwest Interagency Fire Council in Tucson, Arizona

(1968). Specific aspects of the problem were discussed by Cramer (1968a, 1968b), Beaufait (1968) and Green (1968). Experimental work on atmospheric pollution from slash fires is currently being conducted at the University of Washington (Fritschen and others 1970). The general conclusions of these studies are that air pollution can be minimized with a high energy fire that produces a tall convection column; that burning should be done under conditions favoring rapid atmospheric dispersion of the smoke; and that particular attention be paid to wind directions that may carry smoke to populated centers. The state of Oregon has established procedures for managing smoke during slash fires (Anon. 1970a) and has established specialized weather stations to aid in smoke management (Anon. 1970b). The Weather Bureau assigned air pollution forecasters to several forecast centers in Washington and Oregon to work with forestry agencies in preparing forecasts for slash-burning operations.

It appears that atmospheric pollution from prescribed and slash fires will increasingly become an important factor in the fire prescription. More research will have to be performed in order to delineate appropriate atmospheric and fuel conditions for minimizing pollution hazards.

Fire Weather Forecasting Outlook

What is the outlook for the improvements in fire weather forecasting? Can existing fire weather forecasts be put to better use by forestry services? There has been much public speculation about improvement in long-range forecasts. Unfortunately, most of this speculation has been just that—speculation. It appears that considerable improvement in short-range (3 or 4 day) forecasts may be possible and will indeed be evident in the near future. This is the time scale of development and maturation of mid-latitude storms.

Forecasts for the time span of 1 or 2 weeks will improve but slowly. The outlook for detailed long-range forecasts on the order of a month or more is, in my opinion, very poor indeed. Inherent instabilities in atmospheric circulation patterns introduce random elements that cannot be predicted. The use of satellite photographs and other remote sensing devices may improve our knowledge of existing weather considerably and be of great help in areas where few weather stations are located. But such devices are not likely to help the long-range forecasting situation.

One area where great strides can be made is in the climatology of fire weather and its application to fire planning. Recent advances have been made in application of climatology to agriculture, and many of the same principles can be applied to forest fire weather problems.

And lastly, there is room for great improvement in the cooperation between fire weather personnel and fire control managers. Much of the information is available (see, for example, Paul 1964; Graham 1966; Webb 1966); the problem is to get the information to the fire manager in a form and at a time that he can use it. Some effort has been made (Jackson 1967; Jackson 1968; Pirsko and Scowcroft 1969) to develop ways of doing this. In particular, the fire behavior training courses and the fire generalship courses taught by the U.S. Forest Service for supervisory fire personnel have gone a long way in this direction. More needs to be done. It is my hope that this next decade will produce the interaction and cooperation that the advances of the past decade have made possible.

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