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A REVIEW OF FIRE WEATHER INVESTIGATIONS IN AUSTRALIA

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Abstract: The Bureau of Meteorology commenced its attack on the problem of Australian fire weather forecasting in 1947 with the publication of Foley's Bushfire Bulletin. This publication first drew attention to the importance of the lapse rate in determining fire behaviour. Previously investigations into fire weather had been limited to part-time research by forestry departments in the various States, who are still doing useful work in this field. Recommendations from Fire Control Conferences led to the establishment in 1955 of a Fire Weather Service as an integral part of the Bureau's functions and meteorologists were appointed in the various states to study fire weather problems. Attempts to predict fuel state from meteorological parameters were made but abandoned in favour of the establishment of fuel state reporting networks. Individual fires have been studied using the case history method and attempts made to relate the synoptic surface and upper air conditions with the behaviour of large forest fires. The problem of selecting suitable days for prescribed burning by Forestry has received a good deal of attention. Fire phenomena such as whirlwinds have been examined and individual peculiar fire behaviour has been explained wherever possible and attempts made to see if the behaviour could have been forecast. Fire danger tables have been produced by the various states, largely based on North American versions, and recently the Forestry and Timber Bureau has issued tables based on their own observed measurements made on test fires in various types of Eucalypt forest and grasslands. Evaluations of quantitive forecasts have been made to check whether forecasting methods are achieving the standards of accuracy required by fire control authorities.

I. INTRODUCTION

The tremendous holocaust of January 1939 in south-eastern Australia caused an acute public awareness of Australia's growing bushfire problem. The word growing is used advisedly; with the opening up of much former forest land for grazing the opportunity for fire in the forests is increased enormously, and softwood plantations in particular are extremely vulnerable to fires originating in the grasslands outside.

The Bureau of Meteorology commenced its attack on fire weather problems in 1947 with the publication of Bulletin 38, A Study of Meteorological Conditions associated with Bush and Grass Fires and Fire Protection Strategy in Australia. Prior to this date most investigations were the work of forestry personnel in the various States and largely consisted of tests of various overseas fire danger tables and their local modifications, the use of hazard sticks as a method of predicting fire danger and, particularly in Queensland, the selection of suitable days for burning felled rain forest.

Conferences of Forestry and Rural Fire Authority personnel made representations for the appointment of Fire Weather Meteorologists, which was implemented in certain States in 1955, and detailed investigations were commenced into various fire weather problems and aspects of fire behaviour.

II. GENERAL

1. The history of major fires of the past

The important work of collecting synoptic material pertaining to major bushfires of the past was begun in 1947 with the publication by the Bureau of Meteorology of its Bulletin No. 38 (Foley (1947)). Fire occurrences from 1851 on were listed. This necessary work is now continued in the form of case histories of major fires, some of which have been published, e.g. Robin (1957) and Larkins (1958).

2. The estimation of the time of curing of annual grasses

Fire danger rating systems of North American origin and local modifications thereof have been examined and used in the different States with varying degrees of success. In all cases some idea of the fuel state, particularly the degree of curing of the grass, is required at fairly frequent intervals. Robin (1957) demonstrated it to be theoretically possible to estimate approximately the time of curing of annual grasses in inland New South Wales using cumulative soil moisture calculations. However, the idea has not been followed up, it being found more practicable to extend the fuel state reporting network.

3. Synoptic patterns and fire occurrence

The study of synoptic weather patterns associated with and leading up to major fire outbreaks was commenced by Foley (1947). Robin and Wilson (1958) developed an objective method for forecasting major fire occurrences in the Riverina district of New South Wales, using as parameters the maximum temperature, 3 p.m. dew point, amount of last rainfall, number of days since last rainfall, and 3 p.m. wind speed. The analysis was made using the probability ratio method.

4. The relation between fuel moisture content and meteorological parameters

This subject has received attention over a considerable period, particularly from the forestry departments in the various States and the Commonwealth Forestry and Timber Bureau. Wilson (1958) has discussed some of the problems connected with moisture content estimations. McArthur (1958) summarizes the results of his work on the rate of spread of fire in three classes of fuel - eucalypt litter, radiata pine litter and grass - made over a wide range of meteorological conditions. Measurements were made of rate of spread and the intensity, flame height, spotting potential, fire instability, suppression difficulty and fire damage were assessed. All such observations were related to field measurements of air and fuel temperatures, relative humidity, wind velocity (in forest and in open), cloud cover, rainfall and fuel moisture content. Tables are presented giving the surface fuel moisture content of eucalypt litter as a function of air temperature and relative humidity, and the relation between wind velocity in the forest and wind velocity in the open.

Measurements of temperature, relative humidity and wind profiles have been made over a period of years in pine forests at Canberra and Mt. Burr (S. Aust.). Instrument towers were used and measurements made from canopy to ground level. However, the data have not yet been statistically treated.

5. The effect of meteorological factors on fire behavior

Rainbird (1958) has discussed the various ways in which wind affects fire behaviour. He mentions the importance of forecasting new cyclonic developments in existing troughs and points out that whereas conditions favourable for development over a broad zone can frequently be recognized, the exact location of development, critical for a successful wind forecast, is a much more difficult matter. An interesting suggestion for coping with the problem of forecasting local wind variations due to topography is that the local firefighter should himself observe and study local wind behaviour in quiet seasons and compare his observations with broad-scale flow data subsequently obtained from the meteorologist.

The sea breeze is a most important wind mechanism during the fire season in Australian coastal areas and can have far-reaching effects on fire behaviour on account of (a) the changes in fire danger brought about by decreased temperature, increased relative humidity and increased wind speed, and (b) the change in wind direction which may turn a flank into a fire-front and predisposes conditions towards the formation of fire whirlwinds. Accordingly the sea breeze has received considerable attention by Clarke (1955, 1958) in southern Australia and by Whittingham (1958) in south-east Queensland.

The closely allied subject of the cool changes of south-eastern Australia has been analyzed by Berson et al. (1959). These cool changes are often double (and occasionally multiple) and can cause the establishment of new fire-fronts on large previously southward moving bush fires. The prefrontal change is often dry.

The effect of temperature lapse rate on fire behaviour was first mentioned by Hounam in a section of the Bushfire Bulletin (Foley (1947)). The sparsity of the radiosonde network has limited the number of opportunities to examine the matter but Whittingham (1958) has shown it to be important in reafforestation burns in heavy fuel in south-east Queensland. This paper also examines the effects of cloud amount, rainfall and evaporation, gradient wind and vertical wind shear on the success of the burns.

6. Phenomena

Fire whirlwinds have received some attention in the Australian literature. Whittingham (1955) collected many observations of their occurrence in various parts of Australia and attempted to correlate them with meteorological and other parameters. An interesting case of fire whirlwind occurrence in south-east Queensland was examined in detail by Whittingham (1959).

Cases have been described by Whittingham (unpublished) of unusual fire behaviour which seems to have been the result of sudden overturning of the lower 10,000 ft of the troposphere with resulting downward transport of momentum.

Some data on lightning as a fire-causing agent have been accumulated but not published. Fire storms have not been closely examined.

McArthur (unpublished) has concluded that crown fires can best be prevented by prescribed burning to reduce fuel concentration.

7. Fire danger ratings

Various systems of rating fire danger or fire hazard exist in the different Australian States. However, throughout eastern Australia the index developed by Luke (1953) is widely used. This weights the following factors - temperature, relative humidity, wind speed and fuel state. The Canadian grass fire tables described by Foley (1947) have had some application inland. Modifications were made to the Luke index by Whittingham (1960) to adapt it to dew point instead of humidity for greater operational efficiency when using synoptic data. Dissatisfaction with the Luke system as applied to Tasmania was voiced by Hickman (1958) mainly on the grounds of the subjectivity involved in estimating the fuel state, particularly the state of curing of the grass. The Chipman index, involving the use of hazard sticks, is preferred. Hazard stick readings are also preferred in South Australia and West Australia, but are not in general use in the other States, although some observations are being made with standardized materials supplied by the Forestry and Timber Bureau, Canberra.

McArthur (1958, 1960) has produced fire danger tables for low quality eucalypt and for annual grasslands applicable to south-eastern Australia. Based on the contention that the equilibrium fuel moisture content is a function of the meteorological variables he bases his grasslands tables on the following calculations: basic fuel moisture content obtained from maximum temperature and minimum relative humidity, a correction to the basic f.m.c. according to the state of curing of the grass, a correction for recent rainfall, and finally a fire danger rating obtained from the adjusted fuel moisture content and wind velocity with a correction for fuel quantity.

8. Forecast evaluation

The forecast accuracy requirements of forestry have been described by Douglas and McArthur (unpublished). McArthur (1958) has stated that blow-up conditions "are apparently virtually impossible for the Bureau of Meteorology to forecast, although such days probably account for 90 per cent of our total fire damage. The accurate forecasting of such weather would be an immense advance in preventing the appalling damage which occurs on such relatively isolated days". Wilson (1958) found that "a disturbingly high proportion of forecasts fail to predict accurately maximum temperatures of 90°F or more, and a high percentage of forecasts fail to predict low dew points and humidities accurately". He states that errors in prognosis are the root cause, particularly incorrect predictions of cyclogenesis. Whittingham (1958) examined temperature and dewpoint forecasts for Queensland and Mizon (1958) investigated results in South Australia. The latter writer pointed out that lack of information concerning the early morning hydrolapse, because of the time of radiosonde release, precluded the development of an objective method of forecasting the diurnal variation of dewpoint. Maine (1958) has developed an objective forecasting technique for maximum temperature prediction in South Australia.

III. CONCLUSIONS

Many aspects of the interrelations between fire and weather have been examined to some extent in Australia. It is evident that the most serious deficiencies are to be found in connection with the forecasting of the fire-important meteorological parameters, particularly wind, temperature and relative humidity. Very often high winds, high temperatures and extremely low humidities occur simultaneously and with exceptional suddenness; this leads to the widely held belief that such explosive fire conditions are incapable of being forecast. On examining the synoptic situations it almost invariably appears that sudden cyclogenesis has occurred over a relatively small localized area, usually in a broad pre-existing trough of low pressure overlain by a pattern of upper air divergence. The basic need is for better prognostic procedures to cover such occurrences. Momentum transfer is another factor which could receive more attention from forecasters, particularly since it affects absolute humidity at the surface as well as wind velocity. A feature which has received little attention is the problem of 3 to 5 day forecasting. There is a pressing need for this type of forecast from a fire control point of view.

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