METEOROLOGICAL OBSERVATIONS AT A CONTROLLED BURN

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Abstract

A series of temperature and wind soundings to an altitude of some 3000 m was made during February and early March 1975 at Pureora in the King Country. A large controlled burn took place on 4 March. Meteorological conditions were not ideal and the behaviour of the fire was considered to be consistent with the forecast issued some hours before and with the meteorological observations made before and during the burn.

INTRODUCTION

In December 1974, the N.Z. Meteorological Service received a request from N.Z. Forest Products Ltd for assistance in connection with burning operations at Pureora planned for the following February. The area involved, 4000 ha, was a very large one and it was hoped to burn it in two or three sections. The Pureora block lies in the King Country, 45 km southwest of Tokoroa. The average altitude of the block is about 600 m, the highest part being 850 m in the east on the slopes of Pureora mountain, the summit of which reaches 1165 m. As this is a high rainfall area with mean annual rainfall at the State Forest climatological station at Pureora Forest being 2500 mm it was apparent that weather would play an important part in the outcome of the operations.

An obligation to provide meteorological advice to major industries has long been recognised by the Meteorological Service. The request provided an opportunity for forecasting staff to learn at first hand something of forestry operations, as well as to carry out a series of wind and temperature soundings to determine if the existing network of observations was adequate for the purpose of forecasting for the industry in the central parts of the North Island. At the same time, it was believed that a meteorologist familiar with the conditions at the site of the proposed fire could provide advice on the weather to be expected and the prospects of a clean burn without the risk of a blow-up fire occurring.

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While there are many meteorological elements which affect fire operations, one of the most important is atmospheric moisture, because of the continuous interchange of water vapour between the atmosphere and the dead fuel, affecting its flammability. During the course of the day the actual amount of moisture present in the air does not normally vary greatly, but the relative humidity does, varying inversely with temperature changes. If a forecaster, knowing the amount of moisture in the atmosphere in the morning, is able successfully to predict the maximum temperature for the day, he will be able to arrive at the corresponding lowest relative humidity with reasonable accuracy.

Another element of major importance in planning a burn is that of the surface wind, with the rugged topography of New Zealand resulting in great variability within a relatively small area. It was decided to install an anemometer at Pureora well in advance of the projected date for the fire, in order to enable a comparison to be made between the winds there and the general flow over that part of the North Island, and hence to determine any local effects.

EFFECTS OF THE ATMOSPHERE ON FIRE BEHAVIOUR

Fires are influenced by vertical motions within the atmosphere. The heat of the fire itself generates upward motion and the convective circulation thus established is affected directly by the stability of the air. This in turn influences the indraught into the fire at low levels and hence the intensity of the fire. The stability of the atmosphere is determined by the "lapse rate" (the rate at which temperature decreases with increase in altitude). When this is high, the air is unstable and vertical motion is enhanced with strong updraughts and downdraughts. Rising gases acquire energy from the atmosphere, their path upward creating a chimney into which surrounding air is drawn. The potential energy of the unstable air is then converted into kinetic energy as it enters the chimney. When the total energy output (*i.e.*, the energy output of the fire plus the conversion of potential to kinetic energy) is great enough, fire whirls may develop. On the other hand, in conditions of extreme stability when temperature increases with increasing altitude, smoke may become trapped within a shallow layer of the atmosphere and create an unacceptable level of pollution.

Byram (1954) considers that the most significant effects of atmospheric stability conditions on fire behaviour are indirect, in that they operate through the wind profile. He surveyed a number of blow-up fires, defined as those which burn with an intensity that seems out of proportion to the apparent conditions. He found that this type of fire occurrence is associated with a free wind of at least 30 km/h at the elevation of the fire, or just above it, and a decrease of wind with height for a thousand or so metres above the fire (with the possible exception of the first hundred metres). Examples of wind profiles which Byram considered hazardous may be found in many fire meteorology manuals. Steiner (1974) suggested that winds which decrease with height cause increased convergence of air at the base of the fire, resulting in an increased fire intensity.

OBSERVATIONAL PROGRAMME

Late in January the area of Pureora was inspected and arrangements made for the installation of a mechanical Lambrecht anemometer on a ridge near the middle of the block and adjacent to a helicopter pad. This type of anemometer requires no electric power, runs for one month without attention, and provides a continuous record of wind direction and speed.

Comparison of the anemometer record with weather charts showed that, on most occasions, the wind at Pureora conformed to the general wind flow over the whole surrounding area. However, some notable exceptions occurred. For example, on 26 February gale force south-easterlies persisted most of the day at Pureora but not at any of the land stations of the meteorological network.

Early in February meteorological staff set up a mobile radiosonde* observation base at the State Forest station at Pureora Forest. They began a programme of daily radiosonde ascents to heights in excess of 15 km, measuring temperature and humidity. Also, as cloud conditions allowed, balloons were followed by theodolite and upper level winds found. One of the main objects of this programme was to determine if the routinely made radiosonde observations at Waiouru and Auckland were sufficient to enable a meteorologist to determine the temperature structure of the atmosphere in the King Country and adjacent areas. A comparison of these soundings with those at Pureora suggests that this is the case and that meteorologists should be able to rely on the regular soundings to provide adequate data. In addition to the normal radiosonde, there was available a number of "low-lift" sondes with an ascent rate of about 100 m per minute. These had no humidity element but recorded the fine structure of the temperature

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*The radiosonde is a balloon-borne instrument that measures temperature, humidity and pressure. Data are transmitted via a simple radio to a ground station.

profile to a height of about 3000 m. These special sondes were reserved for days when a controlled burn was considered likely.

THE BURN

Preparations for the burn at Pureora were delayed by an unusually wet summer until nearly the end of January, and a revised target date of 17 February was set. However, further delays occurred as, although the next 10 days were fairly dry over most of the Auckland province, the air over the King Country was moist and slightly unstable with the result that light showers or drizzle kept occurring at Pureora. Rainfall amounts were low, but, as there was little wind, there was also little drying. Towards the end of February there was a period of good drying but wind speeds were too high for a safe burn.

It was not until 4 March that conditions were considered adequate, if far from ideal. The fuel was dry over most of the block, although perhaps not completely so on the slopes of Pureora mountain. Winds at 6 a.m. were between NE and N to above 3000 m with speeds decreasing from 33 km/h at an altitude of 1000 m to 9 km/h at 2500 m. Later in the morning the upper winds became more uniform with highest speed 24 km/h, and at 3 p.m. speeds did not exceed 15 km/h up to the top of the smoke column. At the latter time the wind direction was NNE at low levels and NNW above 1500 m. Surface winds at the anemometer remained a constant NNE 12-15 km/h throughout the day.

The 8 a.m. temperature sounding showed a high lapse rate in the first few hundred metres but then a temperature inversion of nearly 2° C between 1000 m and 1400 m. The cloud in the morning was broken stratocumulus with base about 1000 m. Pureora soundings at 8 a.m. and 3 p.m. are shown in Fig. 1 along with the 11 a.m. soundings from Waiouru and Auckland. It can be seen that the 3 p.m. Pureora sounding has a close resemblance to those from the other stations, which have temperature inversions of similar magnitude at slightly lower altitudes.

At 7 a.m. the temperature at Pureora Forest was only 12.4° C with a relative humidity of 95%. By 9 a.m. the temperature had risen to 14.6°C, while the relative humidity had decreased to 82%. A further slow increase in temperature together with a decrease in humidity took place, values at 11 a.m. being 17.7°C and 66%, at 1 p.m. 18.0°C and 64%, and at 4 p.m. 19.0° C and 68%. The moisture content at 10 a.m. of the 12.5 mm and 50 mm hazard sticks was 15% and 24%. N.Z. Forest Products Ltd have been quoted (in Chandler, 1969) as regarding a

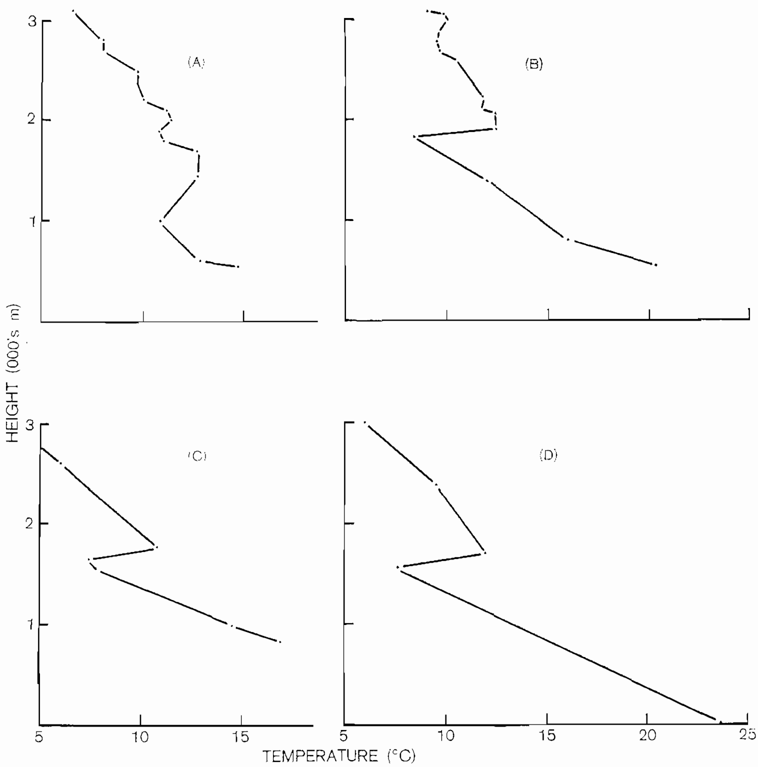

FIG. 1: *Temperature soundings, 4 March 1975. (A) Pureora 8 a.m. (B) Pureora 3 p.m. (C) Waiouru 11 a.m. (D) Auckland 11 a.m.*

combined moisture content of 12.5 mm and 50 mm sticks of 30% or less and humidities below 55% as a reasonable basis for a good burning day. It will be seen that these criteria were not met on the day in question and that the actual conditions fell into Chandler's "marginal" category. The Fire Danger Rating at 11 a.m. was 4.6.

Fire lighting began in the south of the block at 12.50 p.m. on 4 March and it was planned to extend the fire towards the northeast until the eastern half of the block was burned over. Series of still and movie photographs were taken from the anemometer site, approximately 5 km north of the initial lighting point. Figure 2 (top) was taken at 1.27 p.m. when the fire still occupied a relatively small area. Large billows of smoke extend upwards into the base of the cloud, and then spread outwards below the inversion layer, which marked the tops of the cloud. The vigorous convection below the cloud is con-

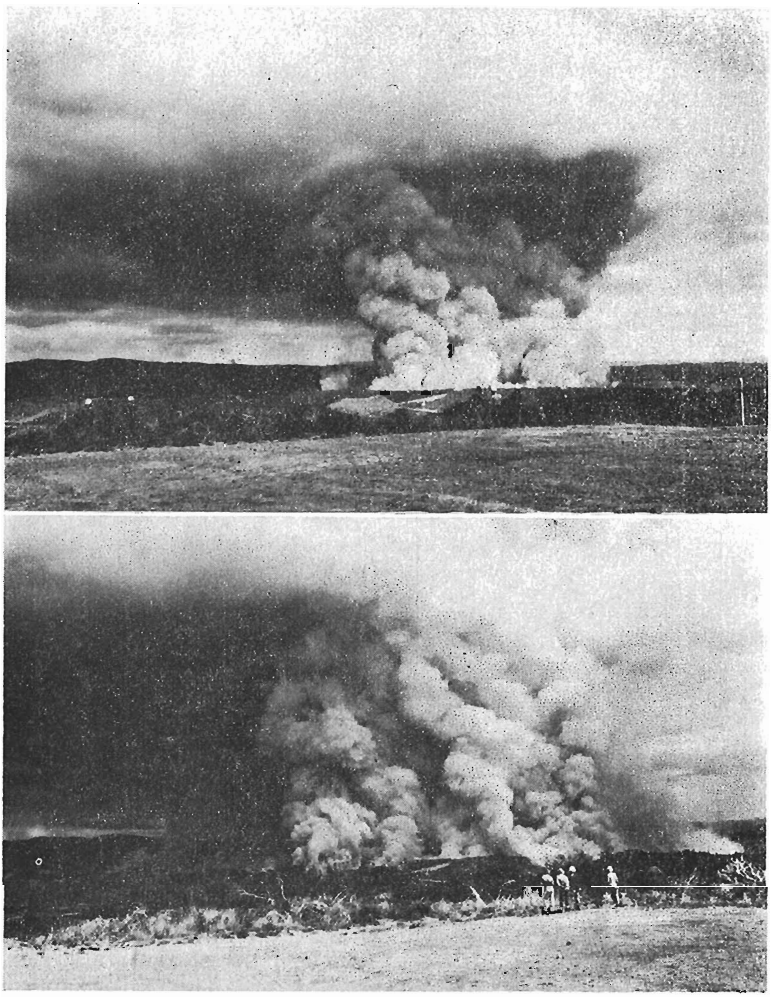

FIG. 2: *Fire at Pureora, 4 March 1975, at 1.27 p.m. (top) and at 1.55 p.m. (bottom)*

sistent with the steep lapse rate in this layer, but the smoke is unable to penetrate the large temperature inversion above. The second photograph, Fig. 2 (bottom), was taken at 1.55 p.m. The fire covers a much larger area and the near side of it is closer to the photographer. None of the smoke is penetrating the top of the cloud layer. The effect of the fire on adjacent low-level winds is shown by the smoke being entrained towards the centre.

The fire was considered successful until about 4.30 p.m., but after that time some difficulty was experienced in igniting the fuel. Next morning, 5 March, attempts were made to burn some of the areas which had been missed, on the slopes of Pureora mountain, although rain was predicted for the afternoon. At 11 a.m. when fires were commenced, the temperature at Pureora Forest was 19.1°C and the relative humidity 69%, the combined moisture content of the hazard sticks being 39%. However, the temperature soon began to fall and the humidity to rise. At noon, temperature and relative humidity were, respectively, 18.1° C and 75%, and at 1 p.m. 17.2° C and 82%. At 1.15 p.m. operations were halted as the fuel was not igniting and at 1.30 p.m. drizzle finally brought an end to any chance of a resumption of the fire.

DISCUSSION

In the burn reported here, the co-operation between meteorologist and forester proved perhaps less profitable to the forester than it might have following a normally dry summer. It was clear from the upper wind and temperature observations that the risk of a blow-up fire was minimal. The light NNE winds over the area were expected to remain constant, except for local changes brought about by the presence of the fire itself. The temperature inversion below 2000 m was expected to restrict the depth of the convective layer, leading to the accumulation of smoke below the inversion. Finally, it was thought that temperatures would not rise sufficiently for the relative humidity to fall below about 60%. Conditions, in short, were not expected to become ideal. The decision to burn was no doubt influenced by the considerations that the fire season was already well advanced and that the shortening days combined with the high altitude of Pureora, with its relatively low temperatures, high humidities and general cloudiness, made it seem unlikely that another opportunity would present itself that season. In fact, none did.

There is no doubt that in this case familiarity with the topography and personal observations of the conditions were of considerable assistance to the forecaster. Whenever controlled burns are planned, the need for local knowledge of the topography and weather effects will be felt by the forecasting centre meteorologists responsible for issuing forecasts. It seems desirable that, early in each fire season, an experienced meteorologist be given the opportunity to make himself familiar with the sites of planned burns and that a programme of wind, temperature and humidity observations be set up a month or two before the projected burns. The provision in the area of several Lambrecht anemometers and thermo-hygrographs could well prove a sound investment for foresters.

REFERENCES

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