Meteorological Aspects of the ACT Bushfires of January 2003

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Abstract

This presentation provides an overview of the meteorological aspects of the devastating bushfires that affected Canberra on 18th January 2003. The talk will cover 3 aspects of the fires.

a. The antecedent climatic conditions leading up to the fire season
b. The weather conditions from ignition on 8th January to 17th January
c. The observed weather conditions and plume development on the 18th

Introduction:

During January 2003, severe bushfires burned significant amounts of southeast Australia. Near the Australian Capital Territory, fires were started on 8 January by lightning strikes and burned under generally westerly winds. On 18 January the fires burned into Australia's capital Canberra and destroyed large amounts of property. The fires burnt through Mt Stromlo, destroying all the astronomical facilities there, and continued on to hit the nearby suburbs of Canberra including Duffy, Chapman, Rivett, and Kambah. In all nearly 500 houses were destroyed and 4 people lost their lives.

This paper provides a brief description of the meteorological aspects of these fires.

Antecedent Conditions

The presence of a persistent El Nino event throughout 2002 and into 2003 led to very much below-average rainfall and abnormally high temperatures across large parts of eastern Australia, including areas in and around the ACT. This followed on from the preceding dry period in 2001. The increased rate of drying of fuel due to low rainfall would have been further exacerbated by higher-than-normal evaporation due to the abnormally high temperatures. Table 1 shows a comparison between average and observed rainfall and maximum temperature for Canberra in the 10 months leading up to, and including January 2003. From this table it can also be seen that below-average rainfall conditions were experienced in all months apart from June and September. A very critical period leading up to the January fire event was the period between October and December. The rainfall for these three months totalled 40.2 mm compared to a median total of 150.4 mm and was the third lowest total on record (records from 1939). Of particular interest is the very large positive maximum temperature anomaly in November 2002 being 5 degrees above normal.

Table 1: Comparison of Actual and Average Rainfall for Canberra Airport April 2002 To January 2003

Month	Median Rainfall (mm)*	Actual Rainfall 2002-2003 (mm)	Rainfall Anomaly (mm)	Average Maximum Temperature (C)**	2002 Average Maximum Temperature (C)	Maximum Temperature Anomaly (C)
April	37.6	21.2	-16.4	19.8	22.4	+2.6
May	39.7	27.0	-12.7	15.4	16.3	+0.9
June	30.3	40.8	+10.5	12.2	13.2	+1.0
July	36.9	16.8	-20.1	11.2	12.5	+1.3
August	45.6	22.8	-22.8	12.9	14.8	+1.9
September	53.5	58.4	+4.9	16.0	17.7	+1.7
October	55.5	11.6	-43.9	19.2	21.3	+2.1
November	55.5	10.4	-45.1	22.5	27.5	+5.0
December	39.4	18.2	-21.2	26.1	28.1	+2.0
January	47.7	10.4	-37.3	27.8	30.5	+2.7

* Monthly median rainfall calculated over period March 1939-January 2003

** Monthly median temperature calculated over period 1961-1990

Figure 1 shows the rainfall deciles recorded across NSW in the 3 months October-December 2002. Much of NSW received rainfall totals for these three months which were in the lowest 10 percent on record with some locations to the west of the ACT receiving their lowest ever totals for these three months.

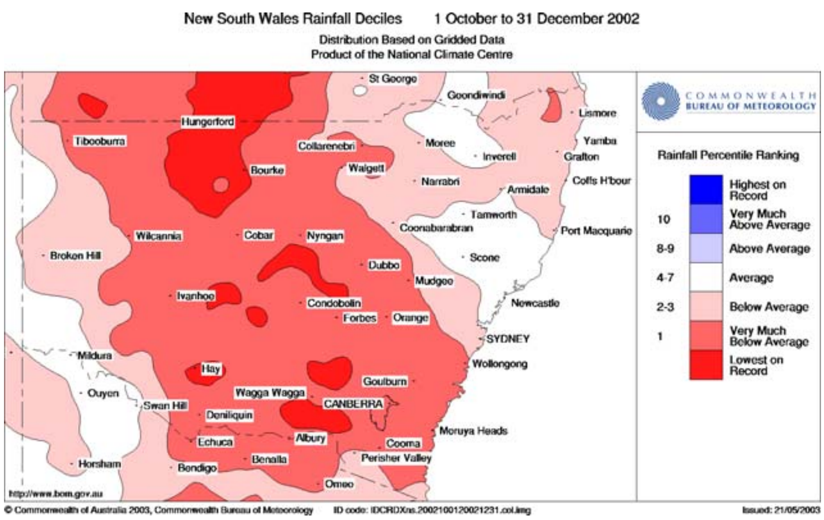


Figure 1: Rainfall deciles in NSW for the period October-December 2002

In NSW and the ACT, fire authorities use a Drought Index developed by Keetch, J.J & Byram, G.M.(1968) to measure the level of dryness of the soil (often referred to as KBDI). Rising temperatures during the Spring of 2002 resulted in a rapid increase in the KBDI values reaching the extreme level of more than 100 mm late in December 2002. Figure 2 shows a graph of the approximate KBDI calculated for Canberra during the period leading up to January 2003 as well as the median value for each month during this period. The combined affects of very dry and hot conditions between October and January can be clearly seen in the rapid rise in KBDI during this period, the rate of increase far larger than would be typically expected.

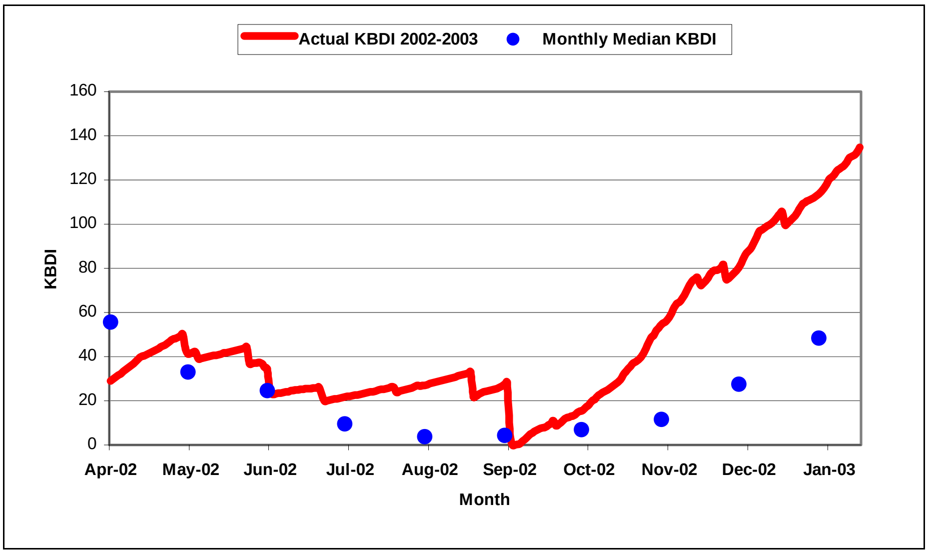


Figure 2: Keetch-Byram Drought Index for Canberra April 2002-February 2003. The blue dots represent the long-term median KBDI for each month.

Ignition of Fires – 8th January 2003

The meteorological pattern on 8th January indicated the passage of a strong front across NSW that triggered the outbreak of thunderstorm activity over the south-east of NSW that is believed to have ignited the fires.

These fires were fanned by the near extreme fire weather conditions being experienced on this day. At the closest Bureau of Meteorology automatic weather station (Canberra Airport), north-westerly winds of near 30 to 35 km/h were recorded, reaching as high as 45 km/h as a decaying shower moved over the area. In addition to these winds, the temperature reached 34C at Canberra Airport and the humidity dropped to between 15% and 20%. Forest Fire Danger Indices (FFDI) developed by McArthur (1967) are used as the basis for determining fire ratings in NSW and ACT. An FFDI of 50 is considered extreme and a forecast of this value would trigger the issue of a Fire Weather Warning by the Bureau of Meteorology. Combining these factors resulted in Forest Fire Danger Indices of between 40 and 45 for much of the afternoon with a short period reaching above 50 at the time of the shower as the wind strength briefly increased.

Meteorological Conditions 09th -17th January 2003

Following the initial outburst of fire activity, the weather conditions were generally relatively benign for the next 8 days, with no rain being recorded in the vicinity of the Brindabella Ranges to assist in fire suppression activities over this period. Figure 3 indicates the diurnal changes in the Forest Fire Danger Indices over this period showing the generally benign conditions until 17th January.

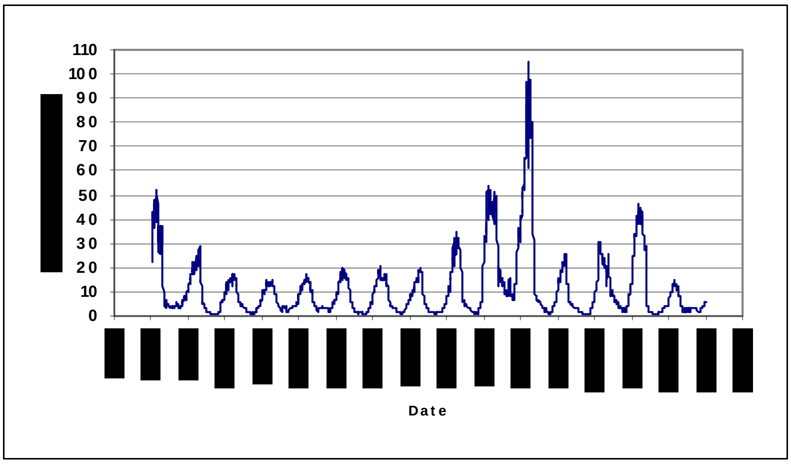
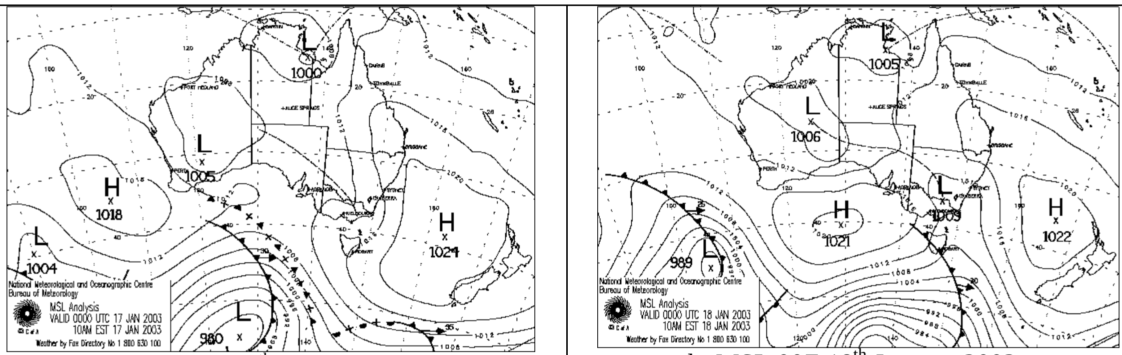


Figure 3: Forest Fire Danger Index at Canberra Airport 08-21 January 2003 based upon 10 minute average data. (The maximum Fire Danger Index reached on 18 January based upon this data was 104.)

Early on 17 January, wind conditions in most areas were light and variable winds though tending northwesterly at higher elevations. As the temperatures rose rapidly during the morning, convective mixing resulted in the stronger middle-level winds being transported to the surface. This increase in the strength of the westerly wind on the 17th was most likely a result of the development of an upper-level system ahead of the larger-scale frontal feature (Figure 4a).



a: MSL 00Z 17th January 2003 b: MSL 00Z 18th January 2003

Figure 4: MSL patterns for 17th and 18th January 2003

The wind speed increased during the morning and tended northwesterly, reaching 30-35 km/h by Midday, then remaining at these speeds for much of the afternoon before dropping significantly during the evening.

The maximum temperature peaked at 36C and the relative humidity fell to a minimum near 15%. The Forest Fire Danger Index remained between 40 and 50 for most of the afternoon, peaking over 50 on several occasions.

Meteorological Conditions on 18th January 2003

A ridge of high pressure was over the Tasman Sea and another high pressure system was approaching from the Great Australian Bight. A trough was situated over Western NSW and was moving eastwards directing very hot west to north-west winds ahead of it (Figure 4b).

Wind Velocity

By 9.00 am the surface winds at Canberra Airport had increased to 30 km/h with gusts to approximately 40 km/h as daytime heating saw mixing downward of the stronger upper level winds. The winds maintained a similar strength until midday when there was a gradual increase in wind speed with the observation at 2.30 pm being 37km/h average with gusts to 52 km/h. From this time on the wind speed increased further and became quite erratic. A graph of the wind speed at Canberra Airport can be seen in Figure 5.

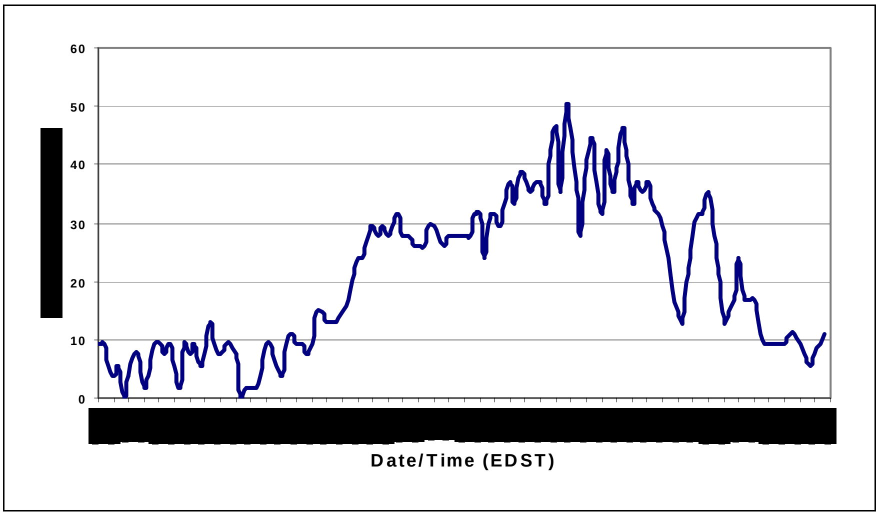


Figure 5: Ten minute average wind speed at Canberra Airport 18 January 2003.

A graph showing 10-minute average wind speed, wind gusts and wind direction between 11.00 am and 9.20 pm can be seen in Figure 6. The strongest 10-minute average wind speed of a little over 50 km/h was recorded shortly after 3.20 pm and the strongest gust of 78km/h was also recorded at approximately this time. The winds began to abate at approximately 5.30 pm with the average reaching a minimum near 13 km/h at 7.10 pm. A south-easterly wind shift developed shortly after this time and again the wind briefly increased reaching 35km/h with gusts to 50 km/h on the change before easing later in the evening.

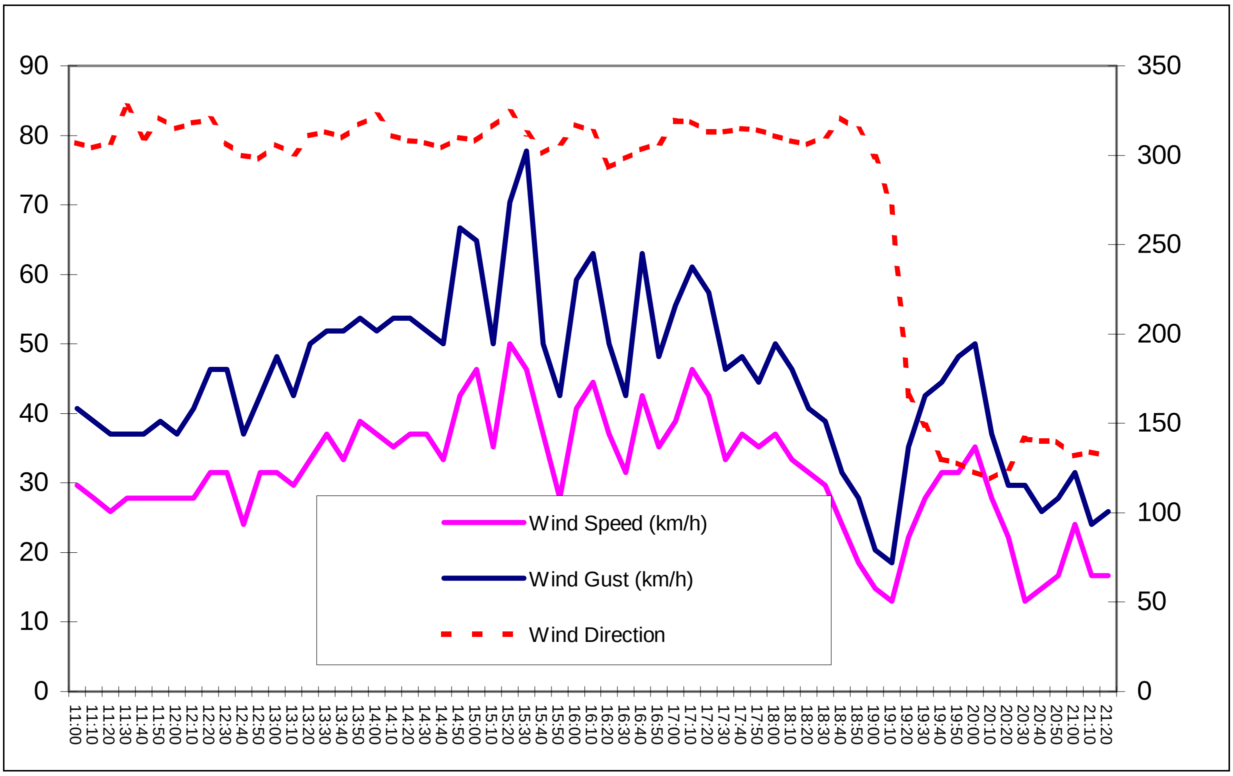


Figure 6: Wind Speed, Direction and Gust at Canberra Airport on 18 January (speed and direction data based upon 10-minute averages).

A number of factors may also have affected the wind characteristics near the fire ground and it is difficult to know exactly what conditions were experienced. Local valley and mountain effects could affect wind direction, speed and gustiness while the fire itself could also have had an effect on the wind conditions experienced. The development of deep columns of vertical motion caused by the heat of the fire, known as convection columns, can influence the wind's behaviour both through the inflow required to sustain the upward motion and the mixing down of air from higher levels.

Temperature and Relative Humidity

Figure 7 shows the hourly changes in temperature and relative humidity during the18th January. The temperature rose quickly during the morning, briefly reaching a maximum of 37.4C at 12.42 pm. At 2.20 pm, the temperature began to slowly fall almost linearly to a point where it was 33.6C at 7.00 pm before falling more rapidly in response to the south-easterly wind shift. Smoke spreading over the ACT also explains the gradual fall in temperature from 2.20 pm onwards.

Normally the relative humidity (RH) gradually increases overnight, reaching a maximum near sunrise. By shortly after 2:00amon Saturday morning the RH had risen to 41%. It then dropped dramatically to 28% before rising again to reach a maximum around 46% at 6.30 am. The maximum overnight RH of 46% is particularly low and would have limited the local vegetation's ability to absorb moisture overnight making it more combustible once temperatures rose again during the day.

As temperatures rose the RH quickly dropped to 13% by 12.40 pm where it remained until 2.00 pm when it then dropped to 8%. This value of 8% was maintained from 2.50 pm until 4.30 pm when another drop to a minimum near 4% occurred.

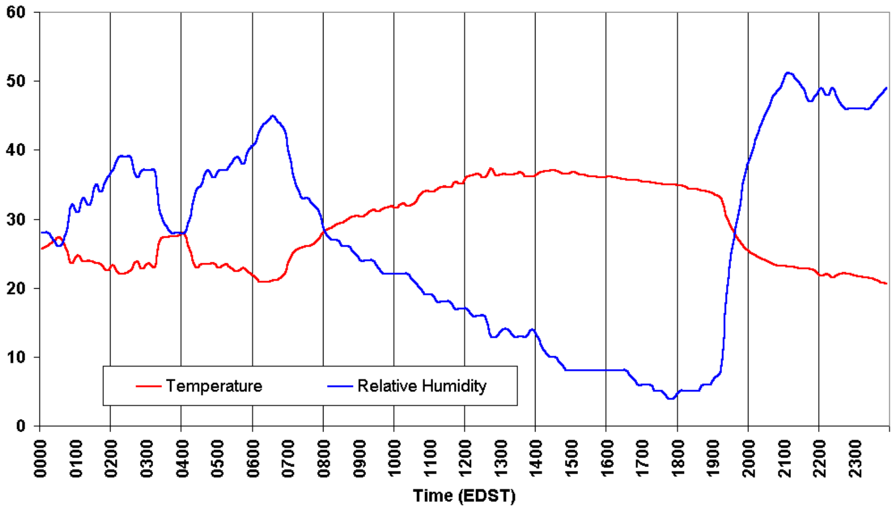


Figure 7: Hourly Temperature and Relative Humidity for 18 January 2003

Fire Danger Index

Figure 8 shows the McArthur Forest Fire Danger values calculated over 10-minute intervals for 18th January. This index was in the defined ‘Extreme’ range (>=50) from just prior to 1.00 pm until just prior to 7.00 pm. The peak in fire danger occurred between approximately 2.50 pm and 6.00 pm. This index is the basis on which the Bureau of Meteorology’s Fire Weather Warnings are issued and provides fire agencies with an idea of the difficulty of suppression of a wildfire on a particular day. It is important to note that the input of wind speed is required to be a 10-minute average at a height of 10 metres.

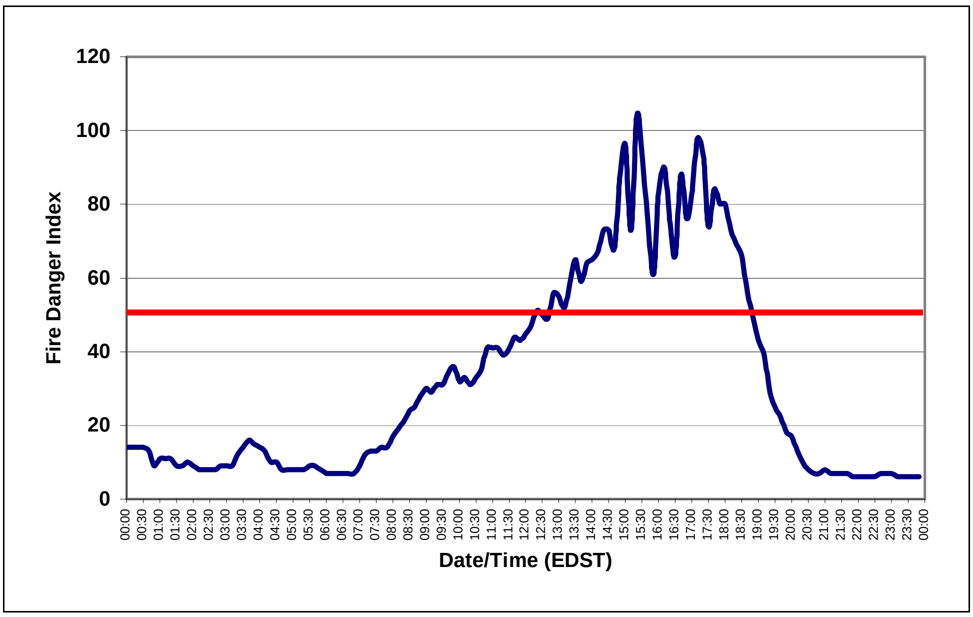


Figure 8: Forest Fire Danger Index at Canberra Airport 18 January 2003 plotted by the 10 minute averages of data sampled at one minute intervals.

Effect of Atmospheric Stability on Surface Winds

As mentioned above, the initial increase in the wind during the morning would have been a result of the morning temperature inversion eroding and allowing some proportion of the mid level winds to be brought to the surface. As the temperature continued to rise, further mixing would have increased the downward transfer of momentum, further increasing the wind speed at the surface.

Based upon the available wind records at 2.30 pm, it appears that there was an increase in the variability of both the average wind speed and the strength of the wind gusts in the Canberra area. This is likely to be the result of a combination of a number of factors. The increased depth of mixing caused simply by increase in temperature would have had a contribution, so too would a modification of the general environment ahead of the main trough. Another factor that probably contributed to gustiness near the fires was the development of very large convective plumes above the fires to the west of Canberra.

The increased mixing would have led to a gradual drop in the relative humidity as drier air was transferred downward from aloft. The further fall in relative humidity late in the afternoon and change in the pressure characteristics suggest a broader change in the characteristics of the air mass, a likely result of the passage of the trough from the west. These troughs are often quite subtle in terms of changes in wind direction either over elevated terrain or when surface winds are dominated by upper level winds, as was the case in this instance.

Later during the early evening, a gusty easterly change moved over the area. This was due to the relatively rapid movement of the trough system up the coast to the east of the ACT, followed by a more gradual penetration inland to the ACT region.

Atmospheric Stability and the Development of a Convective Plume

The McArthur fire danger index is used to indicate the difficulty of suppression of a wildfire. Stability, the tendency for the atmosphere to undergo vertical motion, can also impact on fire behaviour.

In very unstable conditions, large smoke plumes can develop above fires and form cumulus or even cumulonimbus clouds; a result of both energy released by the fire and the inherent instability in the air mass. The vertical motion associated with these clouds means that there is an increase in the amount of air drawn in at low levels. The rate at which air cools with height, or lapse rate of the atmosphere, also plays an important role in development of these plumes.

Bally (1995) showed that the Haines Index can provide a guide to the degree of instability of the atmosphere and the tendency for large-scale fires to become plume dominated. This Index is calculated from temperature and dew point data in the layer between 5000 ft and 10000 ft and is quoted on a scale of 2 to 6 with 6 representing the driest and most unstable conditions. On January 18th the Haines Index was calculated and measured to be 6 in the ACT region, however, this value is not unusual in summer in the ACT due to the hot and dry conditions that can occur. The fires in the ACT developed very large cumuliform plumes above them as indicated by photographs taken from observers in aeroplanes on the day.

A weather radar, located to the east of Canberra at Captains Flat, commenced operation on 19th December 2002. While the main function of this station is to monitor weather systems such as thunderstorm development over SE NSW, the Bureau was able to use data obtained from it to analyse the cloud development associated with the ACT fires. Figure 9 indicates the analysis of the height of this plume during the afternoon of the 18th January and that the maximum height of the cloud tops associated with the plume extended to around 14000m above MSL. Aerial photos suggest that indeed a cumulonimbus cloud did form at the time of this cloud height and there were also some reports of lightning around this time. The timing of this development, at around 3.45 pm EDST, also appears to have occurred near the time the fires impacted on the suburbs of Canberra.

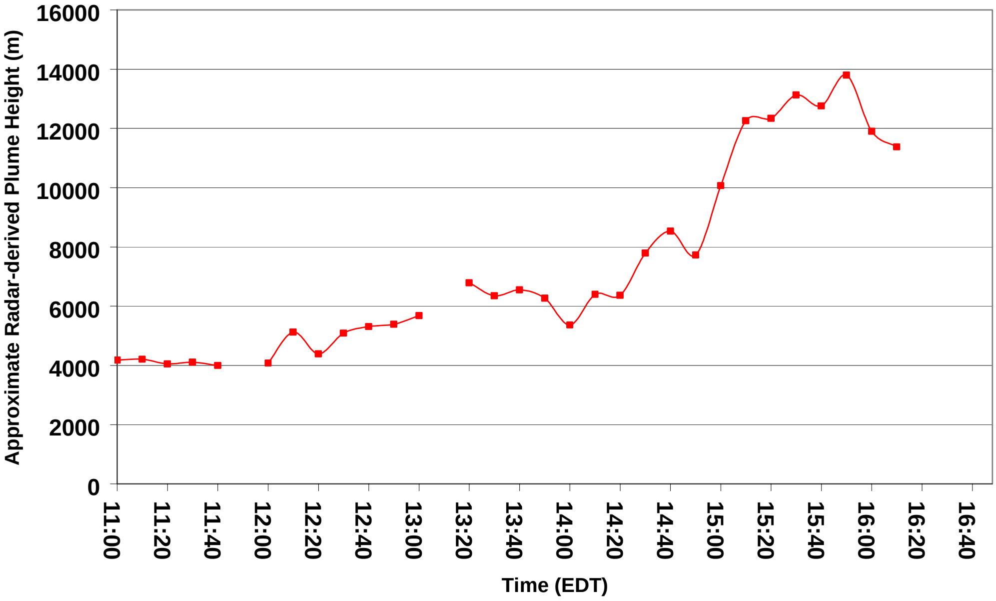


Figure 9: Analysis of Smoke Plume Height to the west of Canberra on 18 January 2003(from Captains Flat Radar).

<u>Summary</u>

The drought prevailing at the time of these fires turned out to be one of the most severe in the nation's recorded history. Large areas of the country were experiencing serious or severe rainfall deficiencies. Additionally, atmospheric humidity and cloudiness had been below normal and daytime temperatures had been at record high levels. This combination of factors led to an early advanced curing of fuels across most of Eastern Australia. Although many of these factors were also present during previous major bushfire events, the high temperatures in the lead up to the 2002/03 fire season appear to have been unprecedented.

Due to the proximity of Bureau of Meteorology surface meteorological stations, upper wind stations and a weather radar station together with aerial and satellite observations, a detailed analysis of the meteorological conditions for the period before and during this fire event was able to be carried out. In particular, the use of weather radar data was used to investigate the development of the smoke plume that occurred with this fire.

Acknowledgements:

Acknowledgement is given to Ian Mason who, at the time, of the fires, was acting OIC of the Canberra Meteorological Office and who also contributed to this report.

List of Tables and Figures

References:

Bally, John (1995) The Haines Index as a predictor of fire activity in Tasmania. Australian Bushfire Conference, Hobart, 27-30 September 1995

Keetch, J.J. and Byram, G.M. (1968) A drought index for forest fire control. U.S.D.A., Forest Service Research Paper Se-38

McCarthur, A.G. (1967) Fire behaviour in Eucalypt Forests. Leaflet No. 107, Forest Fire Institute, Forestry and Timber Bureau, Canberra