# 1.2 LOWER ATMOSPHERIC DRYING, STABILITY, AND INCREASED WILDFIRE ACTIVITY

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## 1.Introduction

In two recent major wildfires in Australia, both involving a number of deaths and massive property damage, substantial screen-level drying was observed at nearby Automatic Weather Stations (AWS) at the same time as high temperatures and strong, gusty winds led to extreme fire behaviour. The dramatic lowering of near-surface humidity in these two cases prompted an investigation of the mesoscale meteorology that led to these two drying events, and some key aspects of the meteorology of these two events, that of the Canberra fires on 18 January 2003, and of the lower Eyre Peninsula fires of 11 January 2005 are described in Section 2 of this paper. These studies have led to an on-going project to explore the generalisation of the concepts suggested by the two case studies, and to explore potential linkages between these drying events and the concepts of atmospheric (in)stability/fire behaviour interactions encapsulated in, for example, the Haines Index (Werth and Ochoa (1993). Some preliminary results from the more general study will be presented, and future directions of the project discussed, in Section 3.

## 2. Case studies

### *2.1 Canberra – 18 January 2003*

On 18 January 2003 fires, ignited by lightning some 10 days earlier, devastated the Australian Capital Territory (ACT) causing the deaths of four people, many other injuries, the loss of over 500 houses and other infrastructure, and burning more than 70% of the parks, forests and pastures in the ACT (McLeod 2003). The fire weather on the day was extreme, as can be seen from the meteograms at Canberra Airport shown in Fig. 1. With the onset of daytime heating around 2000 UTC (local daylight savings time is 11 hours ahead of UTC) the wind speed increased fairly steadily with a peak of 25 knots, gusting above 40 knots, around 0500 UTC (4pm local time), then slowly weakening before a sharp speed increase following the arrival of an easterly wind change at ~ 0800 UTC. Once the temperature reached some 30C, the dewpoint declined, and showed further sharp decreases to ~-5C at around 0300 UTC, and dramatically to –12C at 0700 UTC. The drying to –5C is coincident with the peak in both mean and gust wind speed, while the latter drying occurred just prior to the

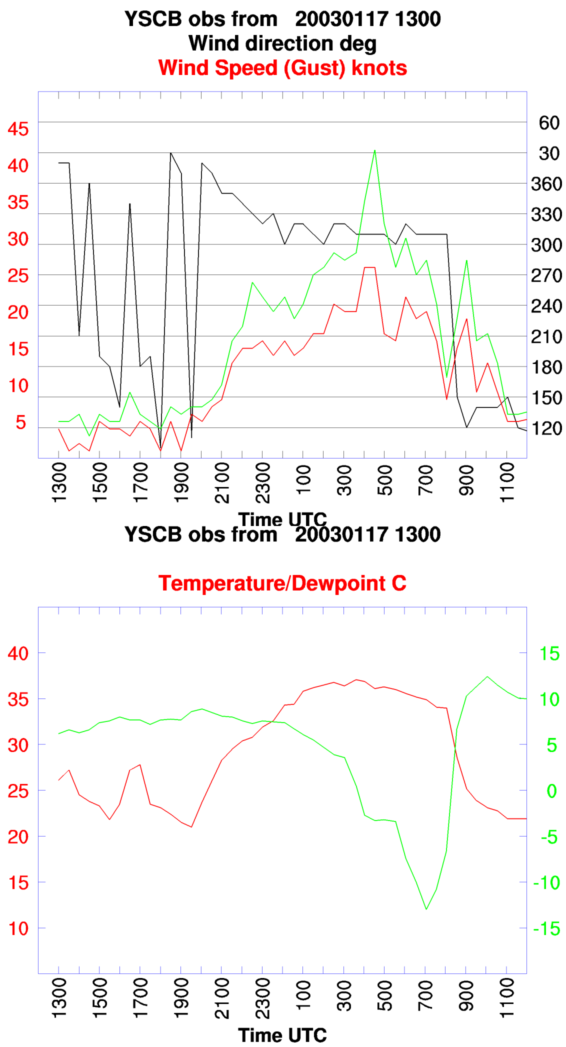


Figure 1. Time series of observations from Canberra Airport (YSCB) from 1300 UTC 17 to 1200 UTC 18 January 2003. Upper panel – wind direction (degrees) in black, with wind speed and gust (knots) in red and green. Lower panel – temperature (red) and dewpoint (green), both in C. Note the offset scales on the ordinates of the lower panel.

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easterly cool change, which was marked by an abrupt temperature fall and dewpoint increase. While some discussions of the meteorology of the event attributed the gustiness observed at Canberra Airport to atmosphere/fire interactions (a huge pyrocumulus cloud was observed above the fires), examination of AWS data over some 100km north and south of Canberra showed similar weather to that seen in Fig. 1. The gustiness is diagnosed by Mills (2005) to be associated with the movement of a small-scale isotach maximum just near the top of the mixed layer, which on this day extended to some 600 hPa, and is shown in that paper to be well-forecast by the operational mesoscale NWP models run by the Australian Bureau of Meteorology.

The initial downward trend in the dewpoint might be ascribed to the onset of mixing through a deeper boundary layer with increased surface temperature. The second dewpoint decrease coincided with the movement of a dark band, or “dry slot”, in the water vapour channel satellite imagery over Canberra (Fig. 2). This dry slot could be identified moving from the west and then southwest across New South Wales, and is weakly evident in the NWP model forecasts. It is thus hypothesised that, given that the mixed layer extended from the surface to some 600 hPa, the decrease in surface humidity at 0300 UTC is a result of the mixing from a region of very dry mid-tropospheric air that moved over the region during the early afternoon of 18 January.

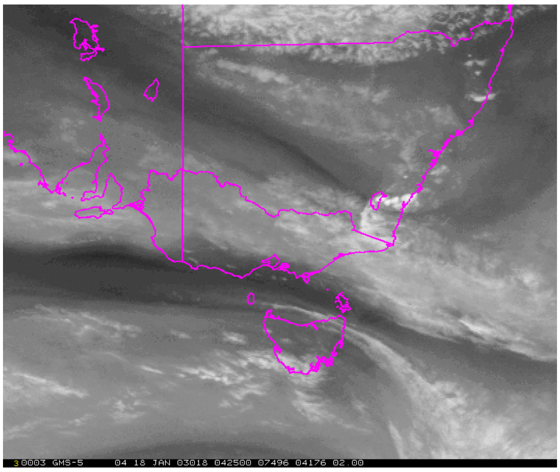

Figure 2. Enhanced Water-Vapour channel ( 6-7 µm) imagery from the GMS-5 satellite at 0430 UTC 18 January.

The “final” drying period, at around 0700 UTC, occurred just before the arrival of the easterly change, and was observed at a number of AWS stations both north and south of Canberra, and at all these stations occurred immediately before the wind shift. Further, the 5km grid-spacing mesoscale NWP forecast for that time (Fig. 3) showed a band of lower dewpoint oriented parallel to and on the western (warm) side of this westward propagating cool change. It must be acknowledged, though, that the forecast model has under-forecast the degree of drying to a considerable extent. Time/space calculations indicate that the width of the dry band is such that its amplitude is unlikely to be fully resolved by the operational 5 km grid spacing NWP model, although inadequacies in initial state specification, or in the model’s physical parameterisations may also contribute to these errors. It remains, however, a working hypothesis that the last, and most dramatic, drying at Canberra on January 18 was associated with some aspect of the frontal circulation associated with the easterly change.

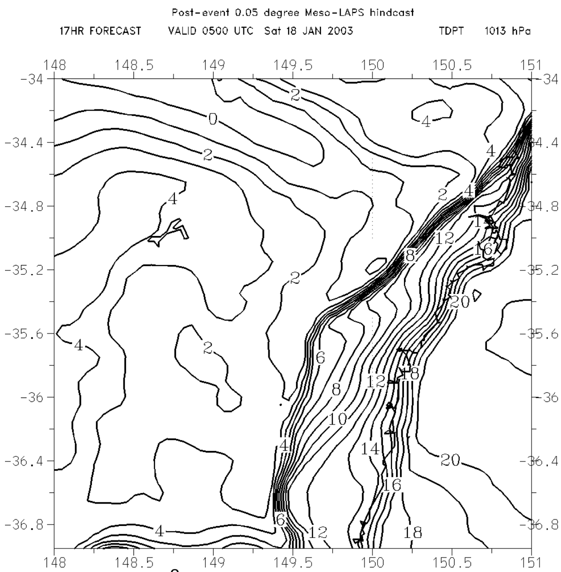


Figure 3. 0.05$^{o}$ meso-LAPS forecast of screen-level dewpoint (C) valid 0500 UTC 18 January 2003.

### *2.2 Lower Eyre Peninsula fires- 11 January 2005*

A fire ignited on the western side of southern Eyre Peninsula, South Australia, on 10 January 2005, and on the morning of 11 January escaped under the influence of strong northwesterly winds ahead of a dry cold front. The fire burnt rapidly across the Eyre Peninsula, and 9 lives were lost, as well as large building, farm infrastructure, and stock losses.

Figure 4 shows the meteograms from Port Lincoln Airport AWS on January 11. There are a number of interesting features here:

- At 2200 UTC there is a dramatic drying, warming, and increase in wind speed
- While there was a dry cold frontal passage, the wind direction change was not that abrupt; however, the very sharp temperature fall at 0130 UTC might be interpreted as the “change time”.
- There was a further drying just before the change time
- While winds were very strong before the change, there was a period of even stronger and sustained winds after the change that drove the rapid spread of the fire

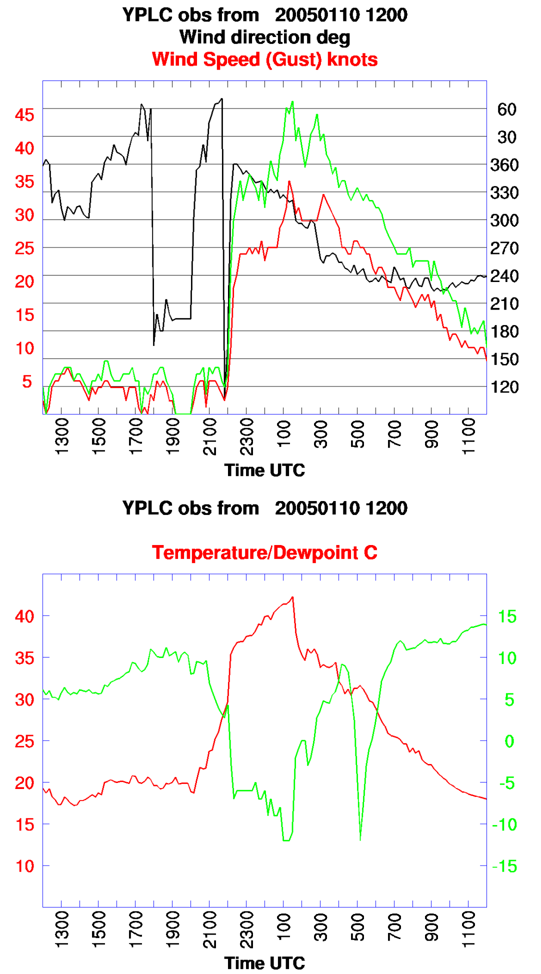


Figure 4. Time series of observations from Port Lincoln (YPLC) from 1200 UTC 10 to 1200 UTC 11 January 2005. Upper panel – wind direction (degrees) in black, with wind speed and gust (knots) in red and green. Lower panel – temperature (red) and dewpoint (green), both in C. Note the offset scales on the ordinates of the lower panel.

In common with the Canberra case, a mid-tropospheric dry region could be identified in the water-vapour channel imagery, and this dry region (Fig. 5) moves from the west over southern Eyre Peninsula very close to the time that the initial surface drying was observed. In this case an upper tropospheric isentropic potential vorticity (IPV) “maximum” (contoured in Fig. 5) can be identified associated with this dry region in the water vapour channel imagery. Weldon and Holmes (1991), for example, describe in some detail the relation between upper-tropospheric IPV structures and features identifiable in water vapour imagery. A short-wave 300 hPa trough could be identified with this IPV anomaly over Eyre Peninsula, while the IPV “maximum” south of the continent is associated with a synoptically more significant deep tropospheric mid-latitude trough.

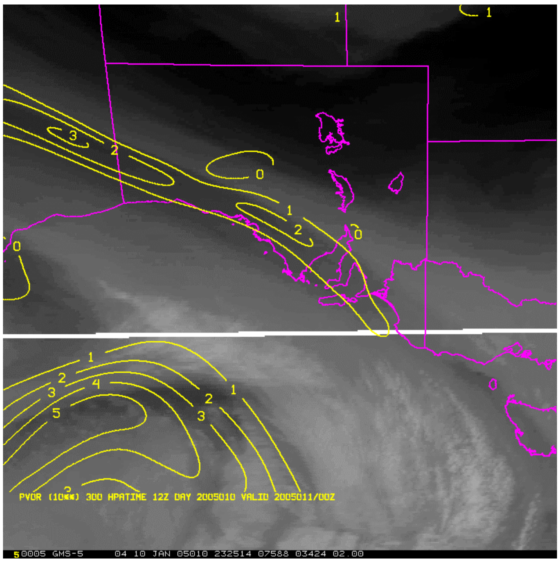

Figure 5. Enhanced water vapour channel satellite imagery at 2330 UTC 10 January 2005, with contours of 300 hPa IPV (negative sign removed) from the 12-hour mesoscale NWP forecast valid at 0000 UTC 11 January 2005.

### *2.3 Case study discussion*

Each of these two cases exhibited extreme fire behaviour, and also recorded extremely high and unusual values of fire danger index. While the wind speeds during each event would have been sufficient to generate extreme fire danger, the abrupt and marked dryings aroused the curiosity of this author, and would have affected fire behaviour via the fuel moisture response of the fine fuels. It is intriguing that mid-tropospheric dry regions were identified to move over the fire locations at the time of the observed surface drying, and given that very deep mixed layers were in present on each day, it might be hypothesised that deep boundary layer mixing "tapped" these dry regions, contributing to the extremely low surface humidities observed. Charney et al (2003) have also associated surface drying and enhanced fire activity with mid-tropospheric relative humidity minima.

The lower mid-tropospheric wet-bulb potential temperatures associated with regions that can be identified as "dry slots" in the water vapour channel imagery has been associated with convective destabilisation of the atmosphere (Browning 1994). It is, therefore, perhaps not a coincidence that a huge pyrocumulus cloud, with radar estimates of tops to ~14000 m, was observed above the Canberra fire on the afternoon of January 18, and later that day thunderstorms occurred off the NSW coast on the eastern end of the dark band in the water vapour imagery (Fig. 2). More active, or "unpredictable" fire behaviour has been noted in conditions of decreased atmospheric stability, and attempts to forecast this using techniques such as the Haines Index (Werth and Ochoa 1993) have been developed. However, the Haines Index is less useful as a discriminator of such conditions when the mixed layer depth is regularly deep (Werth and Werth 1998) and these are just the conditions that are observed over southeastern Australia inland from the coastal regions during the summer. However, the known association between mid-tropospheric dry slots and reduced atmospheric stability may also make the water vapour imagery a useful guide to areas where the atmospheric stability over an active fire may be reduced, in addition their effects on lower-atmospheric drying already hypothesised. It is striking that in their discussion of the Haines Index, Werth and Ochoa (1993) show a water vapour image (their Figure 15) on the day the "Willis Gulch" fire made a major run that bears a striking similarity to that in Fig. 2.

The other feature common to each case is the passage of a cool change, or dry cold front, with an apparent lowering of humidity just before the passage of the front. While low humidity in the pre-frontal airmass is the norm in summertime southeastern Australia, it is yet to be established whether this sub-synoptic drying is a normal feature of such changes, or a peculiar feature of these more extreme events.

## 3. A more general study

These two events were brought to the attention of the fire weather researchers by the fact that extreme fire behaviour was observed on two days when extreme surface drying was observed and when the presence of a mid-tropospheric humidity minimum could be inferred from water-vapour channel satellite imagery. These are only two events, but if the presence of mid-tropospheric dry regions identified in water-vapour imagery is a general condition in such events, it could be used as a forecast tool. The role of the circulations associated with the frontal passage in producing these dryings also requires further study.

Accordingly a broader project has commenced to study the frequency with which extreme surface drying is observed during the southern Australian fire season, the association of such events with water-vapour imagery dry slots and the passage of dry cool changes. Hourly and half-hourly AWS data have been archived in Australia since 1999, and so the initial phase of this study has focussed on the summer months (December-January-February) for the five summers from 1999-2000 to 2004-5, and a network of stations in fire-prone areas across all of southern Australia has been selected for analysis. At the time of writing of this paper four stations (representative of southwestern Western Australia (Bridgetown), South Australia (Port Lincoln), western Victoria (Horsham), and the southeastern NSW tablelands (Canberra) have been analysed. For each of these stations a "drying event" has been defined as

- Screen-level dewpoint < -5C
- Screen-level dewpoint <-2.5C and relative humidity <10%,

with these criteria being determined after a subjective assessment of the time series of half-hourly AWS data for each summer. For each "event", water vapour imagery has been inspected, and whether of not a trough/front passage was likely has been assessed from synoptic analyses and the time-series of station data. The preliminary results are summarised in Table 1.

Table 1 shows, first, that such events are relatively rare at these stations – only some 3-4 events per fire season at these locations. Second, some 60% of events are associated with the appearance of dry mid-tropospheric air as inferred from the water vapour channel satellite imagery. This appears to this author to be a very large proportion, especially as there were a number of other cases that were a little ambiguous, and were not counted, but could have been classed "probable". Finally, the overwhelming majority of events occurred with a trough/dry cold frontal passage.

Table 1. Number of “drying events” at Bridgetown (BDGN), Port Lincoln(YPLC), Horsham (YHSM), and Canberra (YSCB) in the five fire seasons analysed, together with the number of these events for which a clear water-vapour dry slot could be identified, and the number with which a trough passage could be identified.

| Station | No. of events | No. with WV dry slot | No. with trough passage |
|---|---|---|---|
| BDGN | 16 | 10 | 14 |
| YPLC | 16 | 8 | 13 |
| YHSM | 18 | 10 | 15 |
| YSCB | 20 | 14 | 15 |

While this is still an early phase of this study, it does appear that the movement of a dry slot in the water vapour imagery towards an existing fire, or towards an area where fire danger is already extreme might be an indicator of potentially more extreme fire behaviour, and with some hours warning. Thus incorporating the monitoring of water vapour channel satellite imagery into existing fire weather watch procedures may well be advantageous. What has not yet been addressed so far is the number of water vapour imagery dry slots that do not manifest as abrupt surface drying, although this may be an intractable problem. The documentation of the synoptic structures that lead to these mid-tropospheric dry slots, and to the processes that lead to the exchange of this air with the surface needs to be completed, as does the ability of current operational NWP models to forecast these structures.

The relationship of some of the drying events to dry cold front/trough passage is still to be investigated. The Victorian Regional Forecast Centre issued some 16 “wind change forecasts” per year for Horsham (these are days on which a significant frontal wind change associated with very high or extreme fire weather) is expected, and this suggests that the majority of these changes do not show the extreme drying defined in this study. Therefore it is worth further investigation of the structures of those changes that do result in a drying event. A tool that will be used here is the techniques for objectively timing wind changes from AWS data described by Huang and Mills (2005) that will enable the number of change days at any station to be identified.

## 4. References


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