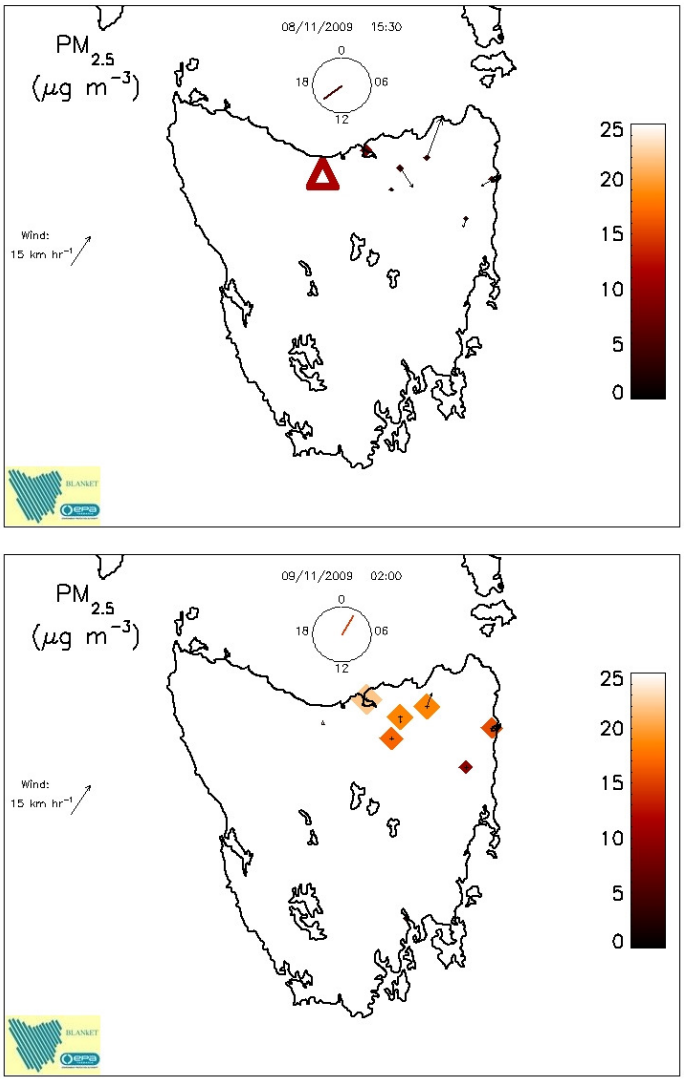
BLANkET[1] Technical report - 6
A smoke event detected across the north-east Tasmania BLANkET stations – 8th/9th November 2009

November 2009



Two frames from an animation showing a smoke event detected in the north-east BLANkET and Tamar Valley air stations, 8th and 9th of November 2009. Top panel: At 15:30 AEST a 20 ha bushfire near Barrington (shown as the red triangle) was reported to be producing a large column of smoke. Lower panel: At 02:00 AEST the following day significant smoke levels were detected in the Tamar and the north-east. There was a clear west-to-east movement of smoke through the BLANkET network. The Barrington fire was the only fire of significant reported on the 8th of November, and appears to be the source of the smoke seen in the air quality data.

[1]Base-Line Air Network of EPA Tasmania

Summary: On the 8th and 9th of November the BLANkET (Base-Line Air Network of EPA Tasmania) stations detected unusually high levels of $PM_{2.5}$ particles (i.e. particles less then 2.5 millionths of a metre in aerodynamic diameter) for several hours on the evening of the 8th of November and early morning of the 9th, indicating significant levels of wood-smoke at the stations. The peak (indicative) instantaneous $PM_{2.5}$ values reached 30 µg m^{-3}. A clear west-to-east movement of the smoke was seen. The smoke was also detected earlier on the 8th of November in the Tamar valley air stations (Launceston, Rowella, and George Town).

Earlier in the day of the 8th of November a 20 ha bushfire occurred near Barrington, south of Devonport. Reports indicated this fire produced a large column of smoke that moved in a north-easterly direction. There are no reports of other fires of comparable size in northern Tasmania on this day. It seems likely, but it is not conclusive, that the Barrington fire was the source of the elevated particle levels seen in the Tamar and BLANkET air stations.

There are two particular points of interest in this event. The first is the detection of a 'pulse of smoke', quasi-gaussian in profile, moving from west to east across the north-east Tasmania BLANkET stations. It is noteworthy that this pulse probably came from a relatively small fire (20 ha, of light fuel load). The multi-station tracking of a widespread smoke plume is precisely for what the BLANkET network was designed; hence this event can be taken as an empirical proof of concept for the BLANkET project. The second point of interest is that it appeared that some of the smoke entered the Tamar valley, and, instead of continuing to move eastwards, was trapped there for up to 16 hours under the prevailing light wind conditions. This point is worth further study.

BLANkET data: Indicative $PM_{2.5}$ data obtained at four of the five north-east Tasmanian BLANkET stations on the 8th/9th of November 2009 are shown in Figure 1. (Derby station was off-line.) Daytime maximum temperatures were in the mid to high twenties at all operating stations, with minimum night temperatures in the range 10 to 15 C. It is considered very unlikely that domestic woodsmoke could be the origin of these elevated $PM_{2.5}$ signals. The smooth appearance of much of the variation in $PM_{2.5}$ is suggestive of smoke that has travelled far enough from the source to have become well mixed and locally homogeneous in concentration. This can be contrasted with, for example, the short-duration 'spike' in the St Helens data near 20:00 AEST on the 8th of November, which may be from a local source.

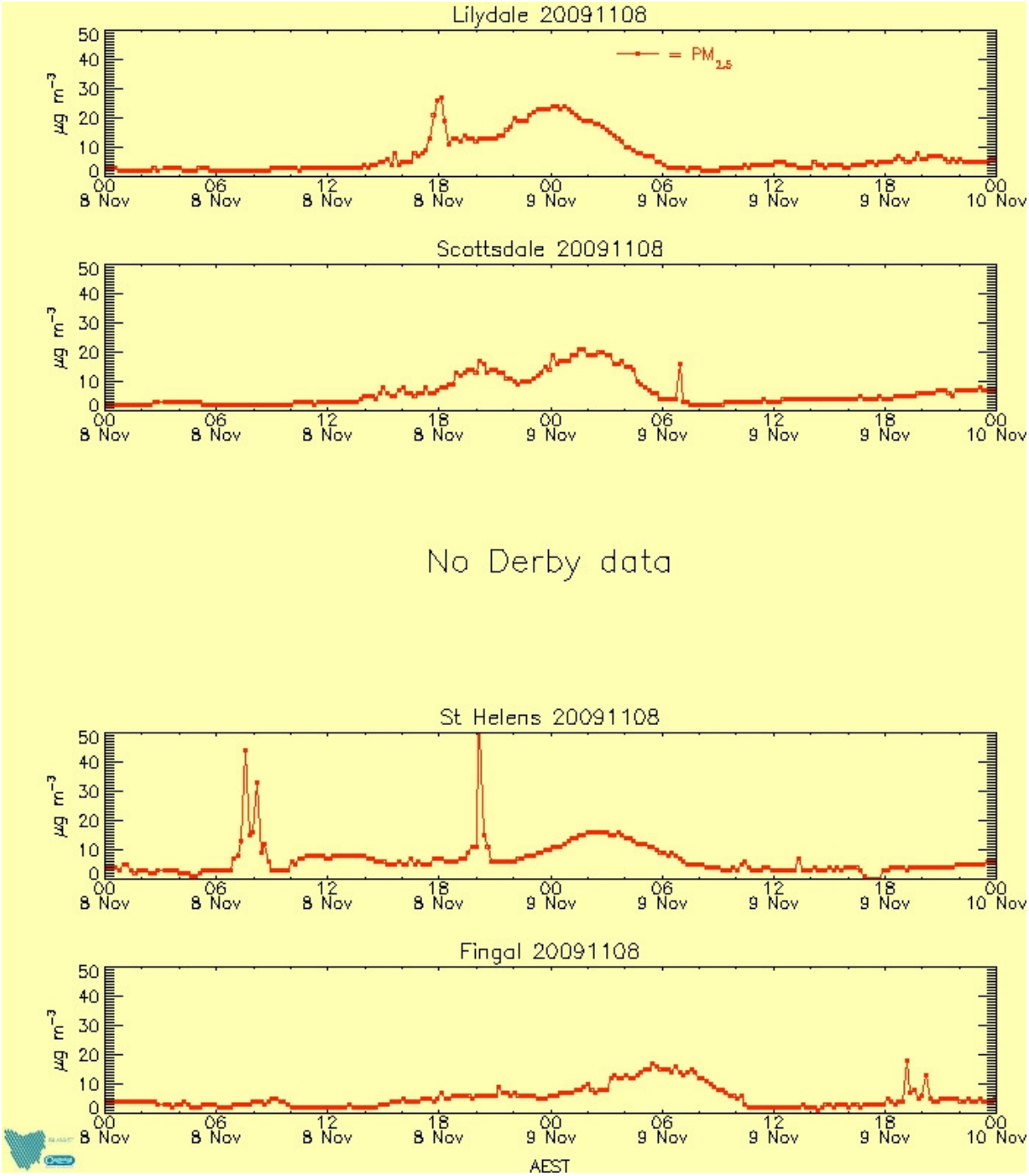


Figure 1 - Indicative $PM_{2.5}$ data from four north-east Tasmania BLANkET stations, 8th/9th November 2009

$PM_{2.5}$ levels begin to rise soon after 14:00 AEST (15:00 EDT) at Lilydale and Scottsdale. A short-lived peak is seen at Lilydale near 18:00 AEST. At St Helens there is clearly some smoke near 20:00 AEST (shown by a short-duration spike peaking near 50 µg m^{-3}). A more monotonic increase commences near 22:00 AEST. At Fingal a near-monotonic increase commences near 00:00 AEST on the 9th of November.

The winds during the smoke event were light north-westerly at Lilydale, light south-westerly at Scottsdale, and largely calm at St Helens and Fingal.

The general similarity of the 'smoke pulse' detected at these four stations is more easily seen in Figure 2. The peak of this pulse occurred at Lilydale near 00:00 AEST 9th November, at Scottsdale near 02:00 ASET 9th November, at St Helens near 02:30 AEST 9th November, and at Fingal near 06:00 AEST 9th November. Note too the general decrease in peak values as the pulse moved eastward.

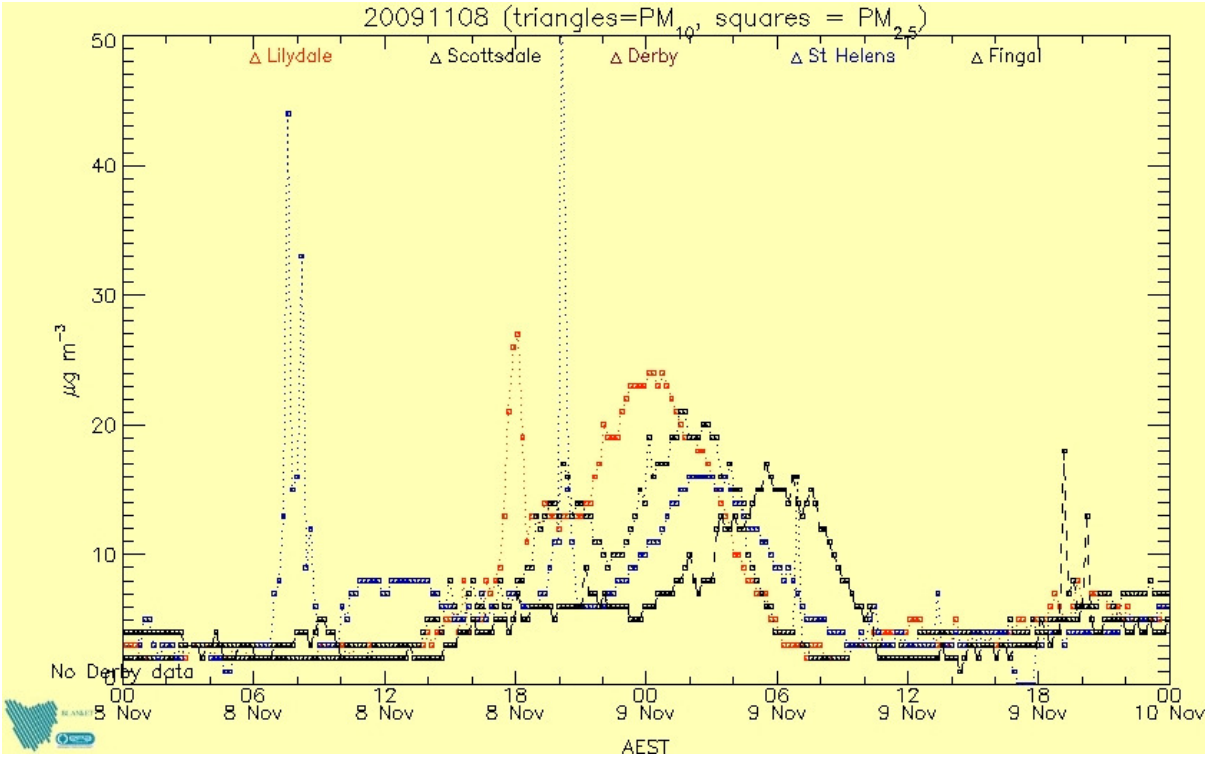


Figure 2 - As for Figure 1, but with the Indicative $PM_{2.5}$ data from the four stations plotted on the same axes

Indicative PM_{10} and $PM_{2.5}$ data from George Town and Launceston for the same interval as in Figures 1 and 2 are shown in Figure 3. George Town is equipped with a GRIMMs optical particle counter, similar to the BLANkET Dustrak instruments. Launceston uses a TEOM for PM10 and an older model Dustrak for $PM_{2.5}$. An earlier study indicated the GRIMMs provided a good indicative measurement for $PM_{2.5}$. The data from George Town show the beginning of a long duration increase in $PM_{2.5}$ near 17:00 AEST on the 8th of November, possibly with a short-duration precursor event beginning soon after 12:00 AEST. The data from Launceston show that smoke impacted at that station near 16:00 AEST on the 8th. Rowella air station was on-line; however the Rowella $PM_{2.5}$ TEOM was at this time configured to operate as a PM_{10} TEOM to check the operation of the system. Hence while the Rowella data confirm high PM levels on the afternoon of the 8th and morning of the 9th they will not be included here.

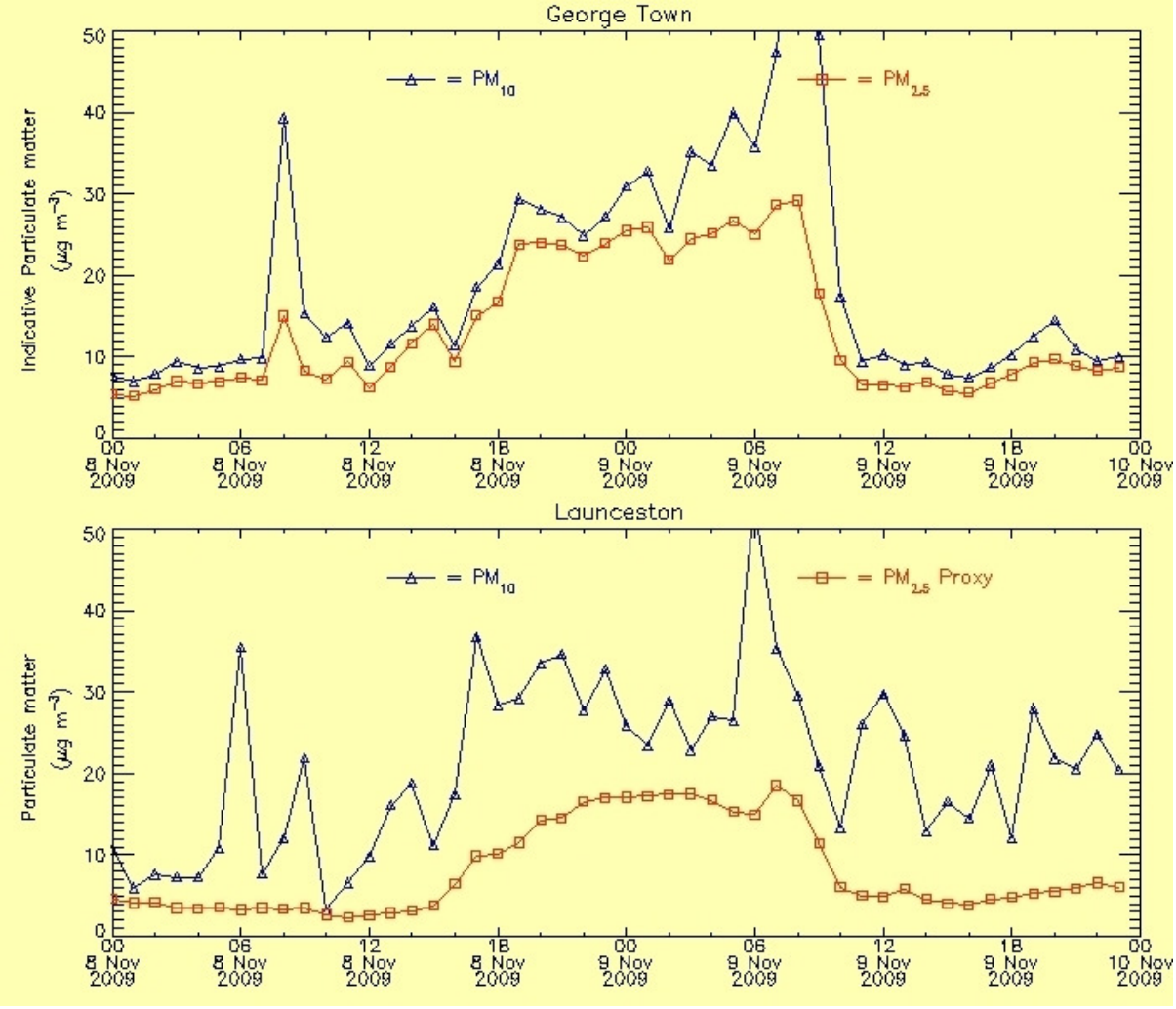


Figure 3 - Indicative PM_{10} (blue triangles) and $PM_{2.5}$ (red squares) data for George Town (upper panel) and Ti Tree Bend (Launceston, lower panel) for 8th-9th November 2009

Figure 4 shows in the one figure the George Town, Launceston, Lilydale, Scottsdale, St Helens and Fingal $PM_{2.5}$ data, where for ease of comparison the data have been interpolated to a common half-hour time base. From this figure it is seen that while the BLANkET stations detected what appears to be a travelling 'pulse' of smoke, the smoke that entered the Tamar valley of the afternoon of the 8th (as shown in the George Town and Launceston data) persisted at these two stations until 09:00 AEST

or slightly later on the 9th of November, around 16 hours after the smoke first impacted at these sites.

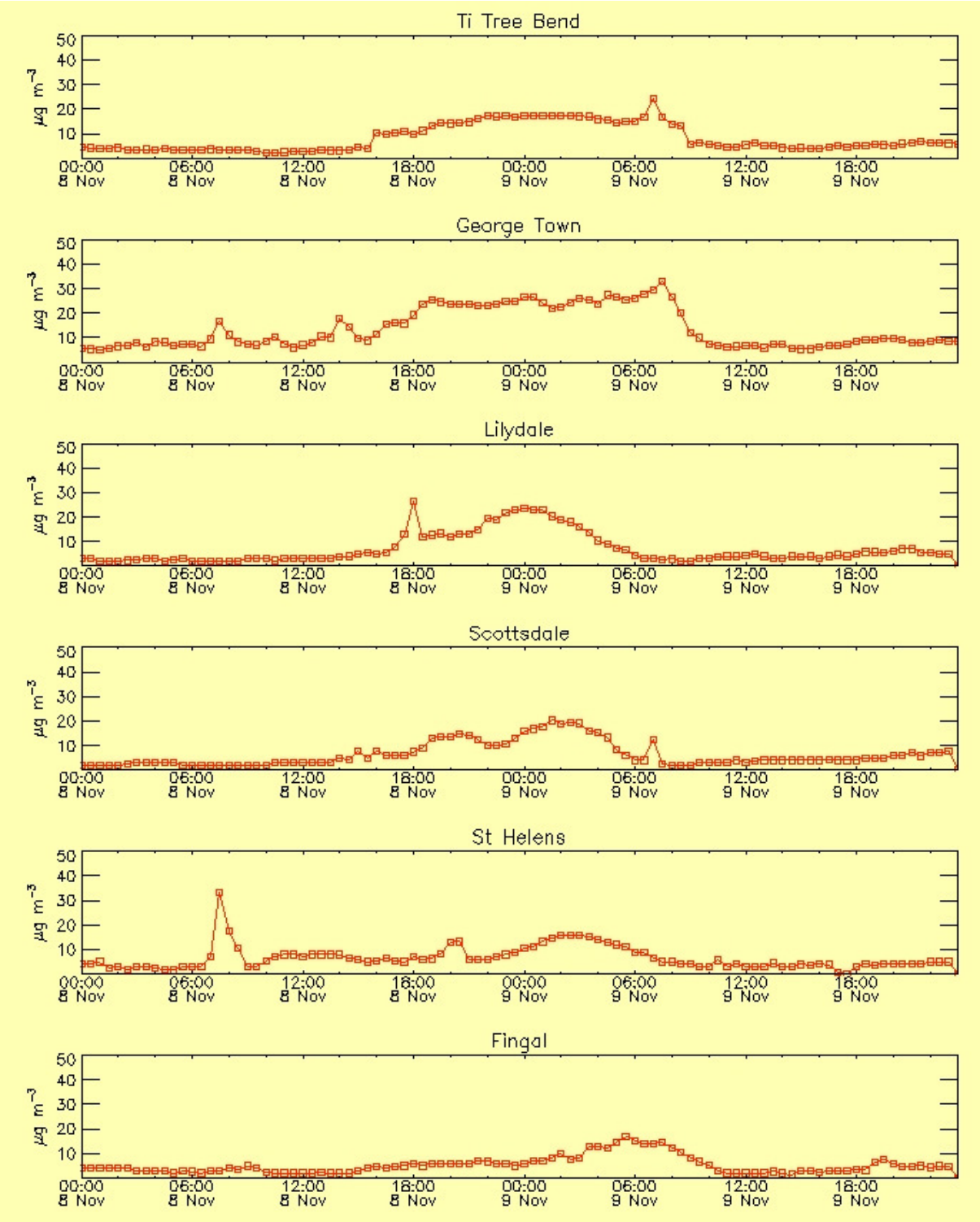


Figure 4 - Indicative $PM_{2.5}$ data from George Town, Launceston, Lilydale, Scottsdale, St Helens and Fingal stations, 8th - 9th November 2009. The data presented here have been interpolated to a common half-hour time grid to facilitate inter-station comparison.

Satellite Images: A MODIS aqua image from 14:25 AEST is shown in Figure 5. Also marked (as a red polygon) is the position of a fire inferred from analysis of the various satellite passbands (see http://rapidfire.sci.gsfc.nasa.gov/subsets/?subset=Tasmania.2009312.aqua.1km&vectors=fires). Inspection of a high-resolution image indicated the fire was to the south of Devonport, somewhere near Sheffield.

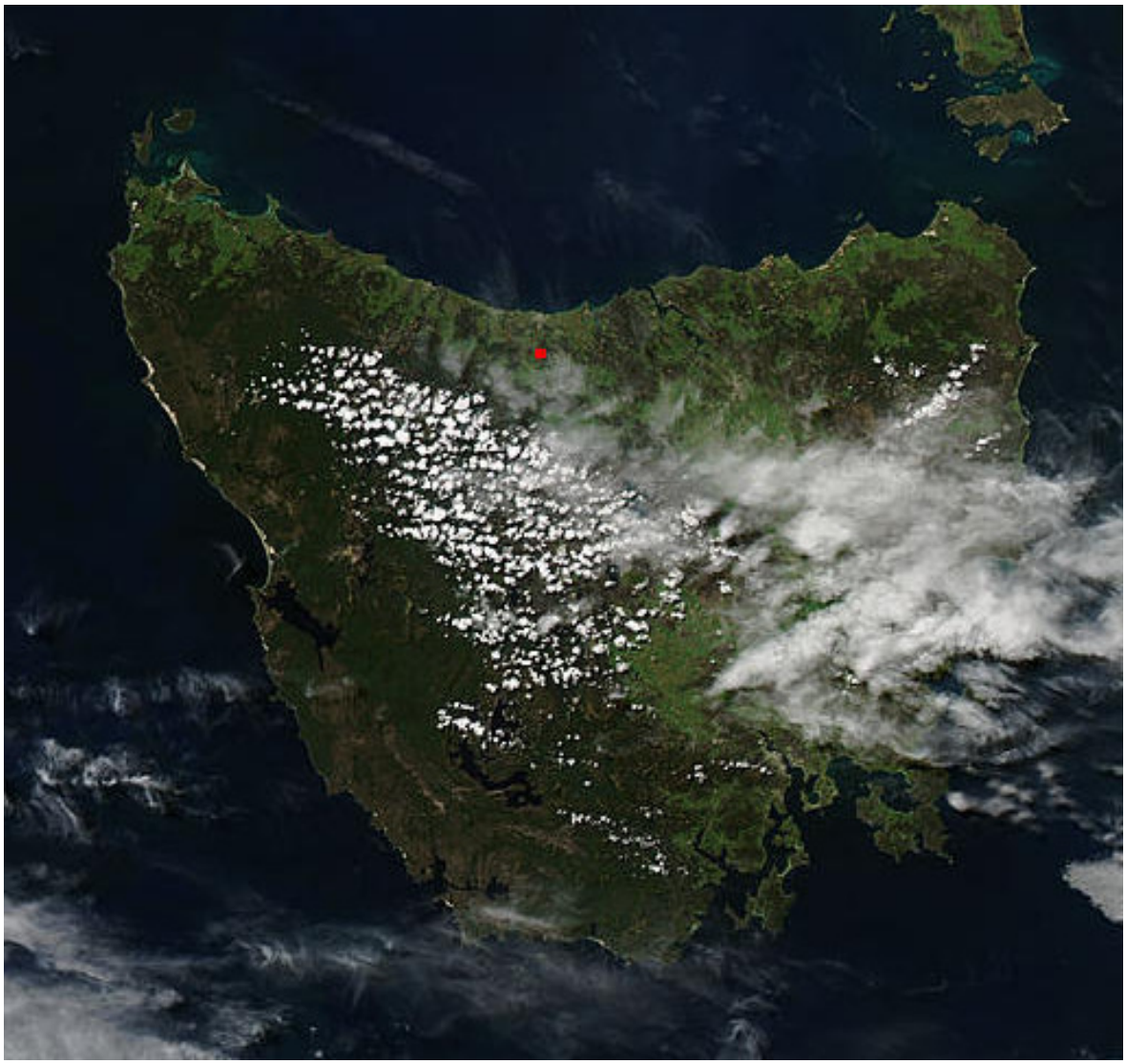


Figure 5 - MODIS Aqua image from 14:35 AEST, 8th November 2009. The inferred position of a fire is indicated by the red polygon.

The fire seen on the satellite image: The North-West office of the Tasmanian Fire Service (TFS) was contacted on the 17th of November in order to enquire about the fire seen on the MODIS image. The following information was supplied. The fire was at Bramich Road, Lower Barrington. It was first reported on the 5th of November and was reported as contained later that day. It flared up again in warm weather on the 8th of November. The TFS received a report of a large fire burning at this location at 16:10 EDT (15:10 AEST). The TFS attended, and reported the fire was controlled at 17:22 EDT (16:22 AEST). It was no longer large, and was burning in a south-easterly direction. The incident

was closed on the 10th of November at 12:54 AEST. The fire burnt approximately 20 ha in total. It was mostly private land but reached the outer margins of a Forestry Tasmania reserve.

When further detail was requested, the TFS officer reported that although they were off duty at the time of the fire, because they lived in the general area they happened to see the smoke from this fire from their residence. They reported a large smoke column 'standing high up in the sky'.

Forestry Tasmania was contacted as it was considered likely that some FT staff may have responded to this incident as FT land was involved. Lee Lockwood of FT attended the fire and reported the following information: 'The fire was predominantly (95%) on private bushland that had been logged, and predominantly burnt logging slash. The fuel loading was not considered heavy. About 5% of the burn was on unlogged state forest. Some bracken and ferns and other green material was burnt. The fire commenced about 15:15 to 15:30 EDT (14:15 – 14:30 AEST) and produced a large column of smoke for 4 to 5 hours. The smoke moved in a north-easterly direction.

On the same day there was a small fire on the Latrobe end of Brown Mountain, of size about 100 square metres, this did not give much smoke'.

TFS Burnie has no record of any other burn of comparable size on this day.

TFS Launceston has no record of any burning of significance in the Launceston/Tamar area on the 8th of November.

Given the data to hand, a working hypothesis is that the smoke seen in the Tamar and north-east BLANkET air stations originated from the Barrington burn.

Synoptic situation: The Bureau of Meteorology chart for 17:00 EDT (16:00 AEST) on the 8th of November is shown in Figure 6. A slow moving high in the Tasman Sea to the east of Tasmania produced light winds over the state. The centre of the high was nearly stationary but slowly tracked slightly northward over the next 24-hours.

By 10:00 AEST on the 9th of November a cold front was to the south and west of Tasmania (Figure 7). Winds in the north of Tasmania would be expected to be light north-westerly. This is consistent with the observed slow eastward drift of the smoke pulse through the BLANkET network.

Movement of the smoke pulse: The times of occurrence of the peak of the smoke pulse at the four north-east BLANkET stations are given in the following table. These times have been estimated by inspection of Figure 2. Also given are the air-line distances from the Barrington fire location to the station, and an inferred speed, assuming straight-line motion, between Barrington and the station for a postulated peak in smoke production at 15:00 AEST 8th November.

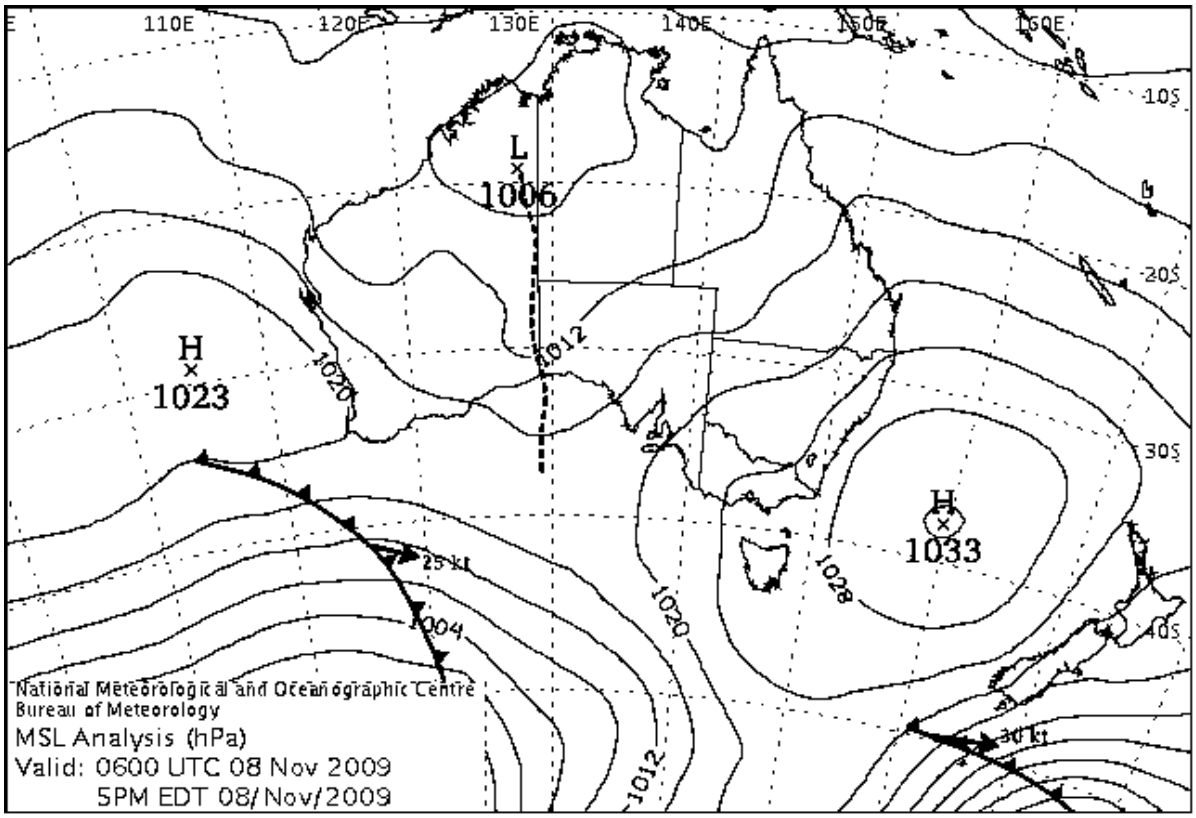


Figure 6 - Bureau of Meteorology chart for 16:00 AEST 8th November 2009

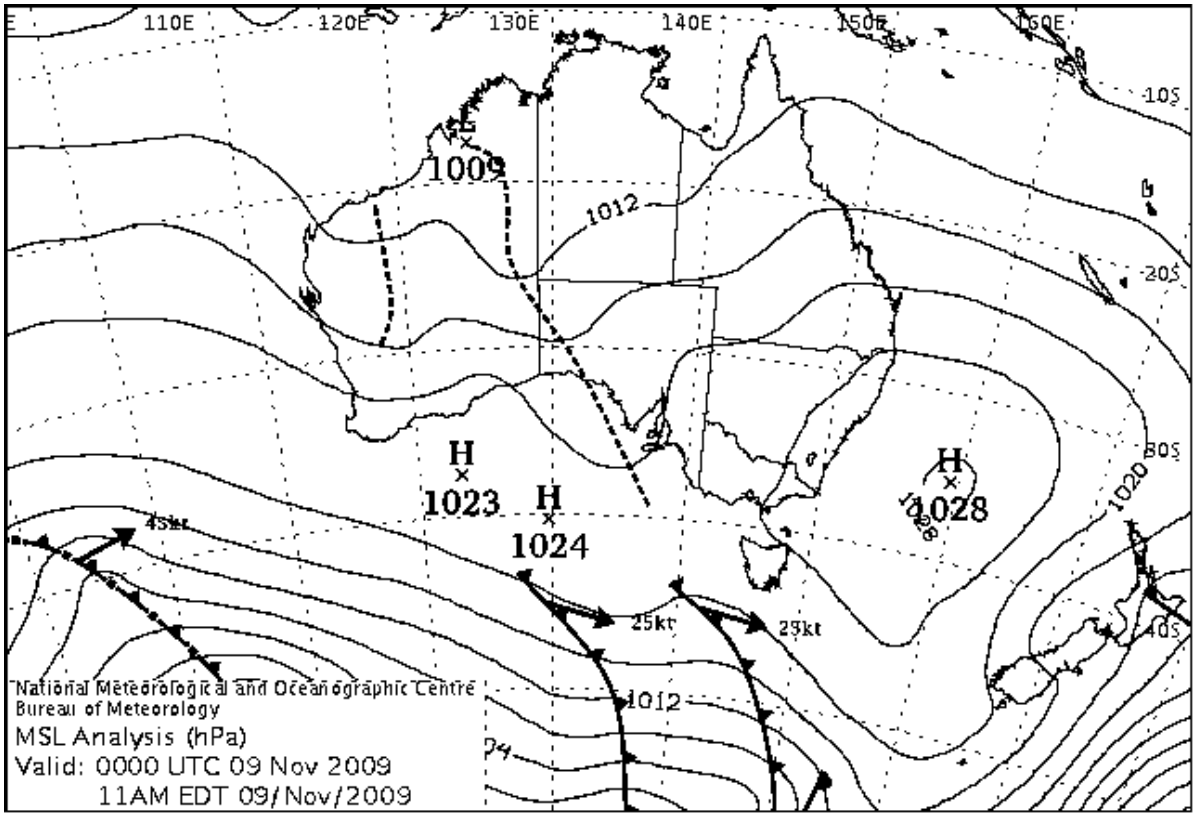


Figure 7 - BOM chart for 10:00 AEST 9th November 2009

Table 1 - Times of peak $PM_{2.5}$ at the four north-east BLANkET stations

Station	Lilydale	Scottsdale	St Helens	Fingal
Time of peak $PM_{2.5}$ (AEST)	00:00 9th November	02:30 9th November	03:00 9th November	06:00 9th November
Distance to Barrington fire site (km)	75	98	160	140
Inferred speed (km hr^{-1}) assuming fire peak 15:00 AEST 8th November	8	9	13	9

Table 2 gives the inferred speeds between the stations based on the relative timings of peak PM25 occurrence and inter-station distance. The observed inter-station speeds are difficult to interpret without knowing the detailed geometry of the smoke cloud. To illustrate this, Figure 8 shows a hypothetical configuration where a smoke front, tilted with respect to the line of motion, can impact on two well-separated stations almost simultaneously, thereby giving rise to a large inferred inter-station speed. This is a possible explanation for the large inter-station speed derived for the Scottsdale-St Helens leg (Table 2), but equally the influence of topography and meteorology on the smoke movement, particularly around the complex north-eastern Tasmanian terrain, is likely to be significant.

Table 2 - Inferred speeds of the smoke pulse between stations based on inter-station timing and distance

Station	Lilydale	Scottsdale	St Helens	Fingal
Lilydale	-	10	28	13
Scottsdale	10	-	124	19
St Helens	28	124	-	14
Fingal	13	19	14	-

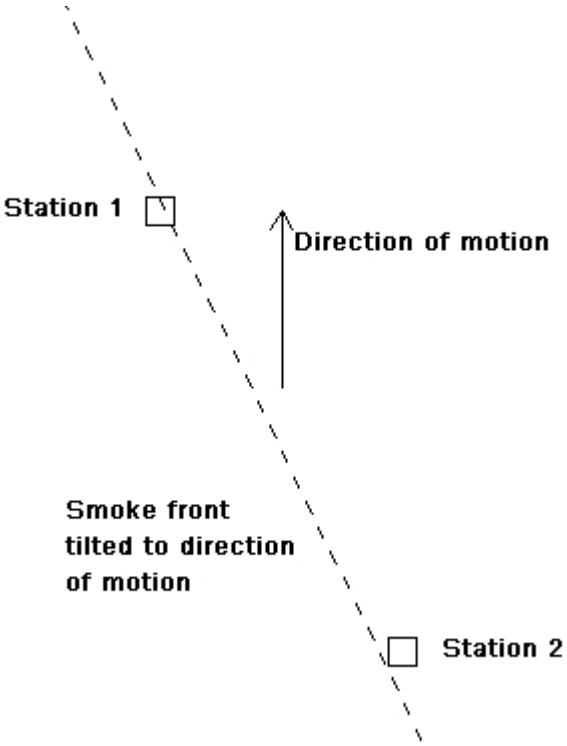


Figure 8 - Hypothetical geometry of a smoke front tilted with respect to the direction of motion. Station 2 will detect the smoke front passage soon after station 1. The inferred inter-station speed would be derived from the inter-station distance and relative timing of the smoke front passage, but cannot be used to determine the actual ground speed of the smoke front unless the angle of tilt is known.

In principle the smoke pulse could be modelled using an expanding Gaussian plume model, such as CalPuff, for assumed propagation and dispersion characteristics. The data from the four BLANkET stations could be used to refine model parameters. Given the nature of the topography in this part of Tasmania however a full modelling analysis using TAPM (The Air Pollution Model) which includes surface relief appears to be required. Such work is beyond the scope of this initial report, but is considered to be a viable topic for future study. For the current purposes, it is noted that the inferred speeds in Table 1, derived assuming the smoke source in the Barrington fire peaked near 15:00 AEST, are at least reasonably consistent for three of the stations. The actual trajectory followed by the smoke particles from source to detection will of course be a more complicated three-dimensional path, and will not, in most cases, be simple straight-line motion.

Smoke production: A very rough estimate of the amount of smoke (particles) in the atmosphere over the BLANkET stations on the night of the 8th/9th of November can be made as follows. Near 03:00 AEST on the 9th the four stations all recorded $PM_{2.5}$ readings near 15 µg m^{-3}. The stations bound an approximate triangular area (Lilydale-St Helens-Fingal-Lilydale, ignoring the small dogleg at Scottsdale, see Figure 9). It is further assumed for the purposes of this approximation that the smoke is confined to a maximum altitude of 1000 m, being a representative inversion layer height. This leads to a volume near 1.6 x10^{12} m^{-3}. Assuming an average $PM_{2.5}$ concentration in this volume of 15 µg m^{-3} at 03:00 AEST (as noted above) leads to a total particle mass near 24 tonnes. For a particle production rate of 17 g/kg of fuel burnt in such a burn, this requires some 1400 tonnes of fuel to have been consumed. This may be an underestimate. The smoke almost certainly extended beyond the Lilydale-St Helens-Fingal triangle. Also there is evidence that some smoke remained in the

Tamar valley rather than moving through the north-east. This estimate also ignores the topography of the region.

The Barrington fire burnt around 20 ha of light logging slash. If this fire was the source of the smoke detected at the BLANkET stations, the inferred fuel loading would therefore be near 70 tonnes ha^{-1}. The fuel consumed in a light logging slash burn is likely to be around 150 tonnes ha^{-1} (Dick Chuter, private communication). It appears that the amount of smoke detected by the BLANkET stations on the 8th/9th of November is around the correct order of magnitude to have originated in the Barrington burn.

Figure 9 - Google Earth view of the north-east Tasmanian BLANkET stations

General remarks: It seems likely that the source of the smoke seen at the various northern Tasmanian air stations on the 8th/9th of November was the Barrington fire. This is indicated as the Barrington fire appears to be the only fire of it size reported on the 8th of November (a Sunday) in northern Tasmania. The inferred transit times from Barrington to the stations appear consistent with the light winds prevalent on the day.

The observation that some smoke appears to have dropped into the Tamar valley and remained there while other parts of the plume were carried over the north-east BLANkET stations is also of considerable interest. It appears that under the meteorological conditions at the time, the Tamar valley may have trapped some of the smoke for 16 hours or more. This is an issue that requires further study, as it has implications for the dispersal of all smoke that enters the Tamar valley, not just bushfire smoke.

The detection of a 'pulse of smoke', quasi-gaussian in profile, moving from west to east across the north-east Tasmania BLANkET stations, is a very good empirical proof of concept of what the BLANkET network is designed to do. It is noteworthy that this pulse probably came from a relatively small fire (20 ha, of light fuel load). Significantly bigger burns can be carried out by the forest industry in the autumn burning season.

There is further information that could be extracted from this event with the use of computer dispersion modelling. This would appear to be a worthwhile extension.

Acknowledgements: Valuable assistance and information was obtained from Tasmanian Fire Service North West Region (Burnie) and Northern Region (Youngtown) offices, and from Lee Lockwood of Forestry Tasmania Mersey Office. Tony Blanks, Manager of Forestry Tasmania Fire Management Branch is also thanked for assistance.

Report compiled by John Innis.