BLANkET[1] Technical Report 25

Smoke from an agricultural burn near Campbell Town, 16 July 2013

Air Section, EPA Division, July 2013

Context of the BLANkET reports

BLANkET (Base-Line Air Network of EPA Tasmania) reports are compiled using BLANkET and other Tasmanian air quality data, as well as data from other sources. The topics and events chosen for these reports are selected for one or more of the following reasons: Scientific interest – for example if the event demonstrates a principle or principles of general value in understanding smoke movement and dispersal in the Tasmanian context; Well-documented events – such as if the event is captured by two or more stations and hence provides general information on smoke movement; General public interest – this includes large–scale or other smoke events that have generated comment at the time or are of intrinsic public interest for other reasons.

1 Summary

On the afternoon of the 16th of July 2013, a short–duration (∼15 minute) Travel BLANkET survey was conducted to measure smoke from an agricultural north of Campbell Town (northern midlands of Tasmania). The smoke initially appeared to be localised to the northern part of the town, although the plume was found to be moving relatively quickly and was variable in its impact. Peak $PM_{2.5}$ levels were over 200 μg m^{-3}. After ∼15 minutes from survey start the smoke plume was seen to move towards the central and southern end of the town. Measurements were made through the plume near town centre at the end of the survey. The smoke largely appeared to have cleared the town soon after this.

The Campbell Town BLANkET station is located near the town centre. The station recorded a few brief instances of elevated $PM_{2.5}$ in the late afternoon in the 10–minute resolution 'real–time' data set. The first and largest elevation effectively coincided with the time the plume was seen to move through, and was measured in, the central part of town during the survey. In the absence of knowledge of the burn, and without the survey data, the time–series of $PM_{2.5}$ from Campbell Town station on this day could have been interpreted as arising from isolated plumes from local woodheaters. However, the higher resolution 2–minute 'logged data' time-series of $PM_{2.5}$ shows the first elevated peak to consist of a smooth rise and fall, suggestive of a source that is not local to the station. Without the survey this would be the only indication that local woodheaters were not the origin of the smoke.

[1] Base–Line Air Network of EPA Tasmania

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2 Travel BLANkET survey data

An air section officer was returning to Hobart from the north of Tasmania on the afternoon of the 16th of July 2013. Nearing Campbell Town an appearance of smoke, close to the ground, was seen to the south. Closer to Campbell Town it was realised the source was an agricultural burn just to the north of the town. The approximate location was noted, to the west o the Midland highway, a few kilometres north of Campbell Town. The smoke plume was entered just on the northern outskirts of Campbell Town. The officer proceeded to the centre of town, which was clear of smoke[2]. The officer had a Travel BLANkET survey instrument in the vehicle. This was set up and a short survey was commenced.

The plan view of the survey, displayed via Google Earth, is shown in Figure 1. Symbols are colour coded by $PM_{2.5}$ value. Representative colours are: Blue: 0-20 μg m^{-3}; Light green: 20–40 μg m^{-3}; Dark green: 40–70 μg m^{-3}; Fawn: 70–90 μg m^{-3}; Red: above 90 μg m^{-3}. The location of the Campbell Town BLANkET station is shown by the red 'B' icon labelled 'CT'. The *approximate* location of the burn is also marked. The burn ground was not visible directly from the highway, but was over a small ridge. The position shown is based on the best recollection of the officer concerned. The smoke plume was largely confined to the northern end of town, and was moving, apparently back–and–forth, over this area relatively quickly. At one point the plume moved to the west, so the survey was extended along the Macquarie Road, northwest of Campbell Town. The plume was transected, and smoke–free air reached. The car was turned around soon after to return to Campbell Town. A photograph, in fading light, was taken from Macquarie Road looking towards Campbell Town. This is shown in the Appendix A.

Shortly afterwards it became clear that the plume was moving towards the centre of town. The vehicle was driven through the town centre and encountered the plume just north of the river, shown by the isolated sequence of red symbols near the 'Campbell Town' label. South of the town the air was free of smoke. The car was stopped at the southern end of the town. It was seen that the plume had cleared the town, and was moving to the south east. As there are few public roads in that direction the survey was terminated.

The time–series of $PM_{2.5}$ from the survey is shown in Figure 2. The early part of the survey was around the triangle of the Midland Highway, West St, and Pedder St from survey start to near 17:10 AEST. The peak $PM_{2.5}$ value of 250 μg m^{-3} was measured at the northern end of the town, at the junction of West St and the highway, near 17:05 AEST. The outward transect of the plume on the Macquarie Road was near 17:11 AEST; the return transect was near 17:13 AEST onwards. The transect of the plume through the town centre, on the Midland Highway, was near 17:17 AEST.

3 Data from the Campbell Town BLANkET station

Figure 3 shows data from the Campbell Town BLANkET station for the 16th of July 2013. The upper panel shows $PM_{2.5}$ and PM_{10} data obtained by a

[2]The vehicle was re–fueled at this time.

DRX dustrak instrument. The lower panel shows meteorological data. The $PM_{2.5}$ and PM_{10} values are generally low except for some elevated peaks late in the afternoon, and a smaller, general elevation into the evening. The first peak, near 17:20 AEST and 100 μg m^{-3} in size, consists of this one high value and a subsequent measurement near 25 μg m^{-3}. The air temperature was relatively constant near 10 C over the day. The wind was generally a light north–westerly, with relatively little change in direction, or effectively calm. In the absence of other information, the time–series of $PM_{2.5}$ would have likely been interpreted as indicating several isolated smoke plumes from individual woodheaters were detected at the station in the late afternoon, with a small general increase in smoke levels also likely due to woodheater use.

The $PM_{2.5}$ data shown in Figure 3 are 10–minute resolution data that were downloaded in real-time on the day, and were displayed on the EPA web site. The DRX dustrak instrument also is programmed to log data at a 2–minute resolution. These data are downloaded once per day, currently at 14:00 AEST[3]. The time series of the 2–minute $PM_{2.5}$ data are shown in Figure 4. The higher–time resolution data show the 17:20 AEST elevation to be a well delineated increase in $PM_{2.5}$, with nine data points above 20 μg m^{-3}. The smooth time–signature is suggestive a plume passing through the station from a smoke source some distance away, as the smoke has had time to mix with the air an obtain a measure of uniformity. As will be discussed below the 17:20 elevation is due to the plume from the burn to the north of Campbell Town. The subsequent short–term elevations (e.g. near 19:30 AEST) show a more variable time signature. This may indicate a more local source.

4 Discussion

Figure 5 shows the Travel BLANkET $PM_{2.5}$ data (magenta symbols) and 2–minute $PM_{2.5}$ station data (red) on the same axis for the time interval from 16:48 to 18:00 on the 16th of July. When smoke levels were high in the north of the town, near 17:0 AEST, the station was recording background 'clean–air' levels. The survey transect of the plume in the central part of the town (on the highway), near 17:17 AEST (the last peak in the survey time series) coincides with the smoke onset at the station. The peak $PM_{2.5}$ at the station occurred about 2 minutes after the transect through the plume on the highway[4] The station is approximately 200 m west of the Midland Highway.

Figure 6 shows an oblique view of the Travel BLANkET survey data, displayed in Google Earth, as seen from the south of the town looking to the north. The location of the Campbell Town BLANkET station is shown by the red 'B' icon with the 'CT' label. The spatial extent of the plume in the town centre, along the highway, is well demonstrated in this view. It is clear that the elevated

[3]These logged data provide a backup record in case network communications to the station are interrupted, meaning that the real–time data would become unavailable for an interval. All logged data would be downloaded at 14:00 AEST on the first day that communications were restored. The DRX is capable of storing approximately a month's worth of 2–minute time resolution data.

[4]The station data time–stamping is controlled via reference to the Tasmania State government NTP time server. The Travel BLANkET data string also includes GPS clock information. Hence the relative timing of the two data sets should be in agreement to within one second.

$PM_{2.5}$ readings at the BLANkET station at almost the same time were due to the plume passing through the station.

As noted earlier, in absence of other information, the 17:20 AEST elevation at Campbell Town station on this day would have been most likely ascribed to a local woodheater plume, especially if only the 10–minute resolution data were inspected. The smooth variation seen in the 2–minute data provide an indication that the source was not local.

The impact from the agricultural burn on the central areas of Campbell Town was of short duration. It is not known for how long the plume impacted in the north of the town. The elapsed time from the first realisation the plume was present in the north of the town until the survey commenced may have been of order of 15 minutes. Hence, the plume impacted on the north of the town for at least 25 minutes. It is probable, given the relatively constant wind direction measured at the station on this day, that the plume would have been moving towards the northern parts of the town earlier in the day. It is not known when the burn commenced, or whether the smoke was moving at or near ground level during the earlier stages of the burn.

The general low levels of the $PM_{2.5}$ measured at the Campbell Town station on this day indicate the smoke plume impact was likely to be limited in spatial extent.

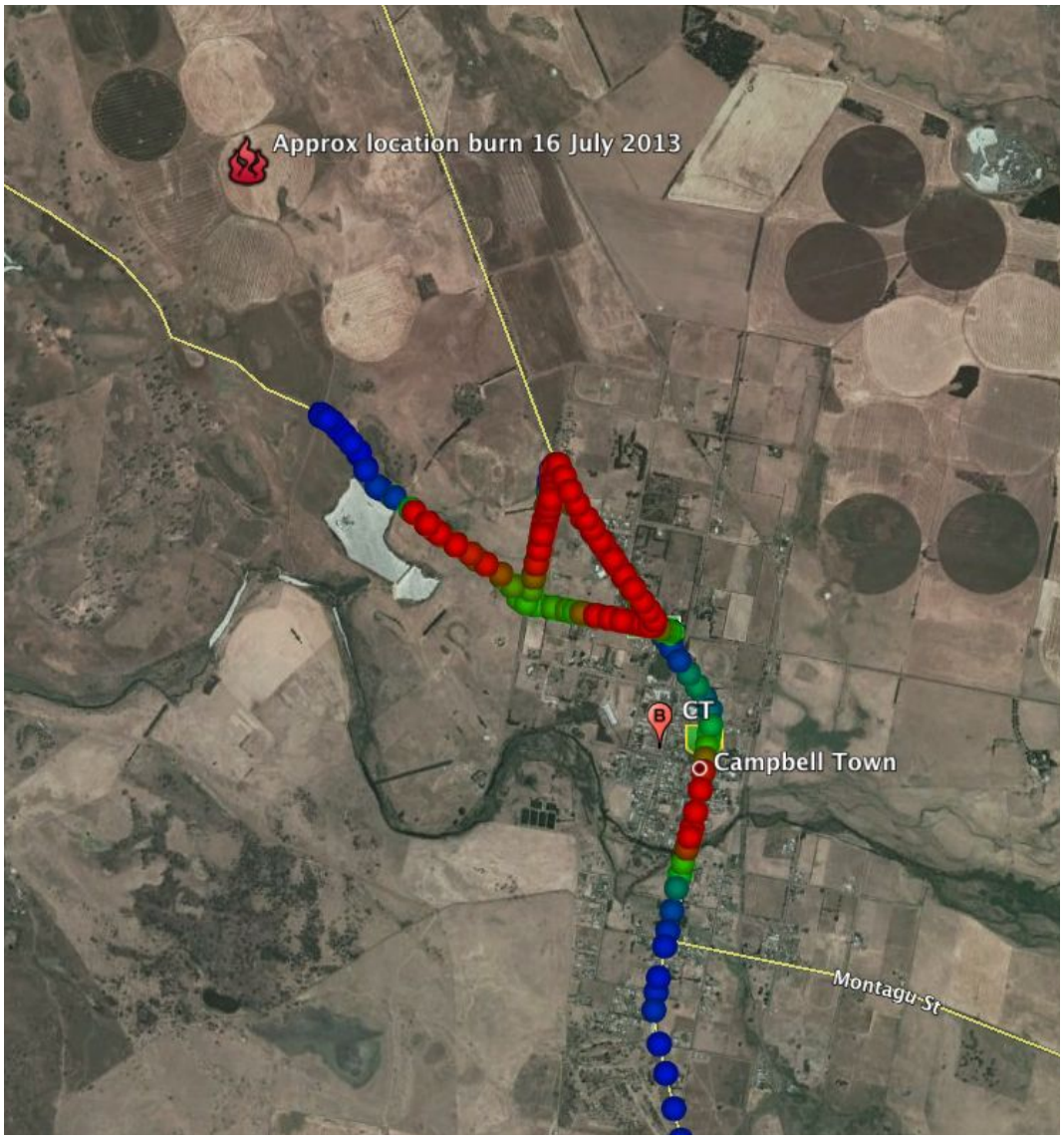

Figure 1: Plan view of Travel BLANkET survey, Campbell Town, 16 July 2013. Symbols are colour coded by $PM_{2.5}$ value. Representative colours are: Blue: 0-20 μg m^{-3}; Light green: 20–40 μg m^{-3}; Dark green: 40–70 μg m^{-3}; Fawn: 70–90 μg m^{-3}; Red: above 90 μg m^{-3}. The location of the Campbell Town BLANkET station is shown by the red 'B' icon labelled 'CT'.

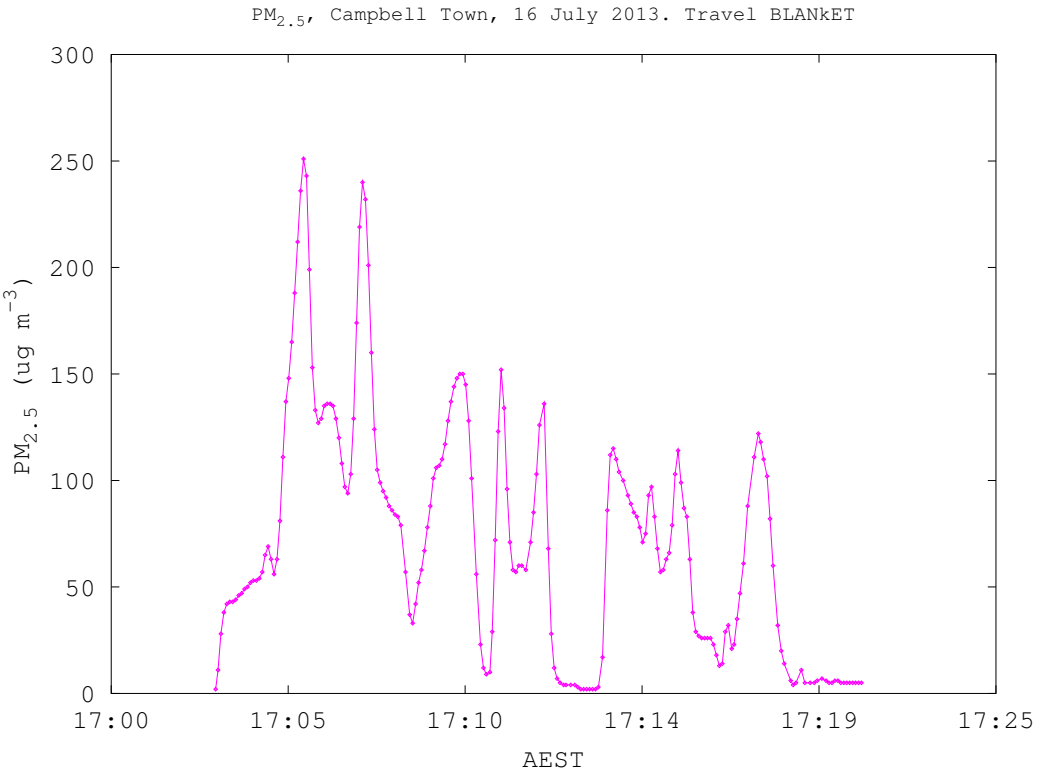

Figure 2: Time–series of $PM_{2.5}$ from Travel BLANkET, Campbell Town, 16 July 2013.

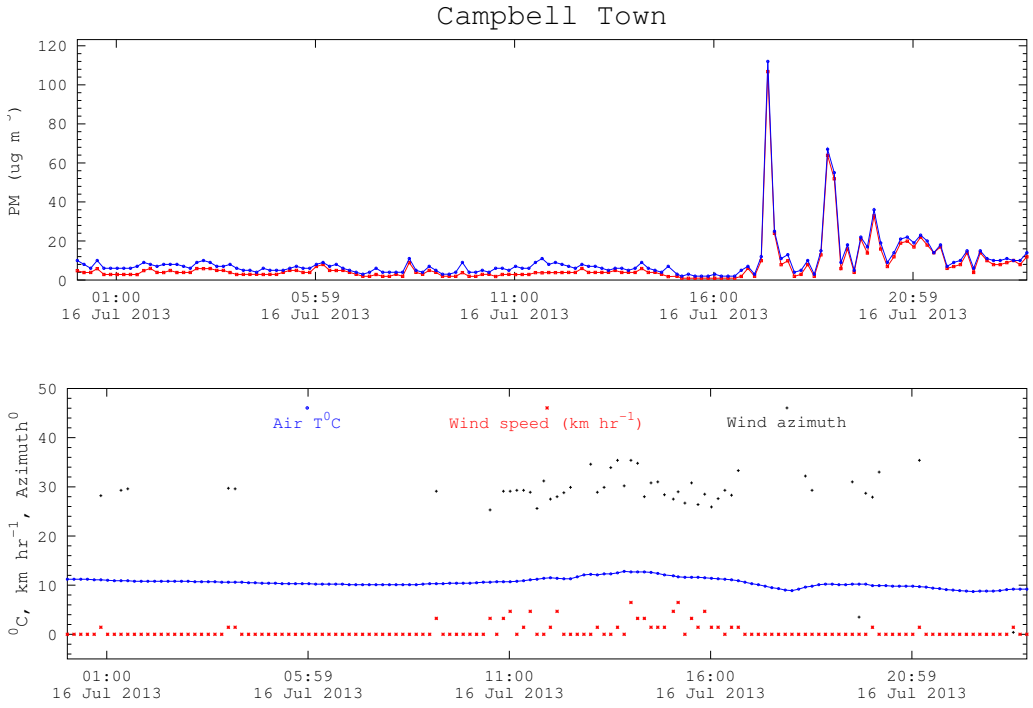

Figure 3: Data from the Campbell Town BLANkET station, 16 July 2013. Upper panel: Time–series of $PM_{2.5}$ (red) and PM_{10} (blue). Lower panel: Meteorological data: air temperature (blue); wind speed (red) and wind azimuth (black). Wind azimuth has been divided by 10 to fit the plot axis. e.g. a wind azimuth of 30 units on the plot corresponds to 300^0.

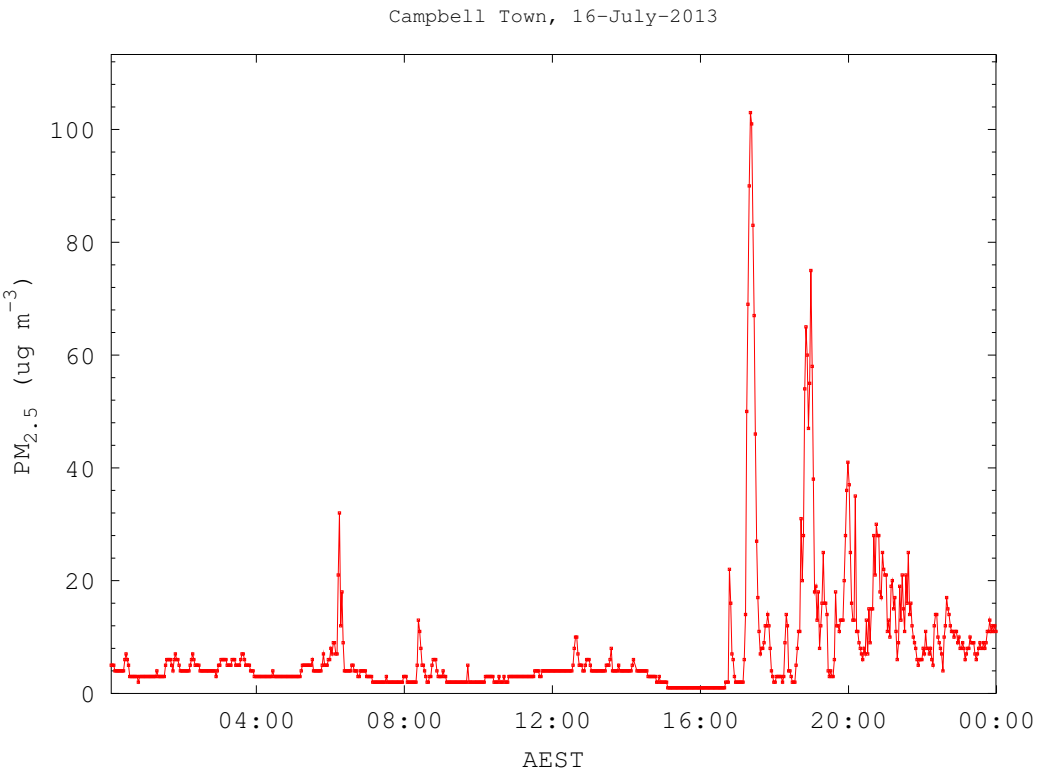

Figure 4: Two–minute resolution $PM_{2.5}$ data from the Campbell Town BLANkET station, 16 July 2013.

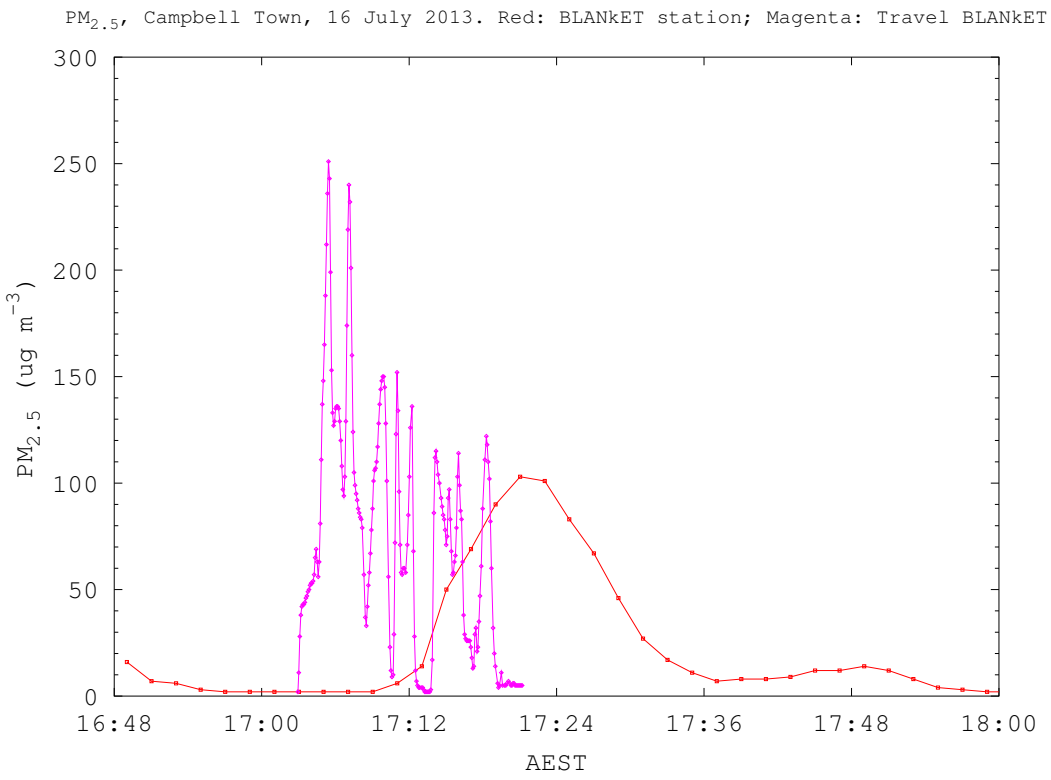

Figure 5: $PM_{2.5}$ data from Travel BLANkET (magenta) and two–minute resolution $PM_{2.5}$ data from the Campbell Town BLANkET station (red), 16 July 2013.

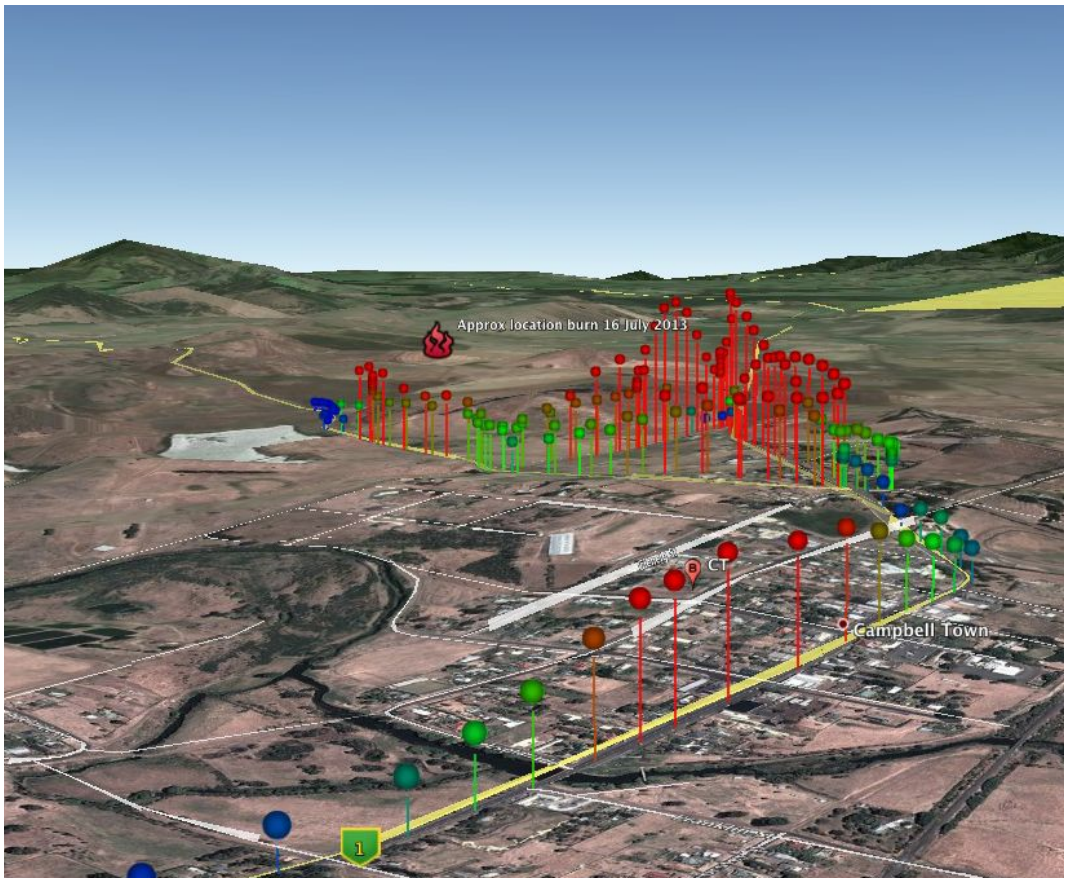

Figure 6: Oblique view of the Travel BLANkET survey data, as seen from the south of the town looking north. The location of the Campbell Town BLANkET station is shown by the red 'B' icon with the 'CT' label.

5 Particle size–distributions

A question that has been asked a number of times of the EPA Division is whether smoke from different biomass fuels have different signatures that could readily be measured under field conditions. There are laboratory methods and advanced techniques that could address this issue[5]. For semi–opportunistic field work however a simpler approach is needed.

Smoke particle size is dependent on a number of complex processes (e.g. fuel type, concentration of water and other contaminants, combustion temperature and conditions, age, meteorological conditions, atmospheric transport processes and potentially the presence of other aerosols). Small differences in particle size–distributions could hence be present in smoke from identical fuel types. However, as the physical property of (indicative) particle sizes can be relatively easily derived from optical–scatter devices, it is considered worth carrying out a preliminary study based on data from Campbell Town and from two contemporaneous surveys of Geeveston, measuring smoke from domestic woodheaters.

During the Campbell Town survey an AeroTrak 9306V particle counter[6] was also operated. The AeroTrak 9306V counts and allocates particles into one of 6 size channels. The two smallest channels are from 0.3 to 0.5 μm, and 0.5 to 1.0 μm. Woodsmoke particle number distributions peak near 0.1 to 0.2 μm, with a tail that can extend up to 1 μm or more. The two smallest AeroTrak 9306V channels hence cover the larger smoke particle sizes. A transformation from the particle counts in these two channels, when measuring smoke, to a $PM_{2.5}$ measurement equivalent to that of the DRX dustrak is possible, as noted in Appendix B.

The same AeroTrak 9306V instrument was also used during two Travel BLANkET surveys of Geeveston, southern Tasmania, on the 28th of May 2013 and the 17th of July 2013[7].

The counting efficiency of the AeroTrak 9306V is specified to by 50% at 0.3 μm, and nominally 100% above 0.45 μm. Small variations in the counting efficiency near 0.3 μm could result in large variations in count rate when measuring woodsmoke. Hence the discussion to follow, from three surveys with the same instrument, is limited to a consideration of relative differences in particle distributions.

Figure 7 shows the ratio of channel 2 count to channel 1 count for the three surveys. The symbols are colour coded as noted in the Figure.The channel counts have been corrected for dead–time losses, using a previously determined dead–time correction of $\tau = 1.1{\times}10^{-5}$ s^{-1}. While some differences appear present, it is difficult to determine if they are significant due to the large number of overlapping data points.

An alternate means of visualising these data are the normalised probability density function plots of the ratio values, shown in Figure 8. The probability density function shows the probability ('chance') of occurrence of a given ratio.

[5]e.g. Maleknia, SD, Bell, T, Adams, MA, *Eucalypt smoke and wildfires: Temperature dependent emissions of biogenic volatile organic compounds*, 2009, International Journal of Mass Spectrometry, Volume 279, Issue 2-3, pp 126–133, describe the use of proton-transfer reaction mass spectrometry, gas chromatography mass spectrometry, and direct analysis in real time mass spectrometry to study the chemical composition of bushfire smoke.

[6]Manufactured by TSI inc., USA, makers of the DRX dustrak used in the BLANkET stations.

[7]i.e. The July survey was conducted on the day after the Campbell Town survey.

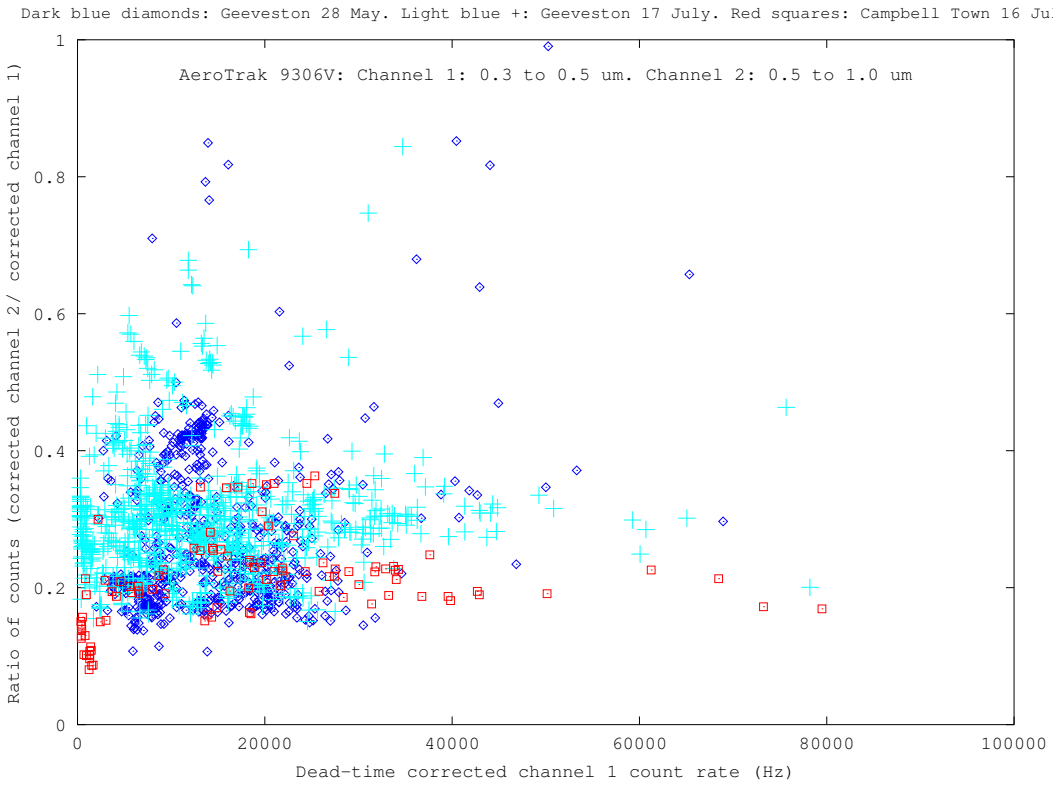

Figure 7: Ratios of corrected counts: channel 2 / channel 1. Dark blue diamonds: Geeveston 28 May 2013; Light blue upright crosses: Geeveston 17 July 2013; Red squares: Campbell Town, 16 July 2013.

The ratios are allocated into bins of 0.05 units in width. As an example to interpret the plot, for the Campbell Town survey (red lines) the chance of a ratio occurring in a bin centred on 0.2 with a full width of 0.05 units (i.e. within a range from 0.175 to 0.225) is 0.4, or 40%.

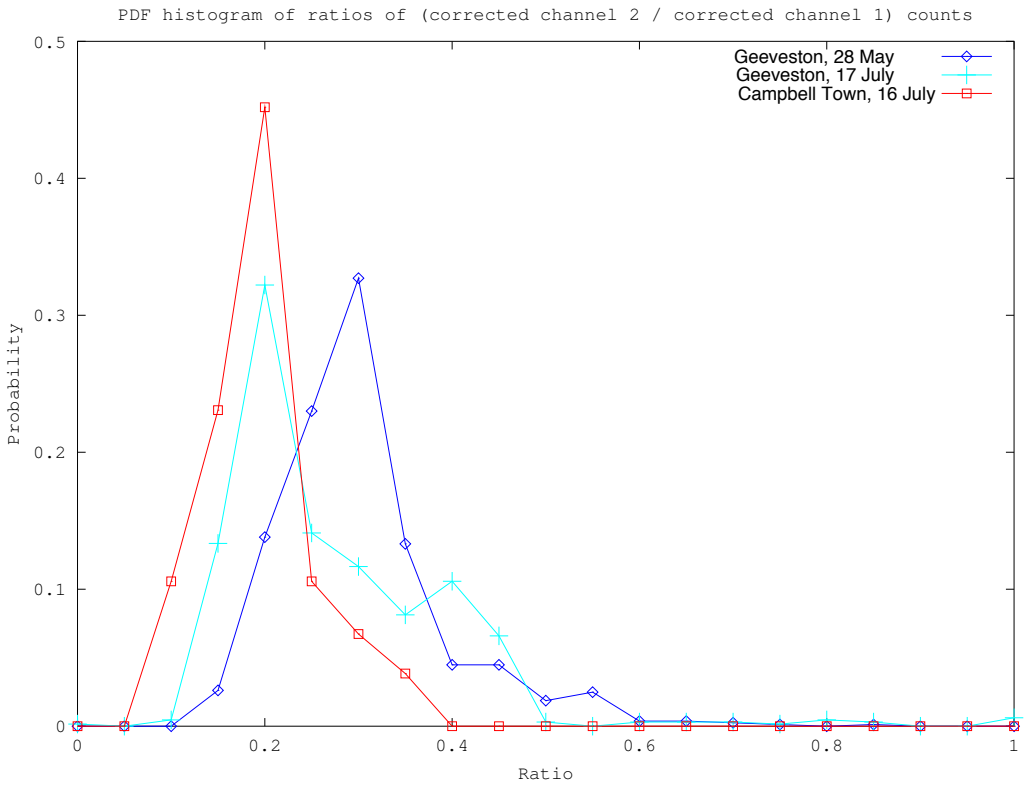

Figure 8: Probability density functions of the ratios of corrected counts: channel 2 / channel 1. Dark blue diamonds: Geeveston 28 May 2013; Light blue upright crosses: Geeveston 17 July 2013; Red squares: Campbell Town, 16 July 2013.

The distributions for the Campbell Town 16 July survey and the Geeveston 17 July survey are very similar, though the Geeveston survey shows a more extended tail to higher ratio values. The Geeveston 28th May survey shows a peak shifted to higher ratio values than for the other two surveys. At present it is not known if the difference is significant, if it arises from real differences in the underlying smoke particle distributions, or if arises due to an instrumental effect. Further data may provide more guidance. At present the data to hand provide no obvious means of discriminating between the 16th July Campbell Town crop smoke and the 17th July Geeveston domestic heater smoke. To study the issue in depth would probably require a higher–resolution particle sizer, with a lower cut-off sensitivity nearer 0.1 μm.

6 Acknowledgements

We thank Aurora Energy for supporting the operation of the Campbell Town BLANkET station.

Travel BLANkET was constructed by A. Cunningham, from a design by A. Cunningham and J. Innis. The car–based surveys were conducted by B. Hyde and J. Innis. Report compiled by J. Innis.

A An image from the 16th of July 2013

A photograph looking towards Campbell Town from Macquarie Road was obtained in fading light about 17:15 on the 16th of July. The raw image is shown in Figure 9

Figure 9: Photograph looking towards Campbell Town from Macquarie Road, about 17:15 AEST 16th July 2013. The image was taken in fading light.

The image was enhanced[8] to bring out detail in the image. The enhanced image is shown in Figure 10. Although the final quality is not high, it can be seen in Figure 10 that the background hills near image centre are much less well defined than at the left of the image. This was due to smoke obscuration. Smoke is also visible, though harder to see, in front of the clouds at image centre and to the right.

[8]Using the GIMP (GNU IMage Processing) package.

Figure 10: Image–enhanced version of the photograph in Figure 9, looking towards Campbell Town from Macquarie Road, about 17:15 AEST 16th July 2013. The distant hills at image centre are less well defined, due to smoke, than at image left.

B Using the AeroTrak to derive an effective $PM_{2.5}$ measurement when sampling smoke

A brief discussion of the AeroTrak 9306V instrument was presented in the report of the EPA Division's monitoring of the Longford tyre depot fire in 2012[9], which also noted the difficulty of inferring a *mass concentration* (e.g. as μg m^{-3}) from optical particle counts unless a direct method is available to provide a calibration.

The DRX dustraks used in the BLANkET network, and Travel BLANkET, are all calibrated against one of two DRX dustraks that are in continuous operation at the EPA Division's New Town air station in Hobart. These two New Town DRXs have been calibrated against reference air quality instruments also in operation at New Town, specifically Low–Volume Air Sampler (LVAS) and Tapered Element Oscillating Microbalance (TEOM) instruments. Regular checks are carried out to verify the calibration factors.

The AeroTrak 9306V used in the analysis above was operated in conjunction with the EPA Division's 'Travel BLANKET unit 3' on the three nights discussed here. It was also used on another Travel BLANkET survey on the 20th of May 2013 at Longford in northern Tasmania. A polynomial fit between the sum of the counts in the AeroTrak channels 1 and 2, and the TravelBLANkET $PM_{2.5}$ was derived. This polynomial was applied to the AeroTrak data from the following three surveys. The figures below show the comparison between the AeroTrak 'proxy' $PM_{2.5}$ and the Travel BLANkET $PM_{2.5}$ for each survey.

There is generally a large measure of agreement between the Travel BLANkET $PM_{2.5}$ and that derived from the AeroTrak data for the two Geeveston surveys. There is a suggestion that the AeroTrak underestimates $PM_{2.5}$ at the highest measured concentrations (i.e. over 250 μg m^{-3}). This has been noted before (see the Longford tyre fire report noted earlier). There may also be some sampling effects contributing to this difference – the AeroTrak was run on a 9–second measurement cycle, with a 1 second pause between measurements. The DRX was operated on a continuous 5–second measurement cycle. The AeroTrak is measuring on average, during 90% of the interval it takes for two DRX measurements to be taken. At very high and variable concentrations, where the DRX measurement can change significantly between adjacent 5–second samples, the 10% non–measuring time of the AeroTrak could be a factor in the difference.

The agreement for the shorter Campbell Town survey is also reasonable, but with the suggestion the AeroTrak has underestimated $PM_{2.5}$ at the higher concentrations. Except for these instances, the agreement appears similar to that seen in the two Geeveston surveys.

[9] *The tyre–depot fire at Longford, Tasmania, 15–17 February 2012. Air quality monitoring by vehicle–based surveys*, http://epa.tas.gov.au/epa/document?docid=972

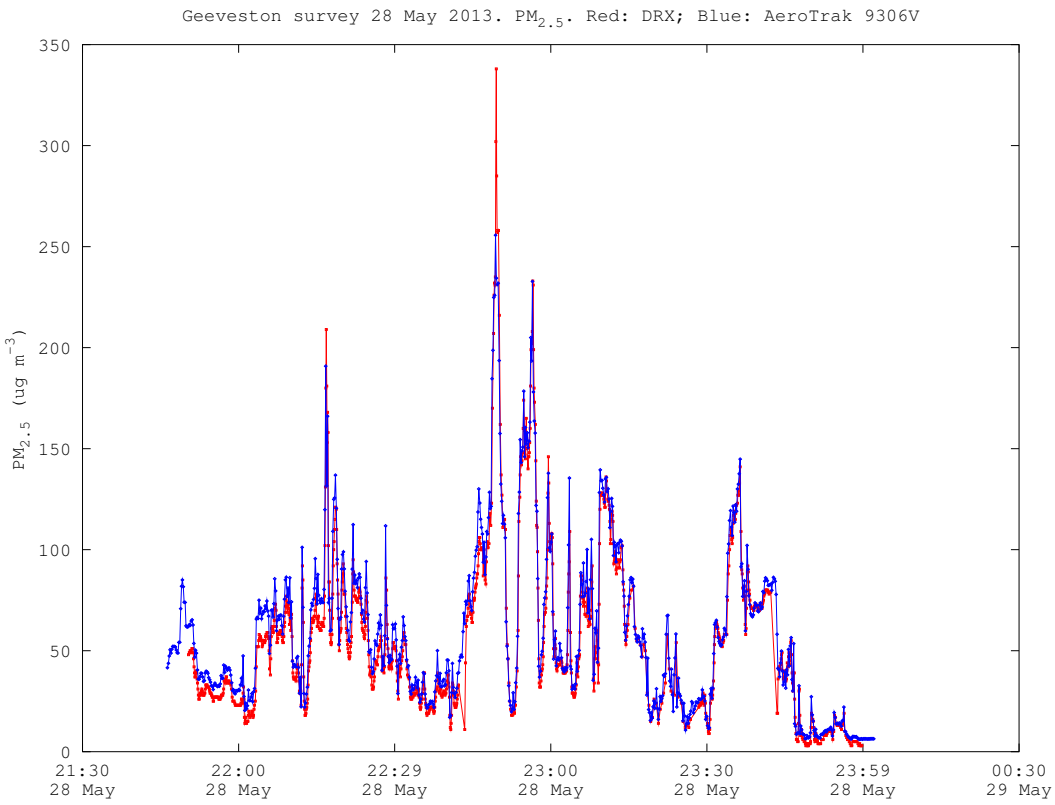

Figure 11: Geeveston 28 May 2013, $PM_{2.5}$; Blue: AeroTrak proxy $PM_{2.5}$; Red: Travel BLANkET $PM_{2.5}$

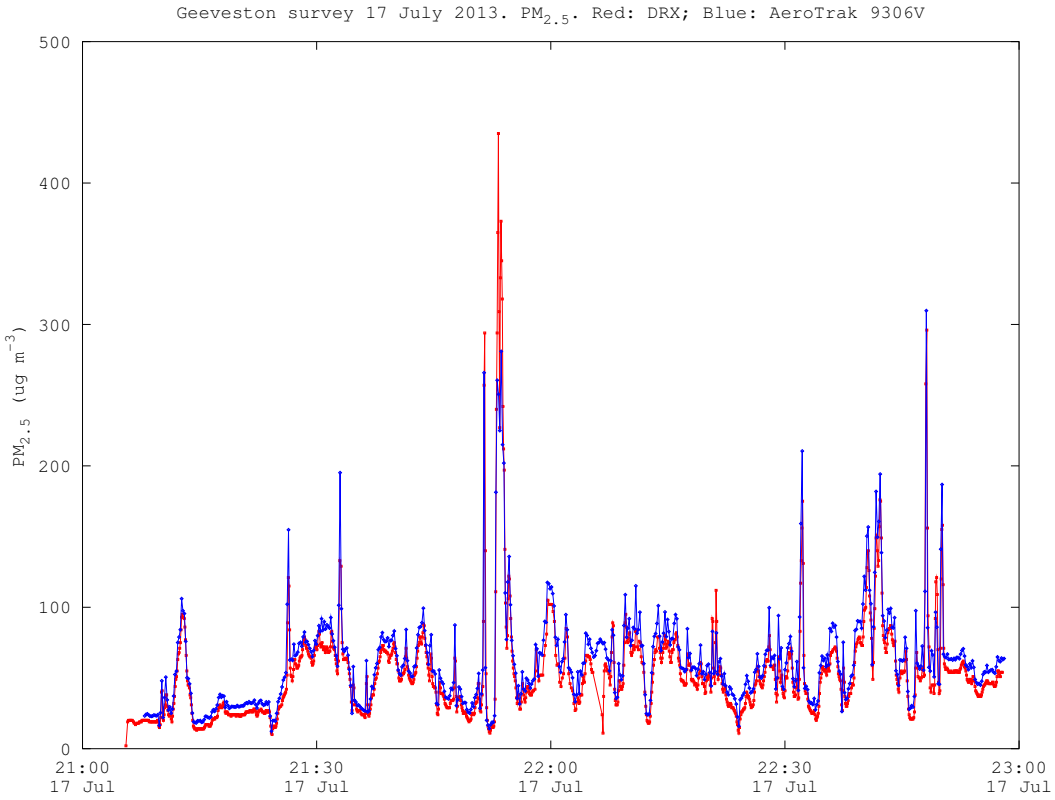

Figure 12: Geeveston 17 July 2013, $PM_{2.5}$; Blue: AeroTrak proxy $PM_{2.5}$; Red: Travel BLANkET $PM_{2.5}$

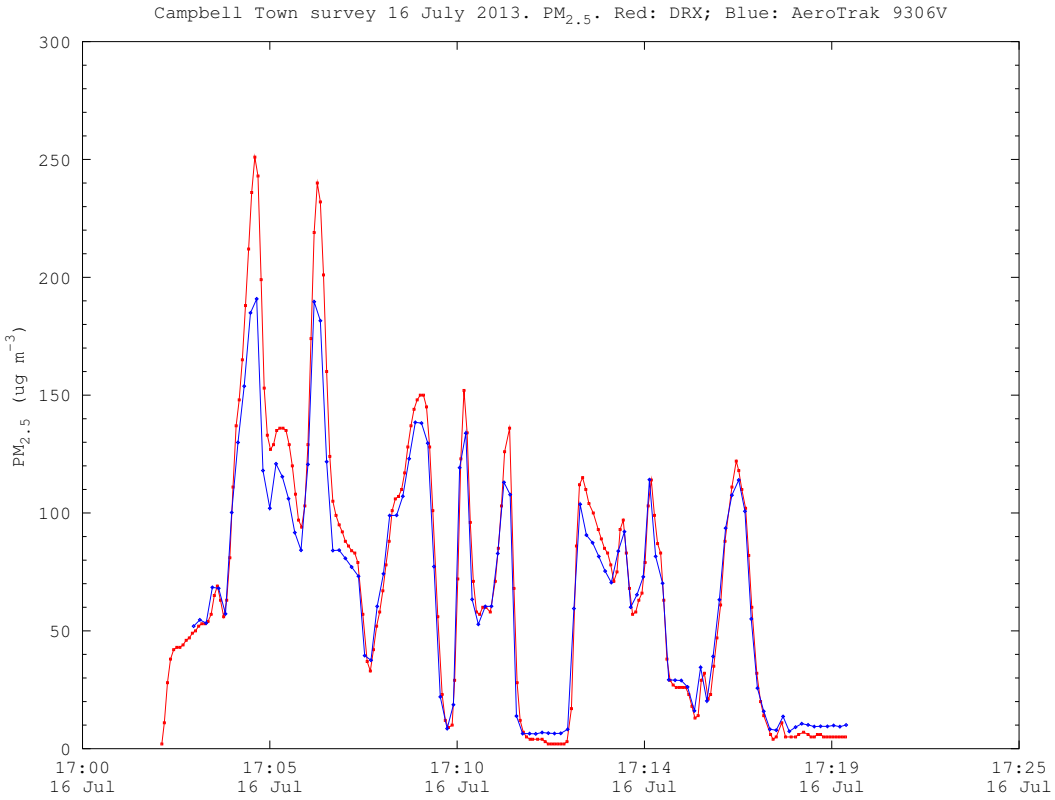

Figure 13: Campbell Town 16 July 2013, $PM_{2.5}$; Blue: AeroTrak proxy $PM_{2.5}$; Red: Travel BLANkET $PM_{2.5}$