BLANkET Technical Report – 9

Smoke in Northern Tasmania - 17 March 2010

August 2010

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.

A note on the time conventions used:
Air quality data obtained at the Tasmanian EPA Division air stations are collected and reported in Australian Eastern Standard Time (AEST), in accord with the convention recommended by the Peer Review Committee oversighting the jurisdictional reporting of air quality data. On the date of the smoke event reported here Tasmania was operating on Eastern Daylight Time (EDT, 'Daylight Savings Time'), which is one hour ahead of AEST. Bureau of Meteorology data are often reported in Universal Time (UTC), in accord with the requirements of the World Meteorological Organisation. UTC is 10 hours ahead of AEST, and 9 hours ahead of EDT. Satellite image times are also routinely presented in UTC. First-hand accounts of the smoke are reported in EDT.
To simplify comparisons, the various data will be referred to both by the native time as reported by the various organisations, and then (if needed) converted to AEST. In some circumstances EDT will also be quoted for ease of comparison.

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1 Summary

On the 17th of March 2010, much of north–eastern and north–central Tasmania experienced high concentrations of smoke. A study of this event has been carried out using a range of available data, including air quality measurements, satellite images, and Bureau of Meteorology data and analysis. Information on planned burns conducted in Tasmania and in Victoria in mid March 2010 has been obtained and is presented in the report. An estimate of the smoke particle production from the Victorian and Tasmanian fires is made, based on the reported areas of the fires and estimated fuel loadings. From a consideration of the relative time of onset of the smoke at the various air stations, the northerly wind change co–incident with smoke onset, satellite imagery, and air parcel trajectory analysis, it is concluded that the most likely source of the smoke was from planned burns conducted in Victoria in the three to four days preceeding the 17th of March.

2 Introduction - the smoke event

On the 17th of March 2010, much of north-eastern, north-central, the north-east coast, and the midlands of Tasmania experienced high concentrations of smoke for many hours. The highest smoke concentrations (measured as $PM_{2.5}$ – particulate matter up to 2.5 μm in aerodynamic diameter) were recorded in the north-east, reaching nearly 200 μg m^{-3} at Scottsdale, and over 150 μg m^{-3} at Derby near midday. The smoke was present in the Tamar valley, through the northern midands at Longford, Cressy, and Campbell Town, to Tunbridge in the southern midlands, as far east as St Helens and Fingal, and to West Ulverstone and possibly Sheffield in the west. Potentially, one quarter to one third of Tasmania's population was exposed to high levels of smoke. The event was noted in various media (print and electronic) at the time, and a number of public enquiries were received by the EPA, the FPA (Forest Practices Authority), and other bodies.

Smoke events of large spatial extent are relatively infrequent in Tasmania but have resulted from bushfires and from planned burning in the autumn. An example of the latter occurred in 2008, and was described in Appendix 3 of the Tasmanian report for 2008 against the National Environmental Protection Measure for Ambient Air Quality (available at:
http://www.environment.tas.gov.au/file.aspx?id=7556.

Historically, ambient air monitoring in Tasmania was limited to the major cities of Hobart and Launceston, along with the more recent lower Tamar valley stations of George Town and Rowella. Consequently, quantitative data on the magnitude, spatial scale, occurrence rate and behaviour of such events over much of Tasmania was limited. Evidence that such events occured was provided by reports received from the public and other qualitative evidence, often anectdotal. In mid 2009 the first five stations of the new Base–Line Air Network of EPA

Tasmania (BLANkET) were commissioned in north–eastern Tasmania. Another 8 stations were in operation by late February 2010, with one further station being being brought on–line on the 17th of March, the day of the event reported on here[1]. BLANkET was designed and implemented to help fill the knowledge gap concerning the spatial–extent, movement and dispersal of planned burn smoke in the greater Tasmanian airshed, as well as to obtain data on winter–time domestic woodheater smoke levels in some smaller Tasmanian communities.

The 17th March 2010 smoke event was well observed by the BLANkET network. These data provide a level of detail on smoke movement hitherto unprecedented in the Tasmanian context. This report presents an analysis of the BLANkET measurements and other data in order to identify the likely sources and causes of the event.

3 Data

The data to be considered here include:

- Air quality data from the EPA Division stations, including data from the newly commissioned BLANkET network
- Information on planned burns conducted in Tasmania and Victoria prior to and on the day of the event.
- Satellite images from MODIS (two colour images per day) and the Japanese Meteorological satellite (one monochrome image per hour)
- Bureau of Meteorology data from various Tasmanian stations
- Bureau of Meteorology air parcel trajectory analysis
- First–hand accounts of the smoke event
- Air quality data for the Traralgon station of the Victorian EPA

3.1 Tasmanian EPA Division Air Quality Data – General comments

The locations of the EPA Division air quality stations as at 17th March 2010 are shown in Figure 1. BLANkET stations in the north of the state are labelled to aid in identification. Smoke levels at all of the stations in the south of the state on the 17th of March were much lower than in the north on this day and indicate the smoke event was confined to the north of Tasmania. The southern stations will not be considered further in this report.

At Ti Tree Bend (Launceston) the continuous PM_{10} is measured by a Tapered Element Oscillating Microbalance (TEOM), while a dustrak 8520 provides

[1] An additional station was comissioned at Carrick, west of Launceston, in late March 2010, bringing the total to 15 at the time of writing.

an optical proxy for $PM_{2.5}$; At Rowella TEOMs are used for both PM_{10} and $PM_{2.5}$. At George Town a Grimms optical particle monitor provides an optical proxy signal for PM_{10} and $PM_{2.5}$. All BLANkET stations use Dustraks DRX 8533 for optical proxy signals for PM_{10} and $PM_{2.5}$. The optical proxy signals have been calibrated against low-volume (gravimetric) air samplers at Launceston, Hobart and George Town. From this comparison it is known that while the day–averaged raw $PM_{2.5}$ provides a reasonable estimate of the gravimetric $PM_{2.5}$, the PM_{10} signal from the Grimms optical particle counter at George Town usually is a significant underestimate of the gravimetric PM_{10}.

The BLANkET DRX Dustraks are calibrated against a DRX Dustrak that has been running at Hobart (New Town) since early 2009 and which in turn has been calibrated against low volume air samplers operating at New Town.

Smoke is largely composed of particles of less than 1μm aerodynamic diameter. PM_{10} also includes dust, sea-salt aerosols, and other components (such as pollen under certain conditions) as well as smoke. In Tasmania the $PM_{2.5}$ is low except when smoke is present. For this reason the $PM_{2.5}$ data presented here are considered the best indicator of smoke.

3.2 Tasmanian EPA Division Air Quality Data – 17th March 2010

BLANkET station air quality data for the northern and north-eastern stations for the 17th of March are shown in Figure 2. The station at Sheffield had been installed in early March but was awaiting electrical connection. When it was realised a large smoke event was in progress on the morning of the 17th, the site owners at Sheffield were contacted by EPA Division officers to enquire if a temporary power connection could be made. Co-incidentally the permanent mains power was about to be connected on this day, and Sheffield data became available soon after 11:00 AEST as shown in Figure 2. Data for the other stations in the Tamar – George Town, Rowella, and Ti Tree Bend (Launceston) – are given in Figure 3, in north-south order from top to bottom.

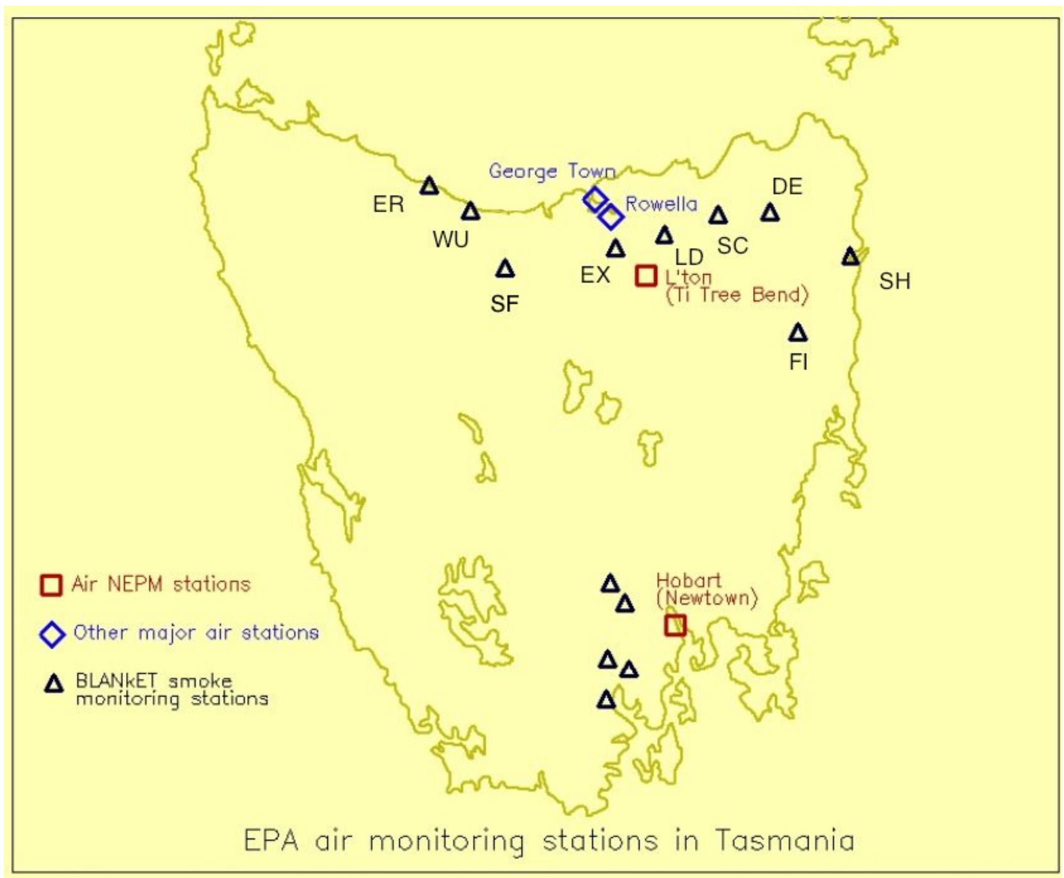

Figure 1: Tasmanian EPA Division Air Stations as at 17th March 2010. Key to northern BLANkET stations: ER=Emu River (Burnie); WU=West Ulverstone; SF=Sheffield; EX=Exeter; LD=Lilydale; SC= Scottsdale; DE=Derby; SH=St Helens; FI=Fingal.

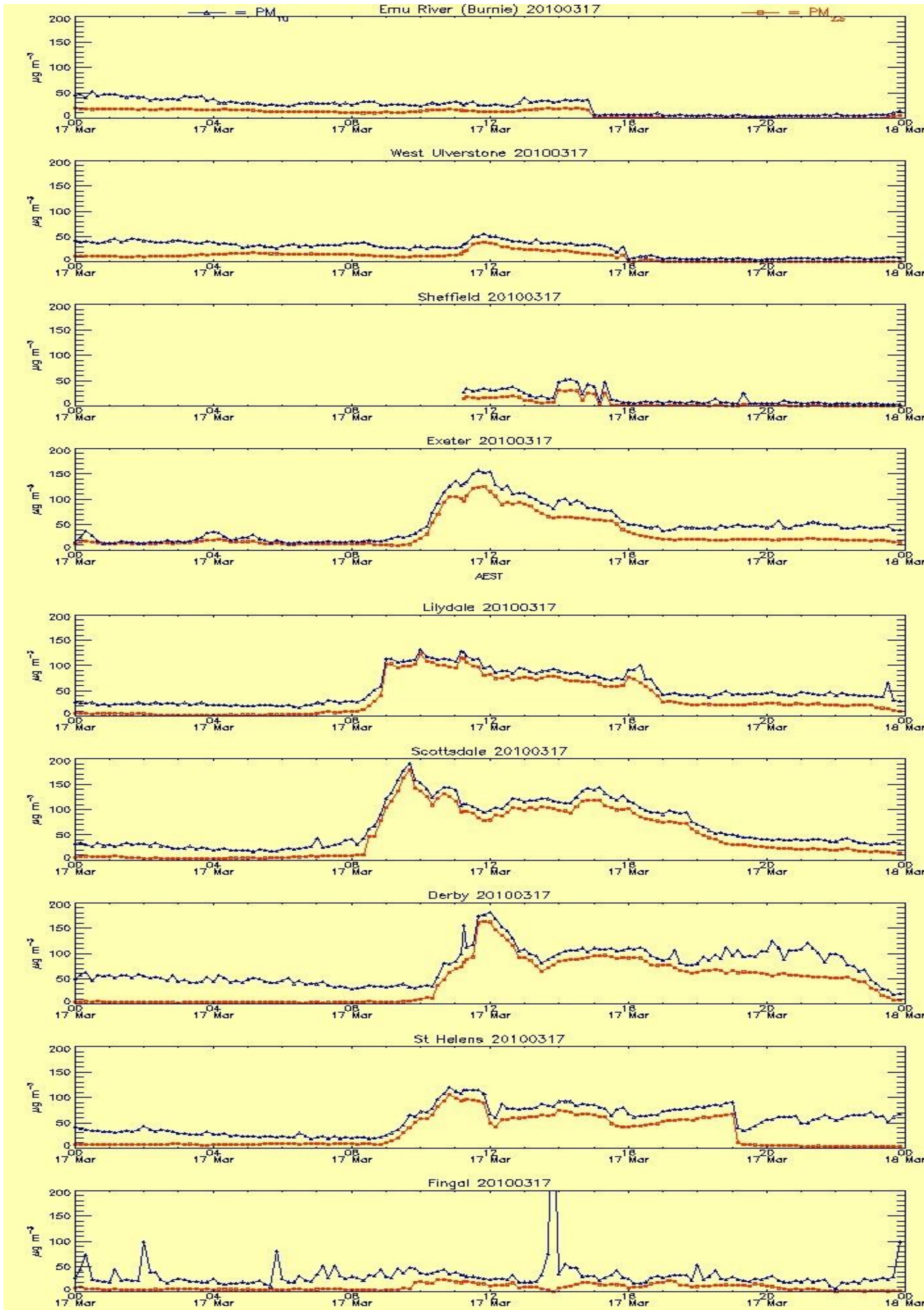

Figure 2: BLANkET station data for northern and north-eastern stations for the 17th of March. More detailed plots (with meteorological data) for each station are shown in the appendix.

Station	Approx start of $PM_{2.5}$ rise (AEST)
Scottsdale	08:30
Lilydale	09:00
St Helens	09:00
George Town	10:00
Exeter	10:00
Rowella	10:10
Derby	10:20
Launceston	10:50

Table 1: Approximate times (AEST) of smoke onset, signified by the rapid and large rise in $PM_{2.5}$, at the northern Tasmanian air stations, 17th March 2010.

Figures 2 and 3 show the general features of the smoke event of the 17th of March. Each station, with the exceptions of Emu river and possibly Sheffield, show a sudden and mostly rapid rise in $PM_{2.5}$ during the morning. The $PM_{2.5}$ peak values that are near or over 100 μg m^{-3} measured at Scottsdale, Lilydale, Derby, St Helens, Rowella and Exeter indicate extremely high smoke concentrations. Peak values at George Town and Launceston also indicate thick smoke. Smoke levels were much lower at West Ulverstone and Fingal. The large spatial–scale of this event is evident from the simultaneously high levels over much of the north of Tasmania, with levels remaining high until the evening. As was noted in media reports at the time visibility was substantially affected over large parts of northern Tasmania.

The onset–time of the event at each affected station is of interest. $PM_{2.5}$ levels started to rise sharply soon after 08:00 AEST (09:00 EDT) at Scottsdale. At Lilydale a steady increase in $PM_{2.5}$ commenced at about the same time, with a rapid rise commencing just before 09:00 AEST (10:00 EDT). A steady rise in $PM_{2.5}$ commenced at St Helens at around 09:00 AEST. Exeter (mid Tamar valley) showed a rise in $PM_{2.5}$ commenced near 10:00 AEST (11:00 EDT), with the increase steepening about 10:10 AEST. George Town commenced to increase just on 10:00 AEST, while significant smoke reached Derby (North-East Tasmania) and Rowella (middle Tamar) soon after 10:00 AEST. The large rise at Launceston (Ti Tree Bend) did not commence until just before 11:00 AEST. A much smaller increase was seen at West Ulverstone, also commencing around 11:00 AEST.

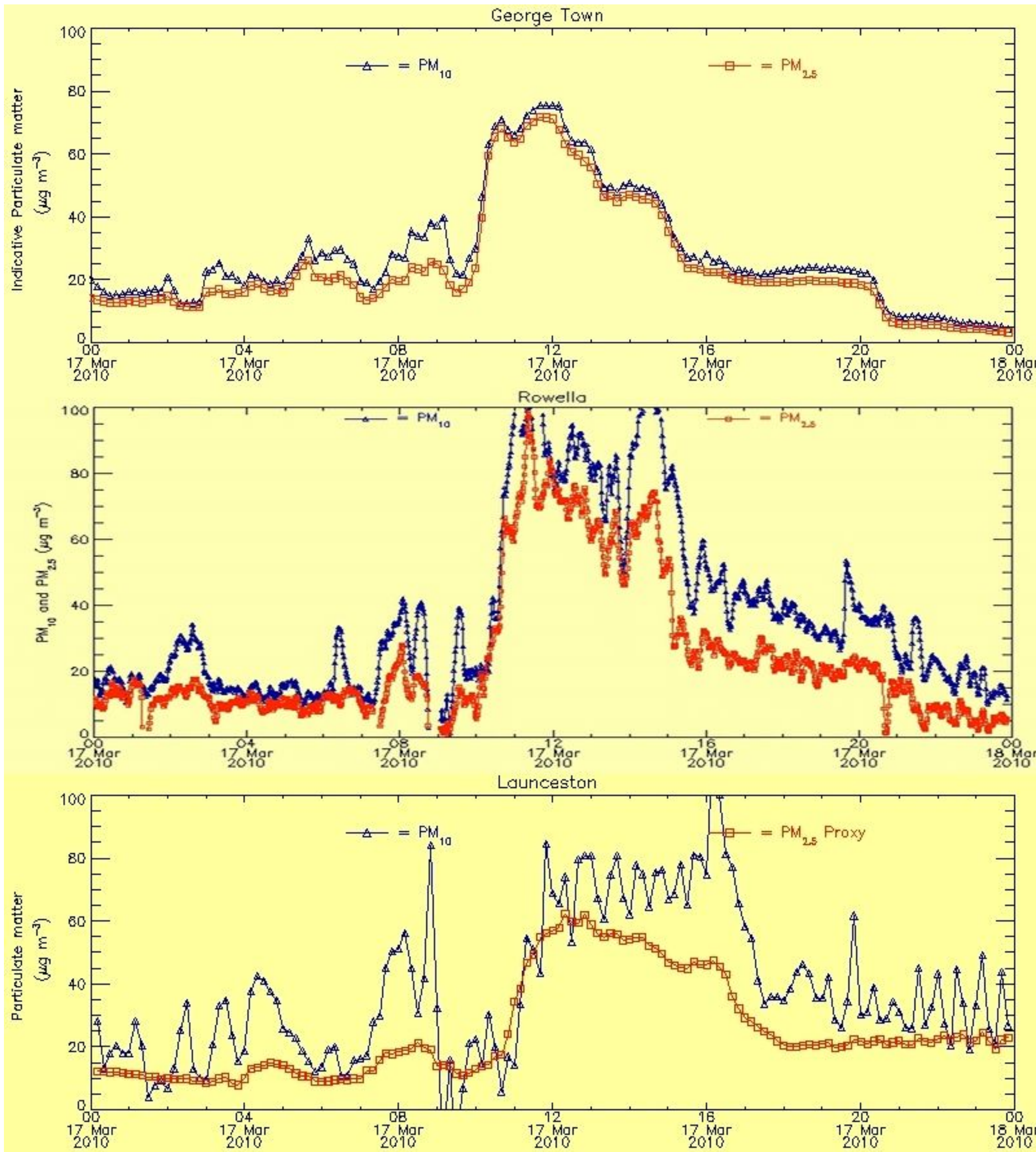

Figure 3: PM_{10} and $PM_{2.5}$ air quality data for George Town (top), Rowella (middle), and Launceston (lower) for 17th March 2010.

Figures 2 and 3 and Table 1 clearly show that thick smoke impacted firstly at Scottsdale and Lilydale, then at St Helens, before it entered the Tamar around 1 to 1.5 hours after first being detected at Scottsdale. It is worth noting for future reference that the impact at Derby commenced at about the same time as the thick smoke reached the Tamar.

It is also important to note that $PM_{2.5}$ levels at a number of stations, including the Tamar stations on George Town, Rowella, Exeter, and Launceston where already somewhat above 'clear air' background levels (which are typically 5 μg m^{-3} or below) before the mid–morning increase: $PM_{2.5}$ in the Tamar stations ranged from around to 10 to 20 μg m^{-3} during the early hours of the morning, indicating some smoke was already present before the major event started.

3.3 BLANkET meteorological data – 17th March 2010

As noted, the 'big' smoke event on the 17th of March was first detected at Scottsdale and Lilydale. Inspection of the meteorological data plots for these stations (see the Appendix) show that, in effect, the large increase in $PM_{2.5}$ coincided with the onset of a moderate northerly wind. The wind direction varied slightly between the stations, and varied between about north–westerly and north–easterly at the stations themselves. A similar effect is seen at St Helens, Exeter, and Fingal. At Derby the smoke arrival corresponds with a south to south–westerly wind. Derby is located in a steep valley, and the wind (speed and direction) observed here often is more due to local effects of topography and local micro–climate than to synoptic weather patterns.

With the exception of Derby, data from the BLANkET stations showed the thick smoke moved in on a northerly wind change. The wind remained generally northerly at the stations during the smoke event.

Smoke rapidly cleared from St Helens around 19:00 AEST on the 17th of March when a moderate south–easterly wind change occurred.

The development of the major smoke event and the wind information can be more easily appreciated pictorially in Figures 4 to 11. These figures shows the air station location along with a representation of $PM_{2.5}$ (size and colour of diamond symbol) and wind data (size of arrow is wind speed, direction of arrow shows the direction the wind is blowing to) for selected times during the 17th.

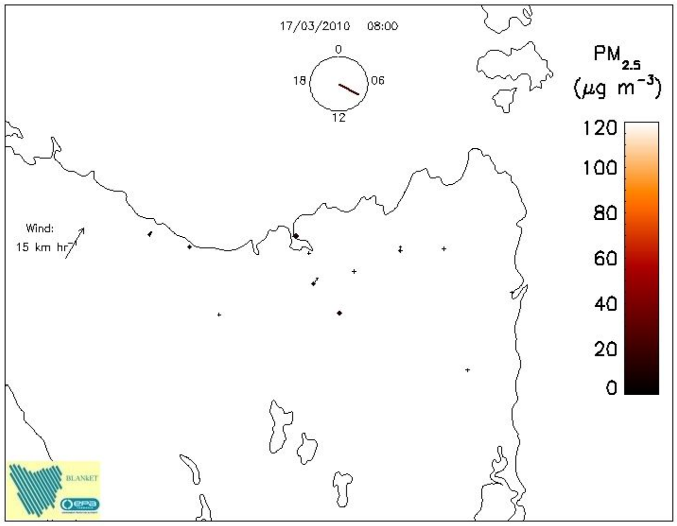

Figure 4: $PM_{2.5}$ and wind data for 08:00 AEST for the northern Tasmanian air stations for the 17th of March. This is about 30 minutes prior to the commencement of the large smoke event, first detected at Scottsdale station.

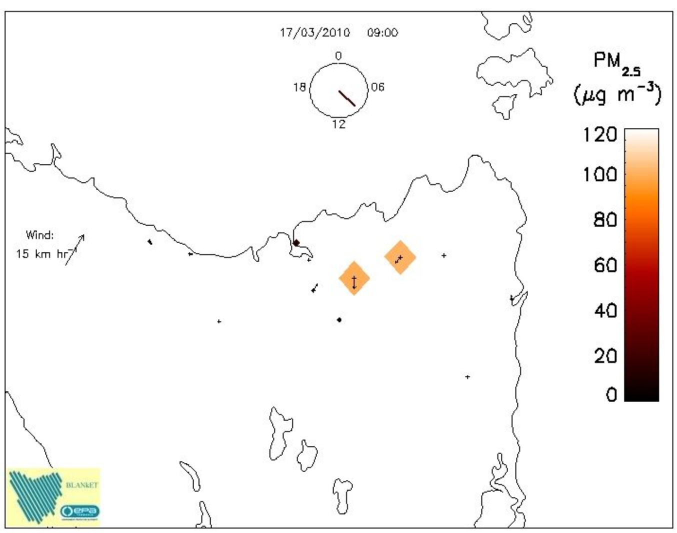

Figure 5: $PM_{2.5}$ and wind data for 09:00 AEST 17th of March. Both Scottsdale and Lilydale stations show elevated $PM_{2.5}$ (signified by the colour and size of the diamond symbol) and northerly winds

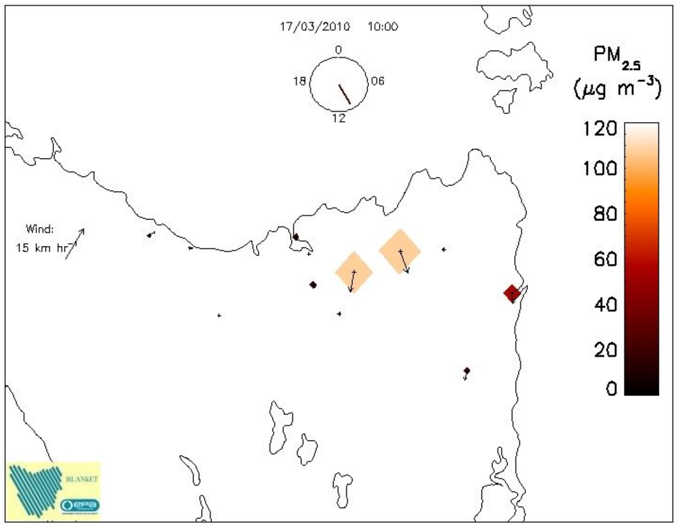

Figure 6: $PM_{2.5}$ and wind data for 10:00 AEST 17th of March. St Helens begins to show elevated $PM_{2.5}$ and a northerly wind.

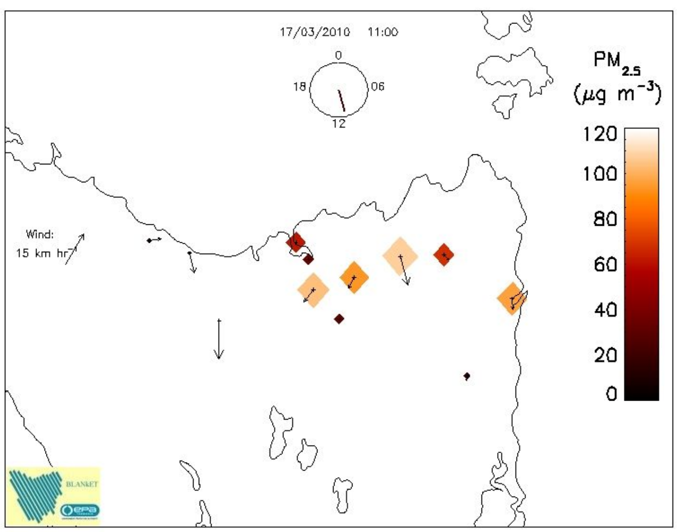

Figure 7: $PM_{2.5}$ and wind data for 11:00 AEST 17th of March. Exeter now shows elevated $PM_{2.5}$ and a north–easterly wind. Derby, George Town, Rowella and Ti Tree Bend (Launceston) show the onset of thick smoke.

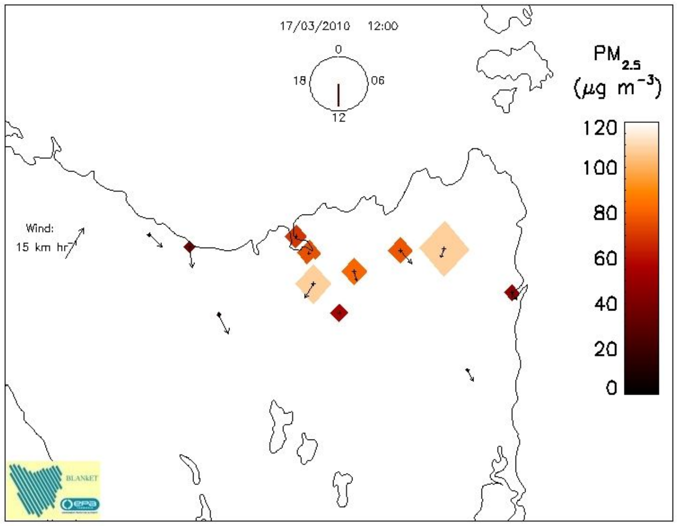

Figure 8: $PM_{2.5}$ and wind data for 12:00 AEST 17th of March. Smoke is present at all north–eastern stations except Fingal. Winds at these stations are north–westerly to north-easterly.

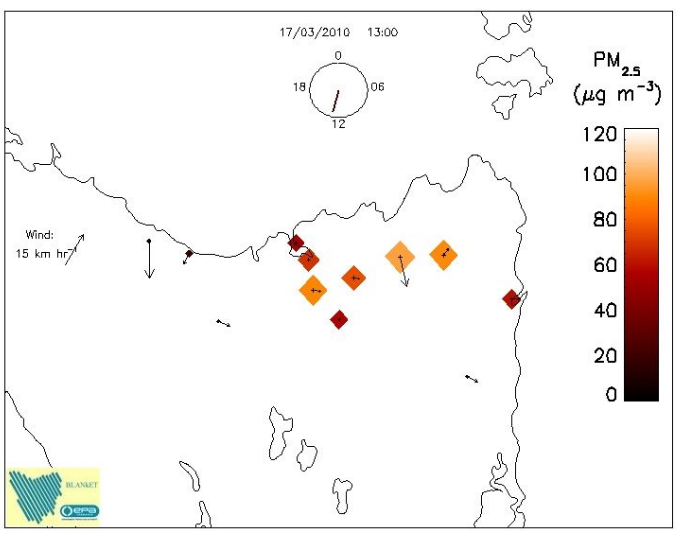

Figure 9: $PM_{2.5}$ and wind data for 13:00 AEST 17th of March. The smoke event continues. Winds have swung to be more westerly.

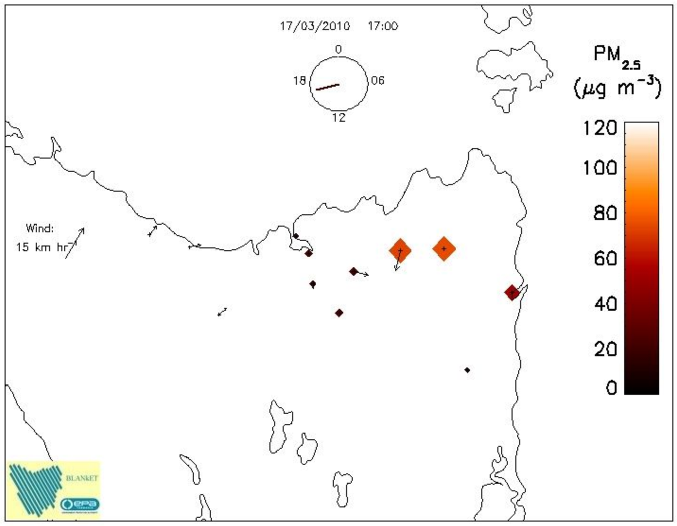

Figure 10: $PM_{2.5}$ and wind data for 17:00 AEST 17th of March (i.e. four hours after Figure 9). Smoke is clearing from the Tamar and Lilydale. High smoke concentrations remain at Scottsdale, Derby, and to a lesser extent at St Helens.

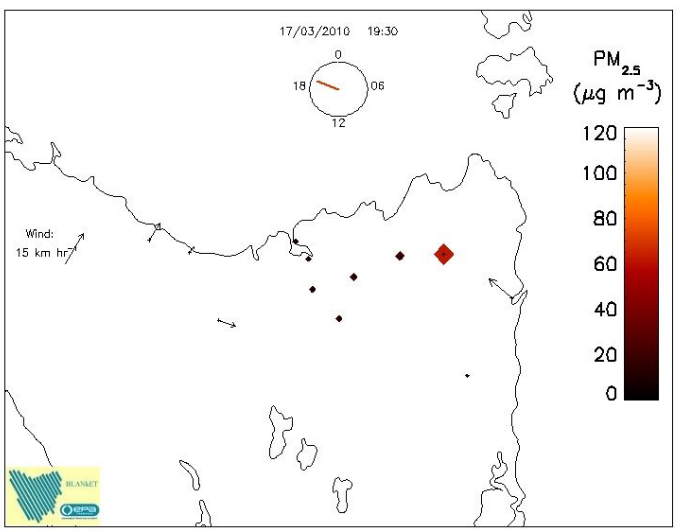

Figure 11: $PM_{2.5}$ and wind data for 19:30 AEST 17th of March. Smoke levels have dropped at all stations except Derby (but mostly remain significantly elevated over 'clean air' levels). A south-east wind at St Helens has rapidly reduced smoke there.

Bureau of Meteorology (BoM) Automatic Weather Station (AWS) data for the 14th to 19th of March 2010 were purchased from the BoM for Eddystone Point and Swan Island in the far north east, St Helens aerodrome, Scottsdale, Launceston Ti Tree Bend, Launceston Airport, Low Head (near George Town), Sheffield School Farm, Devonport Airport, Cressy, and Fingal. Wind data from these stations generally agree with the wind speeds and directions measured at adjacent or nearby BLANkET stations. This is illustrated in Figures 12 to 15, which are of the same form as Figures 4 to 11, but now include BoM wind data (as thicker arrows) as well as wind data from BLANkET. The location of the Scottsdale BoM station has been arbitrarily shifted slightly to avoid confusion with the wind arrow from the Scottsdale BLANkET station.

Some variation between the BoM and BLANkET winds is apparent, particularly at low winds speeds, but the agreement is generally good in higher, more stable, winds. At St Helens the BLANkET station generally recorded lower wind speeds than the BoM station. The stations are separated by about 6 km. The BoM station (at St Helens aerodrome) is in a near–coastal setting. The BLANkET station is further inland, about 40 m higher in elevation, and is in a more sheltered position. At Scottsdale the BLANkET station recorded lower southerly winds during the first part of the 17th of March compared to the BoM station data. The BLANkET station is below the crest on the north side of a small hill. The BoM station is about 0.8 km north–west of the BLANkET station, but in a position much more exposed to southerly winds.

Increased wind speeds at Cressy and Launceston Airport near 11:00AEST compared to many of the other stations may indicate a downward mixing of upper levels winds, increasing ahead of the approaching front, or a funnelling of the wind moving off Bass Strait into the valley between the Great Western Tiers and the Ben Lomond plateau. A combination of these effects may have been in operation.

The change of wind direction from light and variable winds to an established northerly at the time of the thick smoke onset is confirmed by the BoM data.

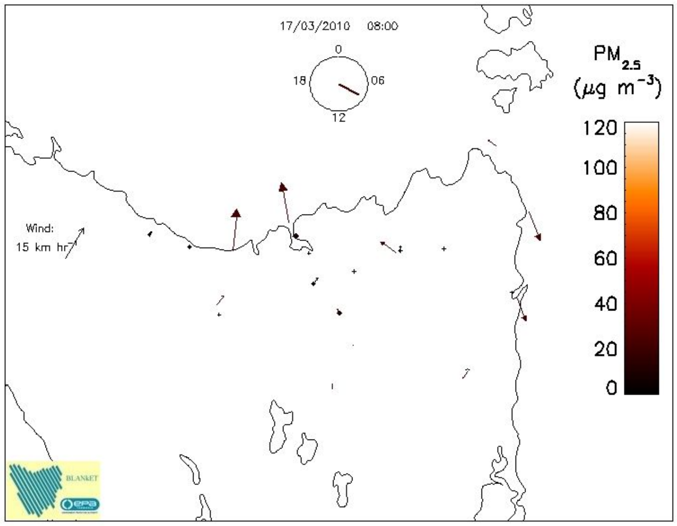

Figure 12: $PM_{2.5}$ and wind data for 08:00 AEST 17th of March. BoM wind data are shown by the thick arrows.

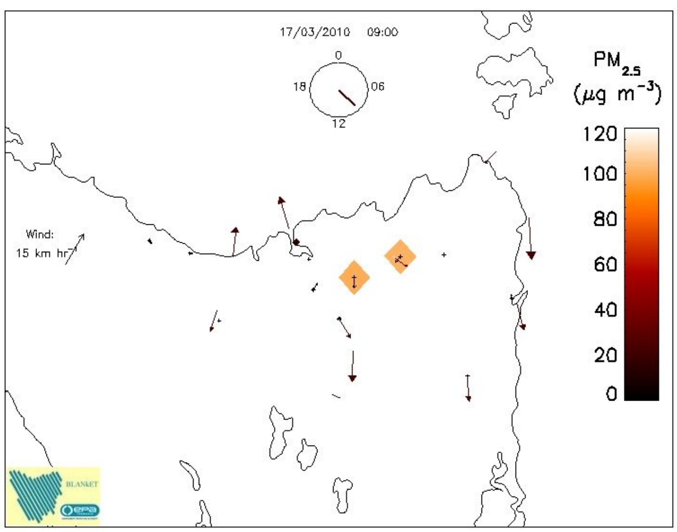

Figure 13: $PM_{2.5}$ and wind data for 09:00 AEST 17th of March.

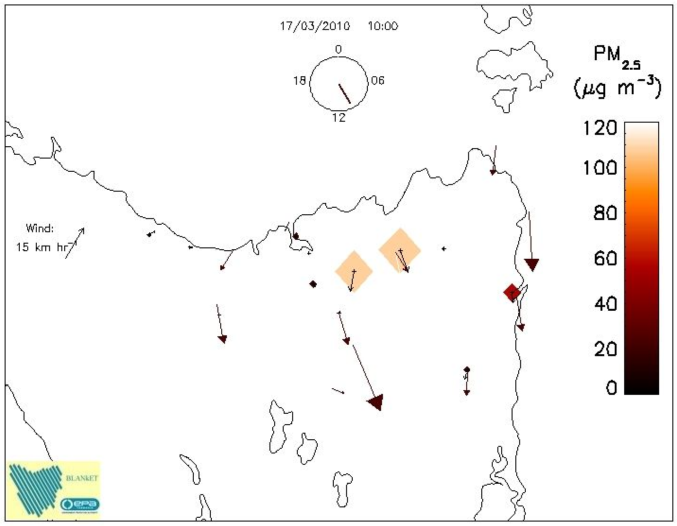

Figure 14: $PM_{2.5}$ and wind data for 10:00 AEST 17th of March.

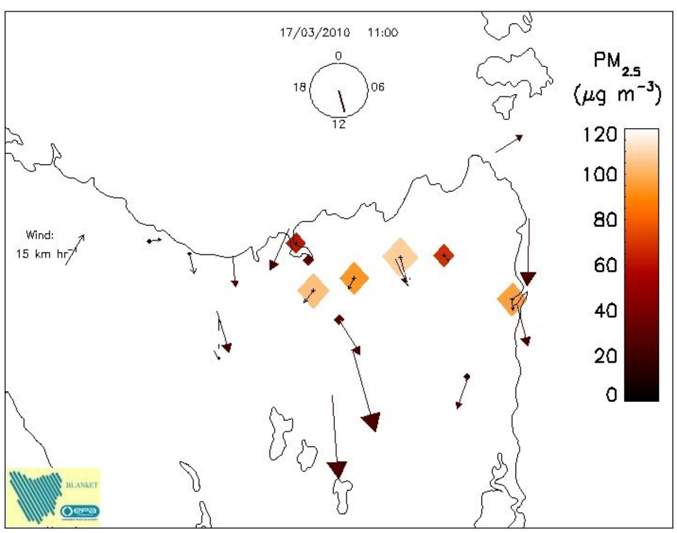

Figure 15: $PM_{2.5}$ and wind data for 11:00 AEST 17th of March.

The BLANkET $PM_{2.5}$ readings and meteorological data (from BLANkET and the BoM stations) strongly suggest the smoke moved into Tasmania from a northerly (possibly north-easterly) direction, then cleared from most stations as a westerly wind stream set in later in the day. The analysis presented below provides an explanation why the smoke event onset was delayed at Derby compared to the other north–east stations, and why smoke arrived at Exeter prior to the George Town and Rowella stations.

3.4 Summary of first–hand accounts

Interviews were conducted by phone with people who were in northern Tasmania on the 17th of March. The selection was not random, but included Environmental Health Officers and other staff at various councils, and two DPIPWE staff based in Launceston. More complete accounts are given in the appendix.

Several people reported the smoke moving in like low cloud and being present in gullies and low areas on the morning on the 17th, seemingly spilling over ridges to move into valleys (reports 5, 6, 10, 14).

Smoke appeared to be present in the Scottsdale region around 6 am EDT (5 am AEST), and in the Golconda region from around 7:30 am EDT = 6:30 am AEST (reports 5 and 6). This is somewhat earlier than the time of the rapid rise in $PM_{2.5}$ observed at the Scottsdale BLANkET station. The smoke may have been thicker in the low areas of Scottsdale near the Dorset Council works depot, east of the town centre, compared to the higher areas at 8 am EDT = 7 am AEST (report 6). It is noted here that the Scottsdale town centre is about 50 m above the depot, and the BLANkET station is a further 20 m above the town centre.

The smoke layer may have been relatively thin in vertical extent (reports 1, 6), and perhaps not much more than $\sim$500 m or so, at 5:30 EDT.

Smoke was present at Longford and Cressy (report 7), and Campbell Town (11, 12, 13), but did not appear to reach south to Oatlands (report 8) or west to Westbury (report 9).

Smoke was present on Flinders Island on the morning of the 17th (report 3).

Thicker smoke may have reached Campbell Town about 3 pm EDT (report 12).

A comment published on the Tasmanian Times web page indicated smoke was present at Tunbridge about 6 pm EDT on the 17th. As noted, the smoke did not reach Oatlands. It is possible that the high ground near St Peters Pass was an effective barrier to southward smoke movement.

3.5 Bureau of Meteorology synoptic charts

Surface pressure charts were obtained from the Bureau of Meteorology web archive. Charts for the 16th and 16th of March are shown in Figures 16 to 21. A nearly stationary high–pressure system (anti–cyclone) was present off the NSW south coast. For most of the 16th and into the early hours of the 17th of March the low pressure gradient (widely spaced isobars) would be expected to

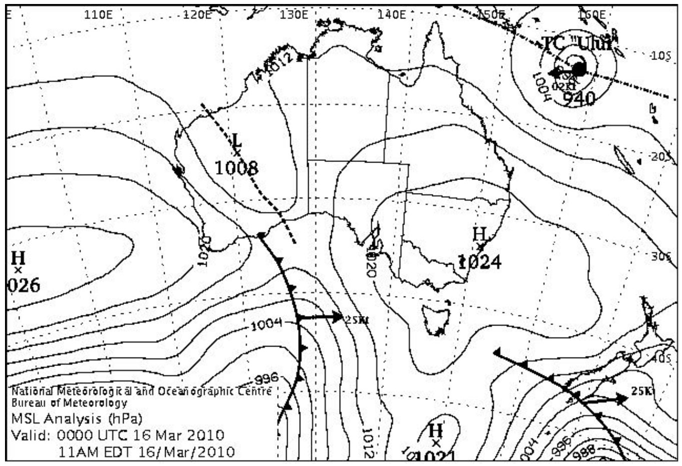

Figure 16: Bureau of Meteorology surface pressure chart for 16th March 2010, 10:00 AEST (11:00 EDT).

produce light northerly winds over northern Tasmania. (In the lower atmosphere the synoptic wind direction is approximately along isobars.) By 10:00 AEST (Figure 20 the analysis chart suggests winds over Bass Strait would be light and north–westerly, while over central–northern Tasmania a more westerly flow may be expected ahead of the approaching cold front just to the west of Tasmania. As was presented earlier however a northerly flow remained over northern Tasmania until later in the day when the front crossed the state.

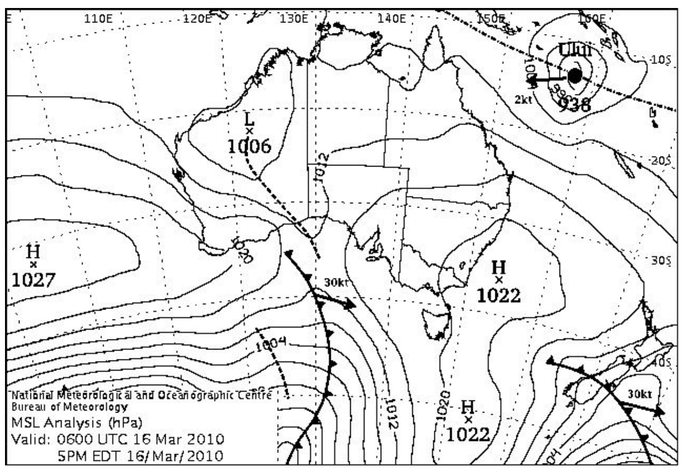

Figure 17: Bureau of Meteorology surface pressure chart for 16th March 2010, 16:00 AEST (17:00 EDT).

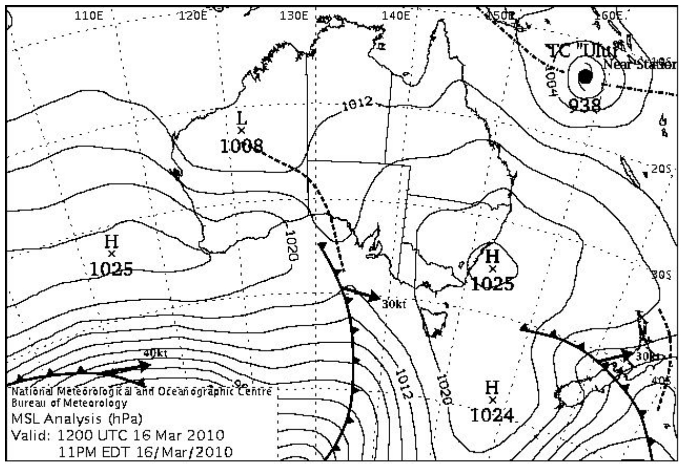

Figure 18: Bureau of Meteorology surface pressure chart for 16th March 2010, 22:00 AEST (23:00 EDT).

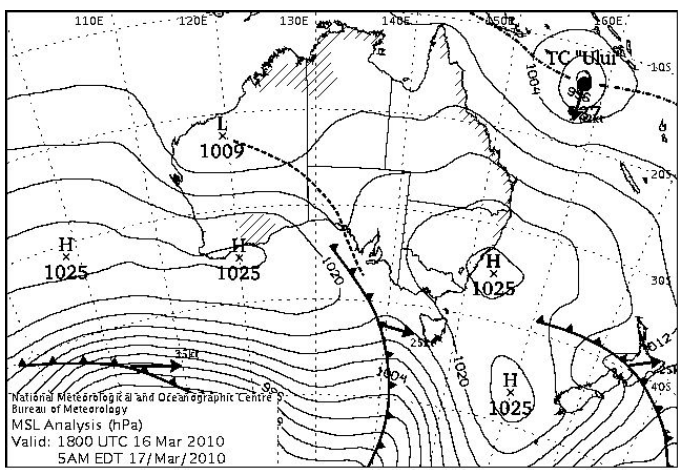

Figure 19: Bureau of Meteorology surface pressure chart for 17th March 2010, 04:00 AEST (05:00 EDT).

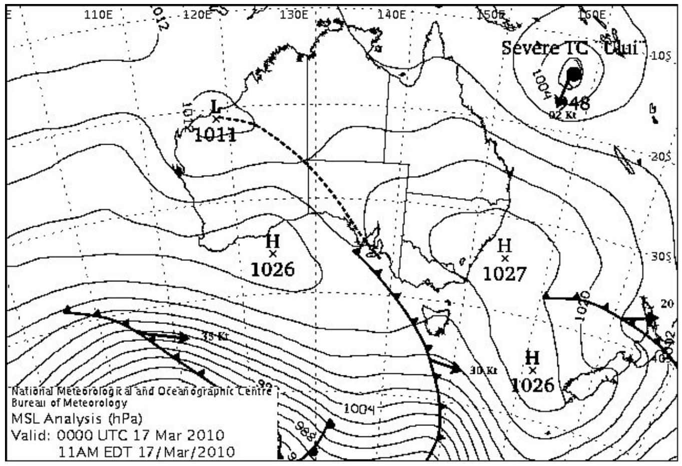

Figure 20: Bureau of Meteorology surface pressure chart for 17th March 2010, 10:00 AEST (11:00 EDT).

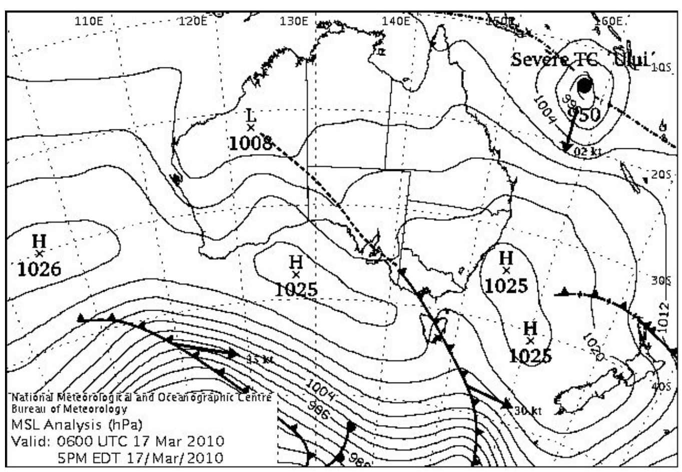

Figure 21: Bureau of Meteorology surface pressure chart for 17th March 2010, 16:00 AEST (17:00 EDT).

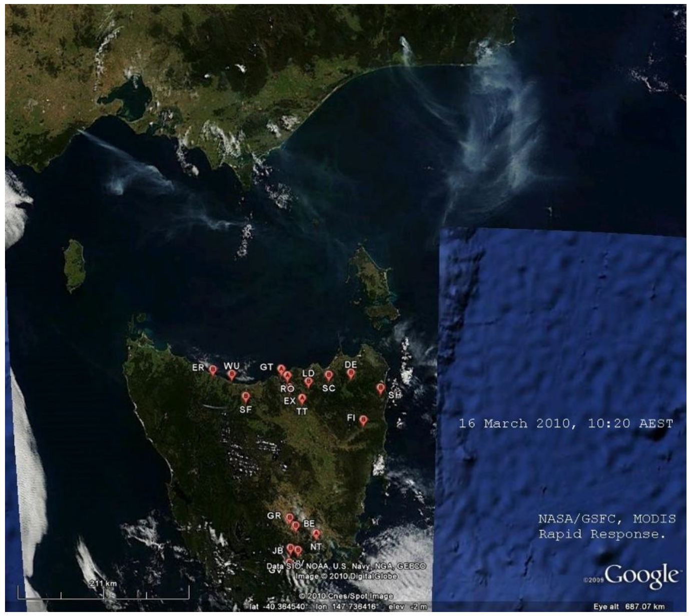

Figure 22: MODIS image for 16th March 2010, 10:20 AEST. The Tasmanian air stations are marked by the red symbols.

3.6 MODIS Satellite Images

True colour high-resolution satellite images are available from the MODIS satellites. Usually there are two such images available each day, from the 'Terra' satellite (usually near 10:00–11:00 AEST), and from the 'Aqua' satellite (usually around 14:00–15:00 AEST). Processed subsets showing areas of interest are usually available from the NASA Goddard Space Flight Centre web pages soon after the image has been obtained. Figures 22 to 25 shows images for the morning and afternoon of 16th and 17th of March showing south–eastern Victoria and Tasmania, composited using two separate such subsets to prepare each image.

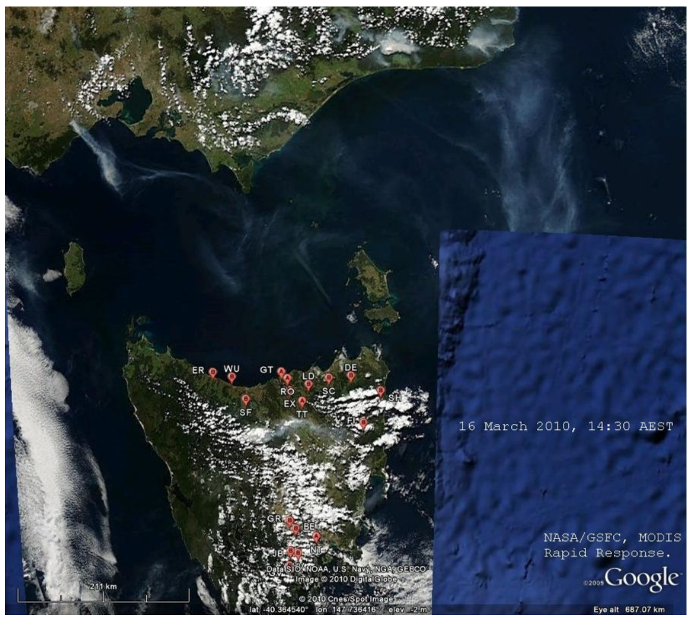

Figure 23: MODIS image for 16th March 2010, 14:20 AEST.

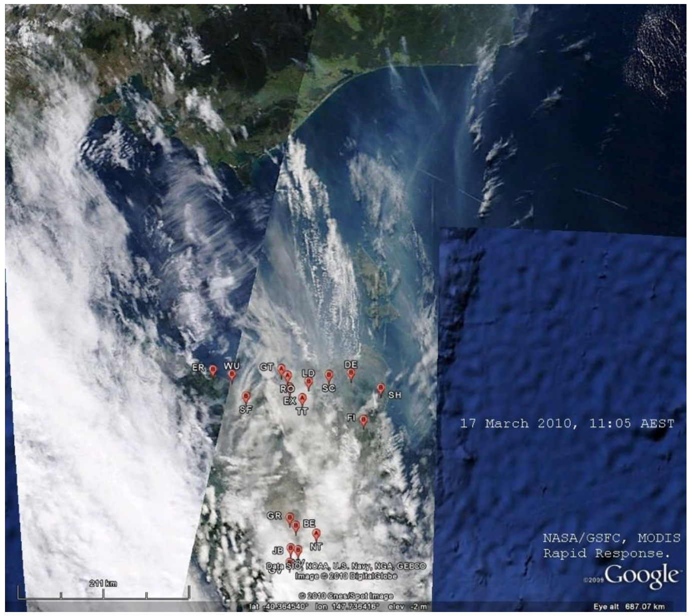

Figure 24: MODIS image for 17th March 2010, 11:05 AEST.

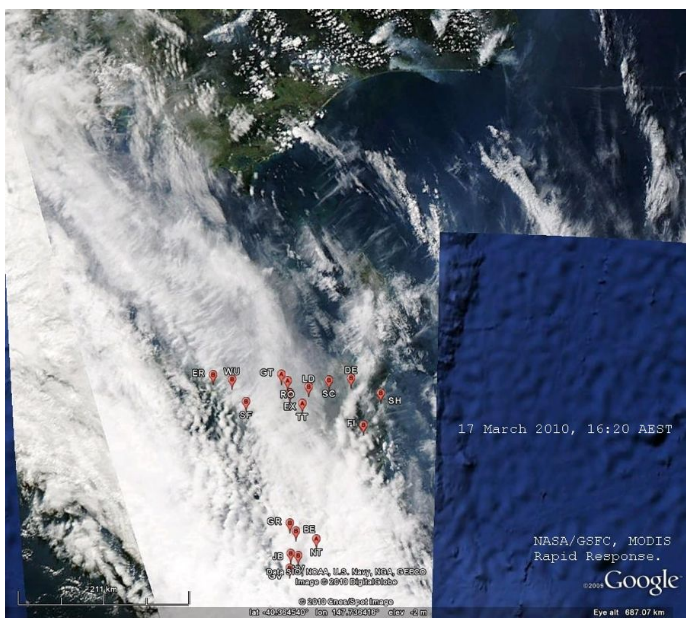

Figure 25: MODIS image for 17th March 2010, 16:20 AEST.

The area to the east of Tasmania is not covered in the subsets used to create these images. The raw source files for these composites are however included in section 9.4 in the appendix for reference, and show the missing area.

Figure 22 shows the situation near 10:20 AEST on the 16th of March, around 24-hours prior to the onset of the major smoke event in northern Tasmania. At left top smoke can be seen streaming into Bass Strait from a fire in the Victorian Otway Ranges, on the coast to the west of Melbourne. In Gippsland in eastern Victoria smoke from several fires is moving generally southwards. In Tasmania a thin smoke plume from a burn in the north–west can be seen. The Tasmanian air stations are marked by the red symbols.

Figure 23 is from images obtained about 4 hours after those in Figure 22, i.e. at about 14:00 AEST on the 16th of March, and shows a similar picture. Smoke is visible in Bass Strait in several areas, including to the north and north–west of Flinders Island. In Tasmania itself a smoke plume is visible moving to the east across north–central Tasmania (to the south of the Sheffield ('SF') and Exeter ('EX') stations. Smoke is also visible over Great Oyster Bay.

Figure 24 shows images obtained around 11:00 AEST on the 17th of March, soon after high smoke levels were established across much of northern Tasmania. The smoke from the Gippsland fires that was in Bass Strait to the east of Tasmania on the previous day is now seen to be much closer to and appears to impact on north–eastern Tasmania. Tasmania itself is nearly completely cloud covered.

The westward movement of the smoke plume between the afternoon of the 16th (Figure 23) and the morning of the 17th (Figure 24) appears a consequence of air driven by the high–pressure system located off the NSW south coast. There may have been some concentration of smoke in this plume as the air mass over eastern Bass Strait is caught between a north–easterly flow from the high–pressure system off the NSW coast and the approaching cold front to the west of Tasmania.

Figure 25 shows images from the afternoon of the 17th of March. A cloud moving eastwards has obscured much of Tasmania and Bass Strait.

3.7 Japanese Meteorological Satellite Images

High–resolution (1km) monochrome visible light images from the geostationary Japanese Meteorological Satellite (JMS) for the 16th and 17th of March were purchased from the BoM. Hourly images are available throughout the day, nominally on the half hour mark (e.g. 00:30, 01:30, etc.) although images taken during darkness show no image information. Selected images are presented in this section. All day–time images from the 16th and 17th of March can be found in the appendix.

As a comparison with the true colour MODIS image for the 16th of March (shown above in Figure 22), Figure 26 shows the JMS image for 10:30 AEST (nominal mid–time of scan) for this day. Smoke from the Otway and Gippsland fires can be seen, as seen on the MODIS image for this time.

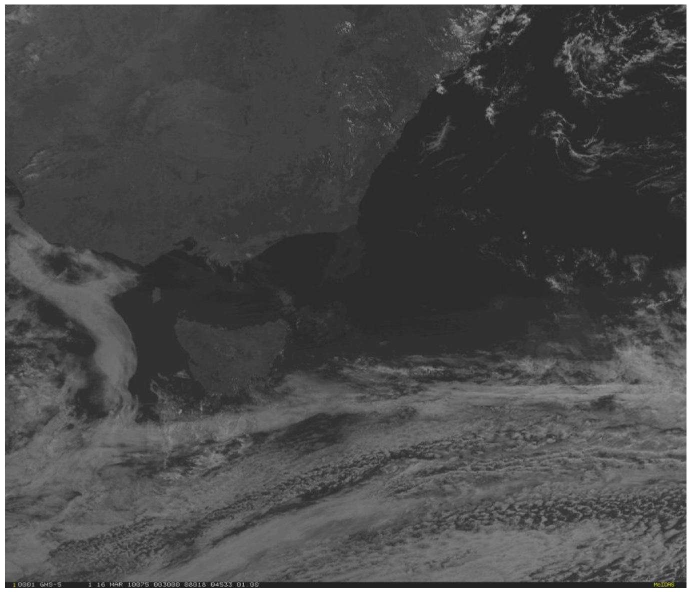

Figure 26: Japanese Meteorological Satellite image for 16th March 2010, 10:30 AEST.

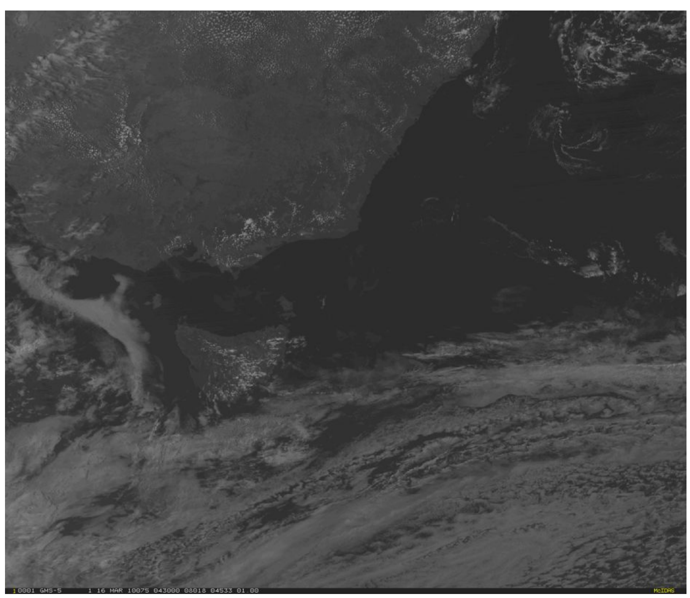

Figure 27: Japanese Meteorological Satellite image for 16th March 2010, 14:30 AEST.

The 16th of March 14:30 AEST JMS image is shown in Figure 27, for comparison with Figure 23. Again, common features can be traced, although the true–colour MODIS images make for an easier identification of smoke.

The JMS image for 16:30 AEST (17:30 EDT) is given in Figure 28. The Gippsland smoke is no longer visible, possible due to reduced contrast as darkness approaches in the east and/or due to less favourable scattering geometry, again due to the solar elevation. However the Otway plume and what appears to be the north–central Tasmania smoke plume seen in the earlier 14:30 AEST MODIS image, remain visible. The Tasmanian plume is heading in a westerly direction towards the upper Tamar. This is likely to be the plume that was well observed and photographed over Launceston on the evening of the 16th.

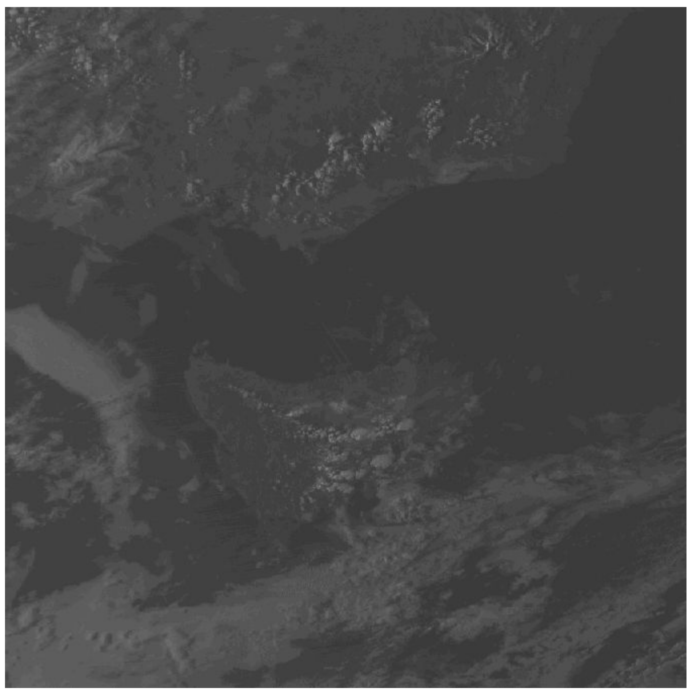

Figure 28: Detail for 16th March 2010 from the Japanese Meteorological Satellite image at 16:30 AEST (17:30 EDT).

For the day of the smoke event, Figure 29 shows the 17th of March 11:30 AEST JMS image, which is close in time to the 11:00 AEST MODIS image shown in Figure 24. Common feature are again apparent.

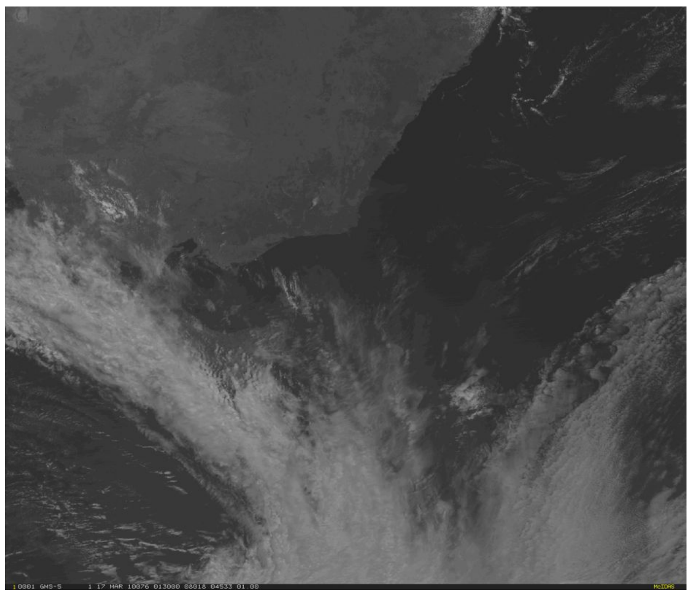

Figure 29: Japanese Meteorological Satellite image for 17th March 2010, 11:30 AEST.

Of interest is the time interval between the afternoon MODIS image of the 16th of March and the morning MODIS image of the 17th of March. The composite MODIS images shown earlier indicated that between these times the smoke plume in the eastern Tasman sea appeared moved westwards and impacted on north-eastern Tasmania. Inspection of the JMS satellite shows that the westward motion, occurred at least partly during the hours of darkness on the night of the 16th/morning of the 17th of March. The 09:30 AEST JMS image for the 17th of March is. shown in Figure 30. Close inspection reveals that smoke from the fire near the Victorian/NSW border is streaming south–west (i.e. moving on a north–east wind). Figure 31 shows both the 09:30 AEST JMS image and the 11:00 AEST MODIS image to allow this comparison to be made more easily. This and the other images from early on the 17th of March are consistent with the westward movement of the smoke plume, seen in the eastern Tasman sea late on the 16th of March and/or early on the 17th of March, back towards central Bass Strait and north–east Tasmania during the night.

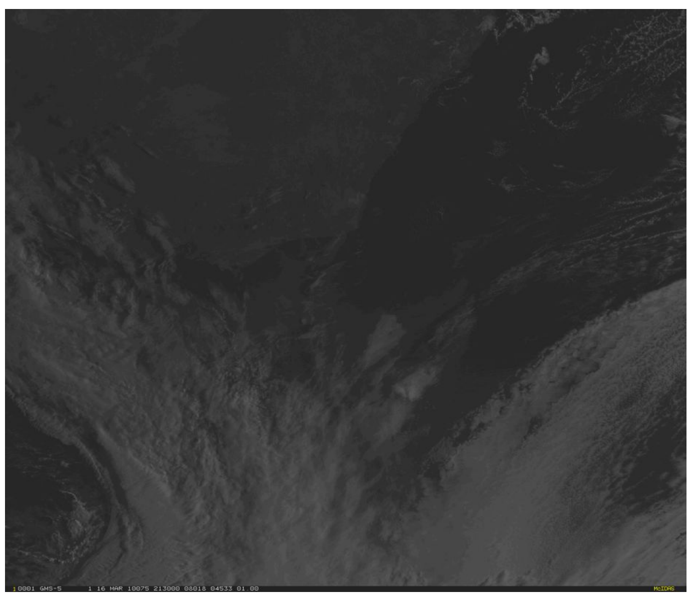

Figure 30: Japanese Meteorological Satellite image for 17th March 2010, 09:30 AEST.

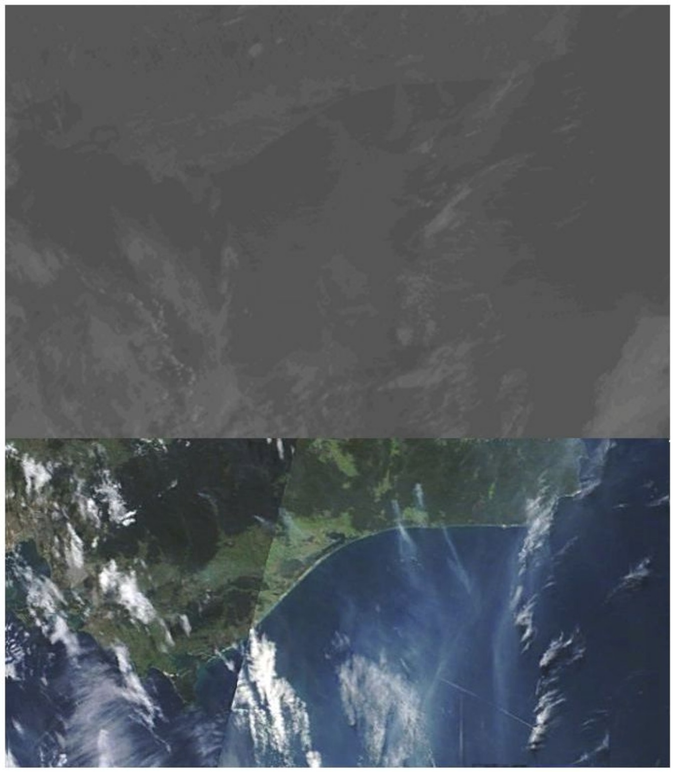

Figure 31: Comparison of detail for 17th March 2010 of the Japanese Meteorological Satellite image at 09:30 AEST (top) and the MODIS image for 11:00 AEST (bottom). The JMS image shows that the wind in far–eastern Gippsland was north–easterly at 09:30 AEST, as seen by the direction of the smoke plume near the Victorian–NSW border.

4 Analysis

The air quality observations, meteorological data, and first–hand accounts appear consistent with a general southward movement (i.e. on a northerly wind) of thick smoke, at low altitude, into north–eastern and north–central Tasmania on the morning of the 17th of March. Satellite images clearly show that a smoke plume from Gippsland impacted on north–east Tasmania early on this day, and as well as showing a general build up of smoke in Bass Strait from various Victorian fires over the preceding few days. The satellite images also show smoke from a Tasmanian burn in north–central Tasmania moving towards Launceston on the late afternoon–early evening of the 16th of March. In this section we consider the possible origin of the thick smoke that impacted on Tasmania on the 17th.

As background, in Tasmania in 2010 a Co-ordinated Smoke Management Scheme (CSMS) introduced by the Tasmanian Forest Practices Authority (FPA) was in operation. This was the second year of a voluntary trial for burns conducted by Forestry Tasmania, Forest Industries Association of Tasmania (FIAT) members, and the Tasmanian Parks and Wildlife Service. The CSMS required planned burn managers to bid for burn units each morning. Each burn unit can be taken as representing, approximately, 10 tonnes of fuel. Allocations were made at 09:00 civil time. Under the CSMS, burning cannot commence before allocations are made. The bid in a given airshed does not necessarily relate to a single planned burn, but indicates the total amount of burning requested by the burner for that airshed for the day.

4.1 Time of the impact versus Tasmanian planned–burn ignition times

The air quality data presented here (e.g. Table 1 indicate thick smoke was first present at the Scottsdale station from around 08:30 AEST (= 09:30 EDT), and about half an hour later at Lilydale and St Helens.

For the 17th of March only one burn bid was registered under the CSMS. This was for a relatively small burn by a FIAT member in the north–west of the state, approximately 40 km south of Burnie. For the purposes of this study the burner was contacted and details of this burn were requested. This was a burn of 9 ha in area, and was ignited soon after 9 am after the CSMS allocation was made. (This was actually a return to a coupe that had been partially burnt on the 16th of March - see below.) As this burn is approximately 150 km from Scottsdale BLANkET station, and was ignited only about 15 to 20 minutes before high levels of smoke were detected at Scottsdale, it is ruled out as a possible source for the thick smoke present in Northern Tasmania on the morning of the 17th of March.

It is known, from the experience gained with the BLANkET network to date, that smoke from a burn on a given day can at times be detected at an air station on the following day. Conceivably a Tasmanian burn conducted on the 16th of

March may have produced the 17th of March smoke. Therefore information on CSMS burns for the 16th of March was obtained as part of this study.

4.2 Tasmanian burns – 16th March 2010

4.2.1 Forest Industry burns reported in the Co–ordinated Smoke Management System (CSMS)

Only two bids were made on the 16th of March. One bid was by a FIAT member for a burn of 500 burn units (300 units were later reported to have been completed), the other was by Forestry Tasmania for a bid of 8033 burn units (all of which were completed). (Note that Forestry Tasmania identified themselves in a report in the Launceston Examiner newspaper on the 18th of March as having completed five burns in the Mersey area on the 16th.) Both burners were contacted for this study to obtain details of these burns.

The FIAT member was the same company as on the 17th of March noted above, and who on the 16th burnt two coupes about 40 km south of Burnie. The burns were commenced soon after 09:00 EDT (08:00 AEST).

Forestry Tasmania Mersey District office was contacted and supplied the following information for this study. A total of five burns were conducted on the 16th, four near Lake Rowellan and one near Lake Gardiner. The first three Lake Rowellan burns were ignited at 11:30 AEST (12:30 EDT, 40 ha size), 12:30 AEST (13:30 EDT, 20 ha), and 13:15 AEST(14:15 EDT, 55 ha). The Lake Gardiner burn (20 ha) was ignited around 14:15 AEST (15:15 EDT). The final burn, near Lake Rowellan (61 ha), was ignited around 15:00 AEST (16:00 EDT). Forestry Tasmania staff noted on the day that smoke from the first four mentioned burns moved eastward in a westerly wind. They also noted that the plume from the last burn (61 ha, Lake Rowellan) moved at a high altitude north–eastwards towards Deloraine.

The locations of all 7 burns (two from the FIAT member, five from Forestry Tasmania) were obtained from the burners and were plotted on the MODIS aqua image of Tasmania for the 16th of March as red 'fire' symbols. (This MODIS image was obtained at 14:14 AEST = 15:15 EDT). Fire locations, as derived by the NASA Rapidfire program, were also included on the image as red polygons. A subsection of the image also showing the locations of the Tasmanian air stations is shown in Figure 32. (Note the full image for Tasmania was given in Figure 23.) There is consistency between the data reported by the burners and the derived fire locations for both of the FIAT burns and for the 20 ha Lake Gardiner burn. For the Lake Rowellan burns no hot spot is detected but a smoke plume originating from the reported burn location is apparent. This MODIS image was obtained before the last Lake Rowellan burn (61 ha) was ignited on this day.

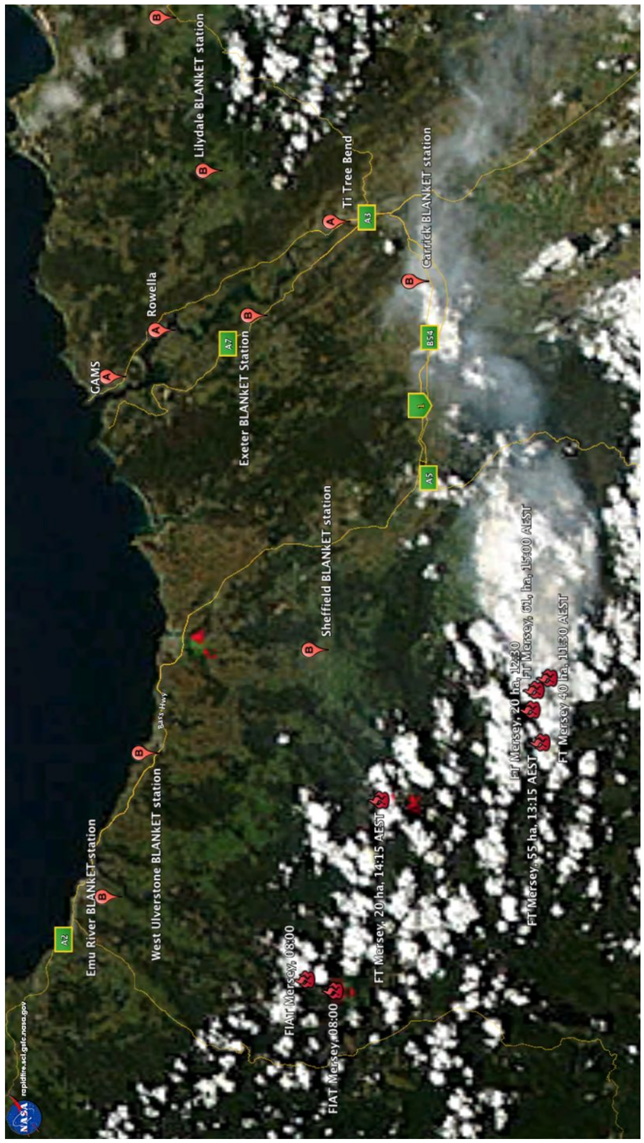

Figure 32: Detail for 16th March 2010 from the MODIS Aqua image from 14:15 AEST (15:15 EDT) showing good overlap between satellite derived fires (red polygons) and the plotted positions of FIAT and Forestry Tasmania fires ('fire' symbols) for this day. The fire (red polygon) near the coast nearly due north of Sheffield is likely to be a green waste fire at the Devonport waste transfer centre. Note that Carrick BLANkET station was not commissioned until late March.

A hot spot in the 16th March Aqua image for Tasmania not attributable to a CSMS burn is located just south of Devonport (almost on the coast, nearly due north of Sheffield. This is probably a detection of the fire at the Devonport waste collection centre at Spreyton, as discussed in the next section.

For completeness, the map of the burns planned for the 16th of March as presented on the 'Planned Burns Tasmania' web page at 10:00 am (EDT) on that day is shown in Figure 33. There is consistency between this map and the fires (either as hot spots or smoke plumes) shown in Figure 32, although only one FIAT burn is marked on this image (from 10:00 EDT). The total FIAT burn on this day (300 burn units) was reported to be well within the CSMS allocation of 500 burn units. The Forestry Tasmania burns ignited on the 16th were noted as still being alight during the afternoon of the 17th, as shown in Figure 34 from the same web site.

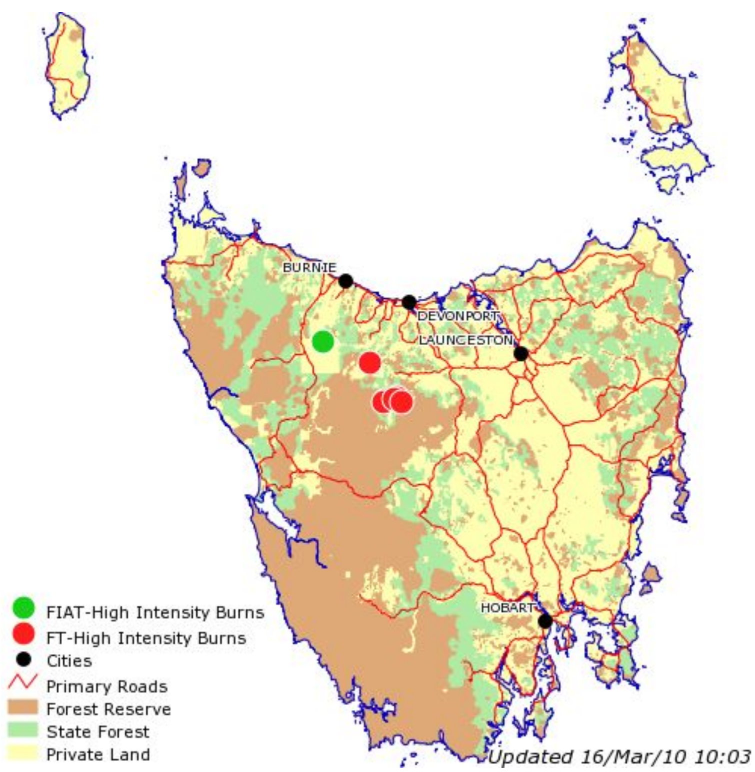

Figure 33: Planned burns by Forestry Tasmania and FIAT members for 16th March 2010, from the 'plannedburnstas' web page.

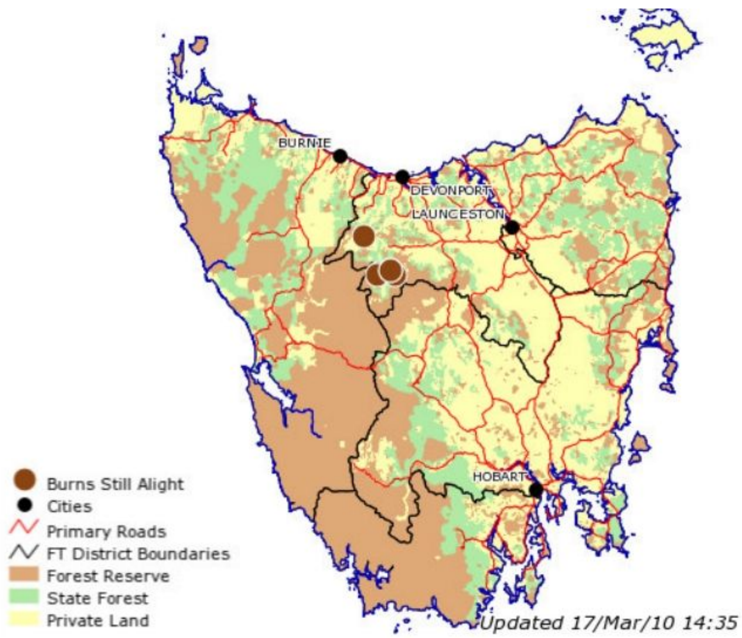

Figure 34: Forestry Tasmania burns 'still alight' on the 17th of March 2010, from the 'plannedburnstas' web page. The burns marked correspond to the locations of fires ignited on the 16th.

4.2.2 Devonport waste collection centre fire

It was reported in the media that a green waste fire started at the Devonport waste transfer station on the 16th March 2010. The centre is at Spreyton, approximately 4 km south of the Devonport CBD.

The following information about this fire was obtained by telephone interviews on the 24th of March.

- Tasmania Fire Service (TFS) at Burnie: "The TFS was called to the waste transfer site about midday on the 16th of March. A pile of green waste around 80 to 100 metres in diameter was on fire. Initially it was burning hot, with little smoke. After securing the area and assessing the fire was not a danger, the TFS handed over to Devonport council and departed. The fire was left to burn out over a few days, and it became smokier as it burnt down late that day. The tip is at Spreyton, near the river. The fire burnt out over 5 or 6 days. The wind was from the north on the 16th, so smoke from the fire moved up (i.e. inland along) the Mersey River valley."

- Report from Devonport Council waste transfer station. The waste transfer station fire warden reported: "The fire was contained quickly. It looked spectacular, particularly at night. The only problem with this fire was the smoke. The local school sent home some students (perhaps they were asthmatics) at one stage. The smoke moved around with the wind, to Latrobe, to Devonport, etc. It was smoky for 3 days or so. We had complaints about the smoke. We had a permit from the TFS to let it burn until Saturday, but after the complaints a reassessment was made and the fire was extinguished before Saturday."

From these accounts it is likely there was smoke from this fire in the vicinity of Devonport and the lower Mersey valley on the 16th of March and for a few following days.

4.3 Victorian burns – 14th–18th March

As noted above and as seen on the MODIS and JMS satellite images presented here, a large number of burns were being carried out in Victoria at this time. The Victoria Department of Sustainability and Environment (DSE) was contacted for information. The DSE provided some general information and referred the enquiry to the Victoria State Fire Manager (SFM). The office of the SFM provided the following information.

In the wake of the Black Saturday bushfires of 2009, Victoria currently has a pro-active hazard–reduction burning policy. Consequently in autumn 2010 large areas of Victoria were burnt. Between the 14th and 18th of March 2010 fires totalling an area of 46,770 ha were either ignited or were underway. Many of these burns were in the East Gippsland region, where 24,670 ha of fires were going. On the 14th of March, among other burns, three separate fires planned to burn 16,000 ha of eastern Victoria were ignited.

The amount of burning in Victoria in the days following the 17th of March remained high. In a phone conversation with the Office of the Victorian SFM on the 23rd of March in Victoria, it was learned that fires planned to burn 27,000 ha were currently alight. A further 13,000 ha of burns were planned to commence on the 24th of March, with another 23,000 ha planned in the coming five to six days.

An indication of the amount of burning that has taken place in autumn 2010 in Victoria is provided by the following figures, from the Victoria DSE website. On the 23rd of March it was reported that 77106 ha of planned burns had taken place since the 1st of July 2009. On the 1st of May 2010, the DSE web site reported that the total burn was currently 136,810 ha. That is, very nearly 60,000 ha of burning took place over these 38 days.

Some heavy-fuel regeneration burns are also carried out in Victoria, but it is likely that most of the above noted burns were lighter–fuel burns. This is discussed in more detail in the following section.

4.4 Particle production estimate for the Tasmanian and Victorian burns

4.4.1 Particle estimate for Forestry Tasmania burns – 16th March

The Tasmanian CSMS classifies burns into three fuel–load categories – heavy, light, and very–light. Very approximately, heavy fuels are around 400 t/ha, light fuels are near 150 t/ha, and very–light fuels are near 50 t/ha. These figures refer to the fuel consumed in a burn – the pre–burn fuel loadings are up to about 30% higher. As examples of each type, environmental and fuel–reduction burns are classed as very–light fuel burns, post–logging plantation burns are classed as light–fuel burns, and 'wet forest' post–logging burns are classed as heavy–fuel burns.

The 16th of March Forestry Tasmania Mersey District burns totalled just under 200 ha in size, with a nominal fuel–loading (for consumed fuel) near 400 t/ha. The total fuel burnt is therefore estimated to be near 80 kt. Fine–particle production per kilogram of fuel can be estimated as about 0.017 kg. (This figure can be significantly affected by fuel moisture content, meteorological conditions, and other effects. It is given as an estimate only.) This yields a particle production near 1.36 kt (1.36×10^{15} μg).

In order to estimate a concentration an estimate of the volume occupied by the smoke is needed. Such an estimate is provided here under the hypothesis that the smoke extent was bounded by the area where either it was detected by the air quality network or was reported by an eyewitness. Smoke was detected simultaneously at a number of air monitoring stations in northern Tasmania. Very approximately the observed area of smoke (i.e. an estimate of the spatial extent) is 100 km$\times$40 km as a coastal strip (taking in Derby, Scottsdale, Lilydale and the Tamar valley), plus a 70 km$\times$30 km strip taking in Longford and Cressy, along the eastern edge of the Great Western Tiers to Campbell Town. The wind speed during the interval was around 5 km hr^{-1}, for typically 10 hours at the affected stations, meaning the air moved about 50 km during the smoke event, adding to the spatial extent. This neglects the data from the observation that smoke was also measured at St Helens, hence this will underestimate the total area affected by smoke and hence will overestimate – i.e. provide an upper limit for – the concentration in μg m^{-3}.)

First–hand accounts suggested the smoke was relatively limited in altitudinal extent. If the smoke was confined to 500 metres altitude and below (e.g. from first–hand account number 6 in the appendix, section 9.2), the approximate lower limit to the volume occupied by smoke is (6.3×10^{12} m^3). Therefore an upper limit to the average concentration would be (1.36×10^{15} μg) divided by (6.3×10^{12} m^3), which is around 200 μ m^{-3}. This is comparable to the peak smoke concentrations measured at Scottsdale and Derby. If the smoke was of greater spatial extent than assumed here (e.g. if the plume extended over the ocean as well) the average concentration results would be correspondingly reduced.

It is noted explicitly that this is a very approximate calculation, carried out for the purposes of obtaining an order of magnitude estimate of the smoke concentration for comparison with the Victorian burns, under the hypothesis that the smoke from the Tasmanian burns on the 16th would have been largely confined to the area where air monitoring stations are located in northern Tasmania, along with a strip through the northern Midlands.

4.4.2 Particle estimate for Victorian burns, 14th–18th March

In Victoria due to drier conditions, the equivalent very–light fuel loading may be thought to be lower than in Tasmania. It is noted that the Royal Commission into the Black Saturday fires heard evidence that in some areas affected by fire on that day had forest floor fuel loadings up to 50 t/ha. After the burn information was received the Office of the Victoria SFM, the office was contacted to enquire if fuel–loadings (i.e. in tonnes of fuel per hectare) were available for any of the prescribed burns, but no reply was received. Consequently an estimate is made here. For the purposes of providing an indicative calculation of particle production from the Gippsland fires a fuel loading of 30 t/ha, somewhat lower than the Tasmanian CSMS 'very–light fuel loading' of 50 tha, is adopted. It is further assumed that only one half of this fuel is actually consumed in a burn, giving an effective fuel–loading of only 15 t/ha. This is considered to be a conservative lower–limit of the actual fuel consumed in the burns.

Assuming that 15 t/ha of fuel is burnt, a total burn of 20,000 ha (the approximate Gippsland burns from 14th to 16th of March) would consume about 300 kt of fuel. Again we adopt a fine–particle production rate of 0.017 kg per kg of fuel. This leads to an estimate of 5.1 kt of particles (smoke) emitted from these fires. One tonne is 10^{12} μg, hence the particle mass produced is around 5.1×10^{15} μg. For comparison this is nearly four times the particle production of the 16th March Forestry Tasmania Mersey District fires, although it was produced over 4 days, rather than on one single day as for the Tasmanian 16th March burns.

The MODIS satellite images suggest that several days worth of smoke from the Gippsland fires pooled in the eastern Tasman sea in a long plume, and may have been subsequently pushed westwards and impacted on northern Tasmania early on the 17th of March. The MODIS image for the morning of the 17th can be used to estimate the approximate dimensions of this plume as 400 km$\times$200 km or 8×10^{10} m^2. This includes an area from Tasmania through Flinders Island to Victoria, as well as part of Bass Strait west of Flinders Island reaching over to Wilson's Promontory, and south to Tasmania's mid north coast.

Again assuming the smoke was confined to 500 metres altitude and below (e.g. first–hand account number 6) then the plume is confined to a volume of 4×10^{13} m^3, which when combined with the estimated particle mass of 5.1×10^{15} μg for the Gippsland fires for 14th to 16th of March, yields an estimate of the average particle concentration in the plume of around 130 μg m^{-3}. This is also comparable with what was observed near the peak of the smoke event in northern Tasmania on the 17th of March.

There is also very likely to have been a contribution from the Otway fire, which, as shown by the satellite images, also contributed smoke into Bass Strait in the days leading to the 17th of March. On the 17th of March the Hobart office of the Bureau of Meteorology noted a bushfire near Colac may have produced some of the smoke that impacted in northern Tasmania. The Victoria County Fire Authority web page was checked on the 19th of March. A 50 ha fire was listed to have taken place about 6 km north–west of Airey's Inlet. The fire was first reported at 08:41 am EDT on the 15th of March, and was reported to have been contained at 01:26 pm EDT on the 17th of March, with 92 appliances attending. This is however a relatively small fire compared to the total burns in Victoria around these days. Subsequent correspondance with the Victoria DSE revealed that a much larger fire took place in this region. On the 15th and 16th of March 2010, the Victorian DSE completed the Aireys Inlet Distillery Creek burn, which was approximately 1,280 ha in size. It is probable that most of the smoke seen coming from the Otways on the satellite images from this time was from this burn. In area, this is about 6% of the Gippsland burns over this time. Other bushfires were also present in western Victoria over these days – some contribution from these is also possible.

4.4.3 Identifying the smoke source

The above very approximate calculations indicate that either of the Tasmanian fires of the 16th of March or the Victorian fires of the few days leading up to the 17th of March could hypothetically, under the assumptions outlined above, have produced enough smoke to have caused the large smoke event in the north of Tasmania on the 17th. Hence these calculations alone do not rule out either the Tasmanian burns or the Victoria burns (or a combination of both) as the source.

However, the times of onset of the smoke at the various stations, co-incident with the onset of a northerly wind change, the reported low–level (i.e. low altitude) of the smoke at onset, and the satellite images showing the plume stretching from the Gippsland fires towards northern Tasmania all are consistent with Victorian smoke impacting on Tasmania on the 17th of March. At face value it appears that the dominant source of the 17th of March smoke was most likely from the Victorian burns. The question is whether the Tasmanian burns on the 16th also contributed to the ground–level smoke on the 17th, and if so what were the relative contributions of each source?

These questions are addressed in the following section by reference to Bureau of Meteorology back–trajectory analysis.

4.5 Bureau of Meteorology Back–Trajectory Analysis

The Bureau of Meteorology supplied back–trajectory paths for Launceston for the 16th and 17th of March. These are produced by running backwards in time the meteorological computer model of the weather systems over Australia. In essence, air parcels at a given starting point (in this case Launceston) are mathematically tracked back in time to gain insight into their recent movements. The Bureau of Meteorology supplied the following information. "The back–trajectories use data from the MesoLAPS pt050 Numerical Weather Prediction model. Not all the Numerical Weather Prediction model variables are used but the full 5 km (horizontal) resolution and all vertical (sigma) levels are (used). The trajectories themselves are calculated using the HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory) computer model, and is run using specific temperature, specific pressure, total precipitation, and for each level, U, V, and W wind components, temperature and specific humidity."

The model uses assimilated meteorological observations ('analysis') for 00 UT (10 AEST) and 12 UT (22:00 AEST) where available and then uses forecast data for 03, 06, 09, 15, 18, and 21 UT where needed. Some of the back–trajectories presented here were calculated automatically on the day of the burn as part of the BoM Smoke Forecasting Service and were retrieved from archive storage. Other trajectories have been produced for this report upon request to the BoM, again using the archived analysis and forecast data.

The back–trajectory for Launceston for 16:00 AEST (17:00 EDT = 06:00 UT) for the 16th of March is shown in Figure 35 . The top panel shows the paths of four air parcels on a map for the 36 hours leading up to when they arrived at Launceston at the specified time. In this case, the four air parcels arrive at Launceston at 16:00 AEST at the heights of 100 m, 1000 m, 1500 m, and 2000 m. The lower panel shows the altitude changes of the parcels on their respective trajectories. On this panel, and on the other back–trajectory plots presented here, time *decreases* to the right. The trajectories indicate that the air at 2000 m over Launceston at 16:00 AEST on the 16th of March had, 6 hours earlier, been to the west of Launceston, over north–western Tasmania (trajectory shown by the light blue line). Thirty–six hours earlier this air had been to the south of Kangaroo Island, and at about 1500 m altitude. Similarly, air at 100 m elevation over Launceston, at 16:00 AEST, had been just off the Victoria coast 36 hours earlier at a similar elevation (red line).

As was noted earlier, during the late afternoon and early evening of the 16th of March a large smoke plume was observed (and photographed) passing over Launceston. The trajectory analysis showing the 2000 m air parcel (and to an extent also the 1500 m air parcel) coming in from the west (passing the general area of the Forestry Tasmania burns of that afternoon) towards Launceston could therefore be taken as an indication of the height of this plume. The situation for 18:00 AEST on the 16th (= 19:00 EDT) is similar (Figure 36). It appears therefore that the back–trajectory analysis is reasonably consistent with the observed movement of this plume.

At Launceston at 04:00 AEST on the 17th of March the back–trajectories indicate that the air at ground level and at 10 m elevation (red and dark blue lines and symbols respectively) had been off the Gippsland coast, and effectively at sea level, 36 hours earlier (Figure 37). By 10:00 AEST on the 17th (11:00 EDT), when thick smoke was impacting at most of the northern Tasmanian air stations, the back-trajectories again indicate the air at ground–level in Launceston had moved in across Bass Strait from off the Gippsland Coast (Figure 38). In other words the air feeding into Launceston at the time of the large smoke event had been off the Victoria coast 36 hours earlier. Eighteen hours before 04:00 AEST on the 17th, at 16:00 AEST on the 16th, these air parcels were about half–way between Launceston and Wilson's Promontory. This is also the about the time the smoke plume or plumes from the Forestry Tasmania burns were passing over Launceston. Therefore in the back–trajectory analysis there is a clear distinction between the airmasses at around 2 km over Launceston on the 16th, and the airmass at ground level at Launceston at 10:00 AEST on the 17th. These trajectories suggests that the smoke which impacted at ground–level at Launceston on the morning of the 17th of March came from smoke in Bass Strait, and hence was most likely from Victorian fires.

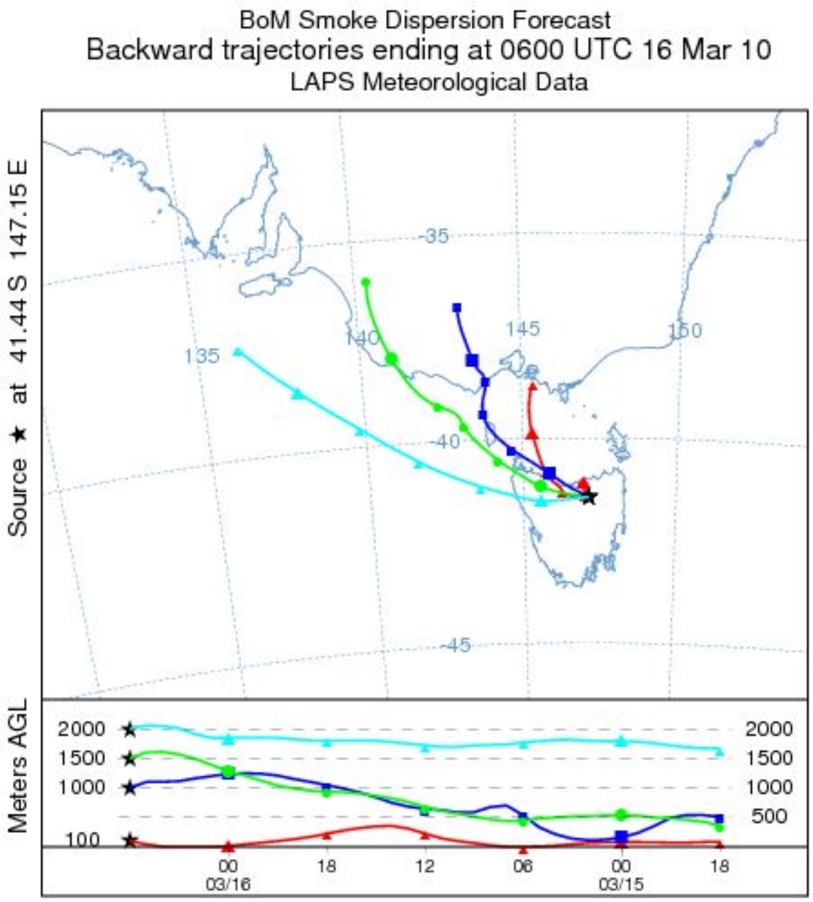

Figure 35: Back–trajectory of air parcels arriving at Launceston at 16:00 AEST (=17:00 EDT), 16th March 2010.

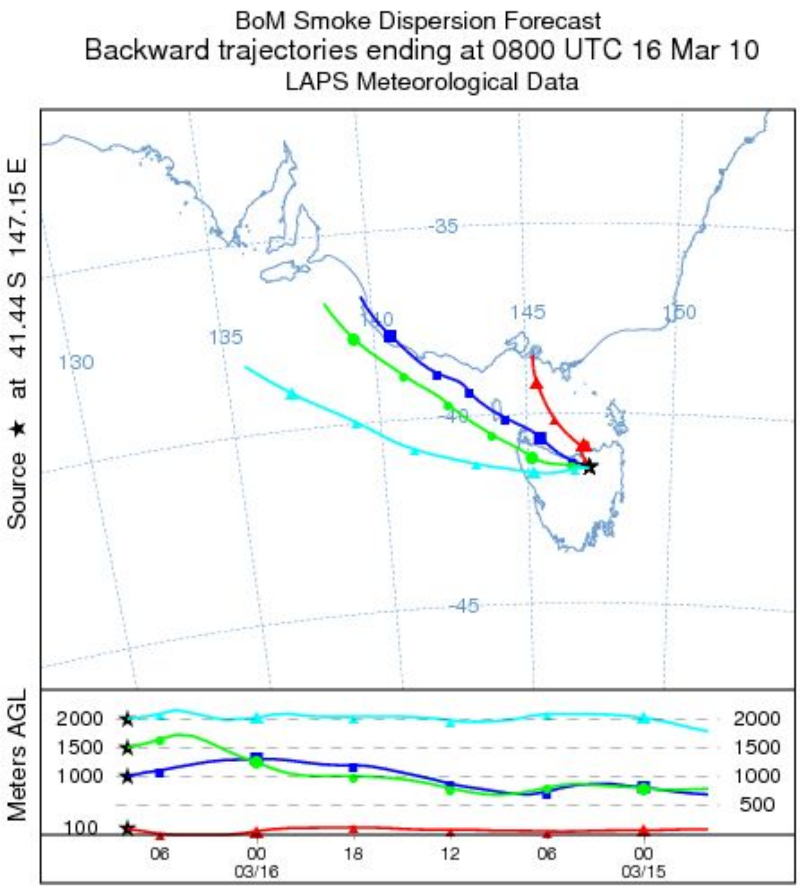

Figure 36: Back–trajectory of air parcels arriving at Launceston at 18:00 AEST (=19:00 EDT), 16th March 2010.

An interesting question is whether any of the smoke that passed overhead at Launceston on the evening of the 16th of March combined with the low–level smoke from Victoria and impacted on northern Tasmania on the 17th. To investigate this the BoM was requested to run a forward–trajectory analysis, starting in Launceston on the 16th of March at 16:00 and at 18:00 AEST. In these cases the metorological model is run in the forward direction, and therefore traces the paths of air parcels that were over Launceston on the specified starting times. The results are shown in Figures 39 and 40. The trajectory paths for air parcels at 1500 m and 2000 m altitude are to the east (i.e. a westerly wind) and slightly upward. The air parcel at 500 m moves to the east and then south. There is no indication from these calculations that the air (and hence any smoke in the air) at these altitudes over Launceston on the afternoon of the 16th of March returned to Launceston on following day. Because of the importance of this issue, it is revisited explicitly in the following subsection.

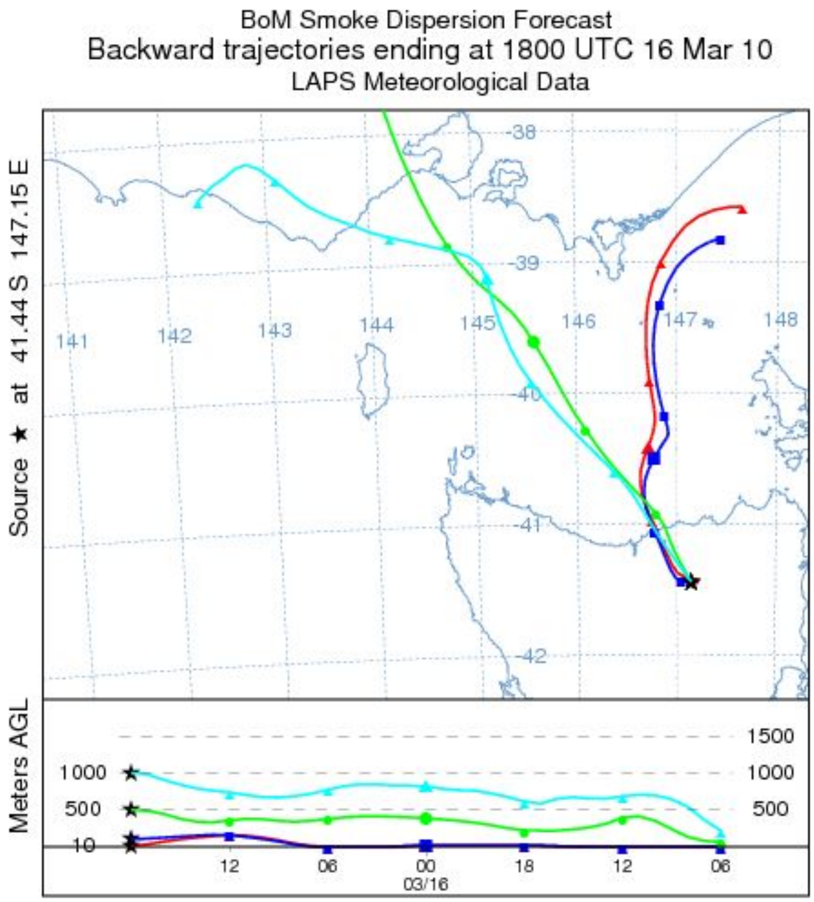

Figure 37: Back–trajectory of air parcels arriving at Launceston at 04:00 AEST (=05:00 EDT), 17th March 2010. (18:00 UTC on the 16th of March.)

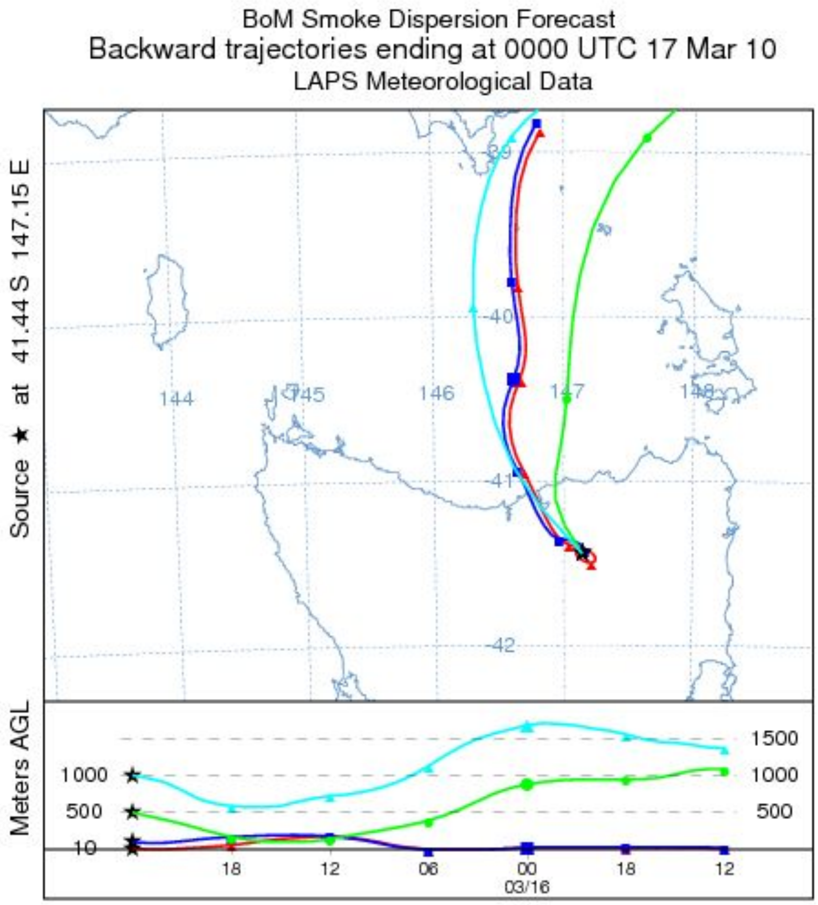

Figure 38: Back–trajectory of air parcels arriving at Launceston at 10:00 AEST (=11:00 EDT= 00:00 UTC), 17th March 2010.

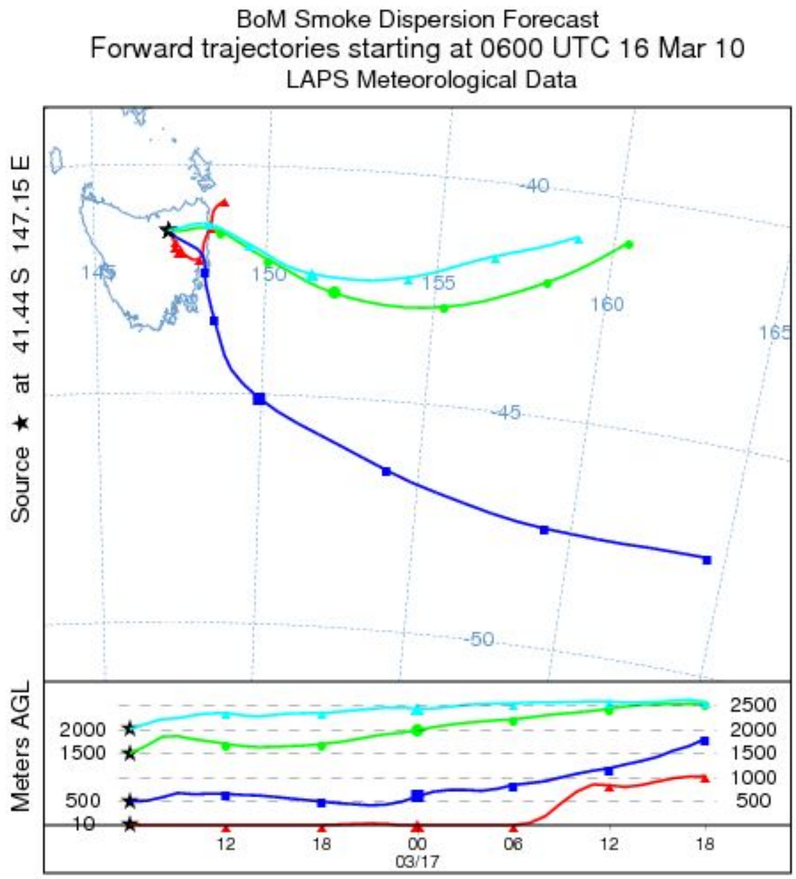

Figure 39: Forward–trajectory of air parcels originally over Launceston at 16:00 AEST (=17:00 EDT), 16th March 2010. (06:00 UTC on the 16th of March.)

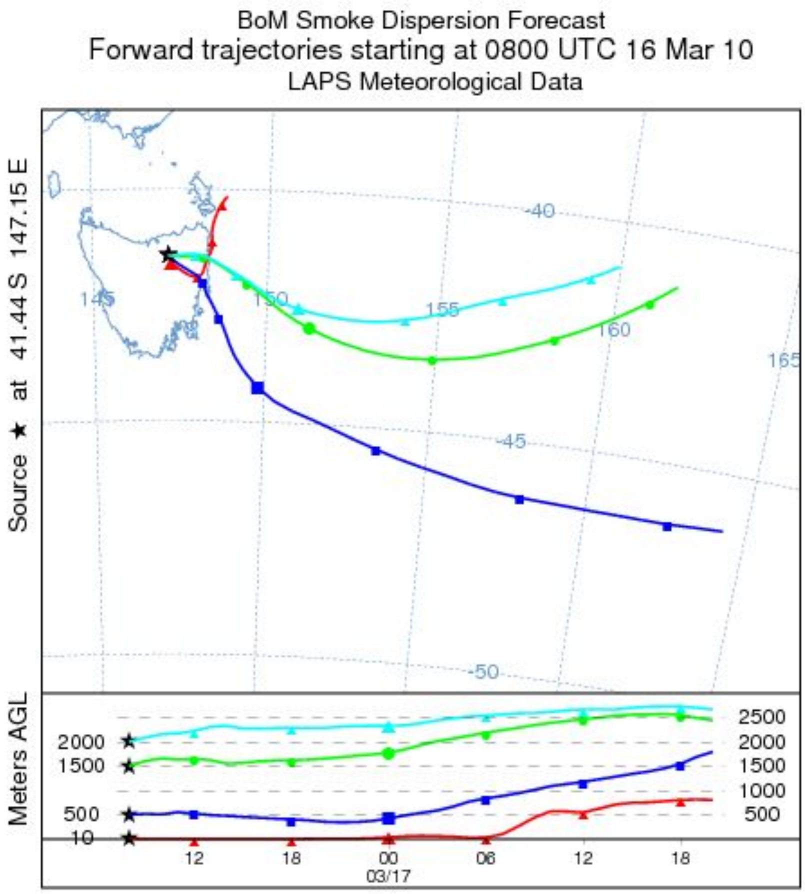

Figure 40: Forward–trajectory of air parcels originally over Launceston at 18:00 AEST (=19:00 EDT= 08:00 UTC), 16th March 2010.

4.5.1 Limitations of the Trajectory Analysis, and two conjectural Tasmanian scenarios

The BoM trajectory analysis is based on the same Numerical Weather Prediction (NWP) computer model as is used to produce operational forecasts. Operational meteorological observations are assimilated into the NWP, including surface meteorological data, balloon flights, and other data such as the Launceston airport wind profiler data (see section 9.3 in the appendix). Discussions were held with BoM staff regarding the utility and reliability of the forecasting and trajectory analysis. The forecasting was generally considered reliable out to 24 to 36 hours from the latest analysis data. The trajectory analysis generally captured large–scale air movements correctly, but was not considered suitable for analysing the detail of small–scale air movement in complex topography. In general terms, the conclusions drawn from trajectory analysis for Launceston, given above, should not be greatly affected by these two issues.

Neither the Tasmanian Mersey area burns on the 16th of March, nor the various Victorian burns for the few days before the 17th, would be explicitly included as smoke sources in the routine trajectory analysis. Given this it is worth exploring whether there may be other mechanisms whereby smoke from the 16th of March Mersey burns could have produced the 17th of March event in northern Tasmania.

There would seem to be two main means by which smoke from the 16th of March Tasmanian burns could potentially impact the north–east of Tasmania on the following morning.

The first concerns the nature of the high–intensity, heavy–fuel load burns. The Mersey burns were of this type, and would be characterised by large convective columns formed due to the high temperatures in the fire centre, which through buoyancy carries air (and smoke) to 1,000 metres altitude or more. As this heated air, originally at ground level near the fire, cools at altitude there is the potential, over time, for it to fall, bringing smoke to ground level many kilometres distant from the fire. In this scenario the plume seen over Launceston on the early evening of the 16th may be thought to have later moved over Bass Strait and subsequently decreased in altitude, and then have been brought back to Tasmania on a low–altitude northerly wind the next morning. The trajectory analysis shown above however indicates the high–altitude plume from these fires very likely moved eastward over Launceston to the Tasman Sea, and therefore would not have been in the correct location to have been brought in to the north–east of Tasmanian from Bass Strait on a low–altitude northerly wind during the morning of the 17th.

Some direct evidence on the movement of the Mersey smoke plumes on the afternoon of the 16th, which can be compared to the modelled trajectory analysis results presented above, is provided by several photographs taken from Launceston on that day and presented on the 'Tasmanian Times' website at http://tasmaniantimes.com/images/uploads/SmokeWednesday.pdf. One photograph shows a view from the Launceston suburb of Mowbray on that afternoon, and is reproduced in Figure 41. As the street is identified in the caption, and as it is a major arterial road, the location and viewing direction were able to be determined using ‘street view’ from Google Earth. The corresponding Google Earth view is shown in Figure 42. From this it can been determined that the approximate viewing direction is to the south. The ‘Tasmanian Times’ article noted that smoke was arriving from the west (i.e. from the right of the photograph). The images from the 16th of March all appear to show the smoke was at some altitude over Launceston (and not at ground–level on this day). Hence there is general support for the trajectory analysis results for the afternoon of the 16th of March as shown for example in Figure 35.

George Town Road, Mowbray: Tue afternoon Mar 16. Smoke arriving from the west.

Figure 41: View from the Launceston suburb of Mowbray on the afternoon of the 16th of March 2010, from the ‘Tasmanian Times’ web site.

Figure 42: Google Earth ‘street view’ from approximately the same location as shown in Figure 41 from the Launceston suburb of Mowbray.

The second means for the Mersey smoke to have moved initially into Bass Strait is the potential for a fire smouldering at lower temperatures on the day or days after ignition to contribute smoke at ground level. Generally, for a well–implemented burn most of the fuel would be consumed on the day of ignition. In this instance, it is likely that most of the particle pollution produced by the fire is also released on this day. This means that total number of particles present on this day, subsequent to ignition, would be a corresponding fraction of the total particle production of the fire. Under this scenario, low–altitude smoke from the Mersey burns would need to move generally to the north–east (i.e. on a south-westerly wind) towards the Tamar and north–east of the state. As noted above, the Forestry Tasmania burns ignited in the Mersey on the 16th were reported to still be alight on the afternoon of the 17th (Figure 34), so some continued smoke production during the 17th would have occurred.

It is difficult however, in this hypothesis, to see how a direct or near–direct path from the Mersey burns to the Tamar and north–east air stations could account for the relative times of onset of the thick smoke, as listed in Table 1. To account for the onset times, assuming the Mersey burns were the source, the smoke would first need to be taken out to Bass Strait (missing the air stations as it went) late on the 16th and/or early on the 17th (after the major part of the burn was completed, in this scenario) before being brought back into the north–east coast and the Tamar, on a northerly wind, over an 8 to 10 hour interval starting about mid–morning on the 17th of March.

Exeter station does show a small increase in $PM_{2.5}$ from around 5 to 15 μg m^{-3} at about 19:00 AEST on the 16th of March (as the wind swings from a light north–westerly to a light–south westerly wind) which may be evidence for some ground–level smoke moving from the south–west into the Tamar. (This light but uniformly–directed south–westerly wind at Exeter may be a katabatic wind, as it has been frequently seen at night at this site.) It is noted also that 24 hours earlier on the evening of the 15th at Exeter, $PM_{2.5}$ reached around 20 μg m^{-3} on a light north–easterly wind, which may also have been smoke moving off Bass Strait. Around 23:00 AEST on the 15th the wind began to slowly change to a light south–westerly, before dropping to a measured zero near 05:00 AEST on the 16th, by which time $PM_{2.5}$ was near 25 μg m^{-3}. These light winds may have been moving some smoke up and down the Tamar over the few days before the large smoke event of the 17th. (As mentioned earlier in this report, during the large smoke event the wind at Exeter was northerly, varying from north–westerly to north–easterly).

In general there is no evidence from the surface synoptic charts, or from other air stations, for a general south–westerly wind, at low altitude, overnight on the 16th/17th of March, that would be needed to move the smoke (at low–altitudes) from the Mersey out in to Bass Strait, prior to a later return on the observed northerly wind in the Tamar and north–east. Hence this second scenario is also considered unlikely.

5 Other data of relevance

5.1 Launceston Airport visibility meter

The BoM operates an automatic visibility meter at Launceston airport. The visibility meter operates on a similar principle to that of the BLANKET dustrak, in the sense that it measures the amount of scatter from particles from a light beam in the optical path of the instrument. In the case of the visibility meter however the output is Meteorological Optical Range (MOR), measured in kilometres.

Figure 43 compares for the 17th of March 2010 PM data from Ti Tree Bend air monitoring station (top panel) with the reciprocal of MOR (i.e. MOR^{-1}), which is taken as a measure (in the broadest sense) of the concentration of scattering particles in the local atmosphere. For completeness the lower panel shows MOR in km. The middle panel shows there was very poor visibility (below 10 km) until about 08:00 AEST. The relative humidity at this time was up to 97%, which together with the visibility meter data may be an indication that fog or mist was present. The relative humidity was 95% at 09:00, 90% at 09:30 AEST, and 59% at 10:00 AEST. Most of the change in relative humidity is probably due to an increase in ambient temperature of 5^0C over this time. Visibility improved about 08:00 AEST before decreasing again to reach a minimum of 7 km near 11:00 AEST. This second minimum in visibility is probably the signature of the onset of thick smoke, as was also measured at Ti Tree Bend station in Launceston at about this time.

5.2 West Ulverstone air quality data, mid March 2010

The measured $\mathrm{PM}_{2.5}$ at West Ulverstone BLANkET station for the 12th to 19th of March inclusive is shown in figure 44. This shows there was a near monotonic increase in $\mathrm{PM}_{2.5}$ from the afternoon of the 14th through to the afternoon of the 17th of March. The wind was consistently northerly (north–westerly to north–easterly) during this time. MODIS satellite images show a build–up of smoke in Bass Strait, largely from Victorian fires. The northerly winds prevailing over several days brought the smoke onshore to the northern Tasmanian coast. The peak signal of $\sim$40 μg m^{-3}, near midday on the 17th, appears to mark the arrival of the smoke event present at greater concentrations in stations further to the east. The sudden drop in $\mathrm{PM}_{2.5}$ a few hours later, during the mid–afternoon of the 17th, occurred about 2 hours after the onset of south–westerly winds that accompanied the cold front, noted earlier, that crossed Tasmania on this day.

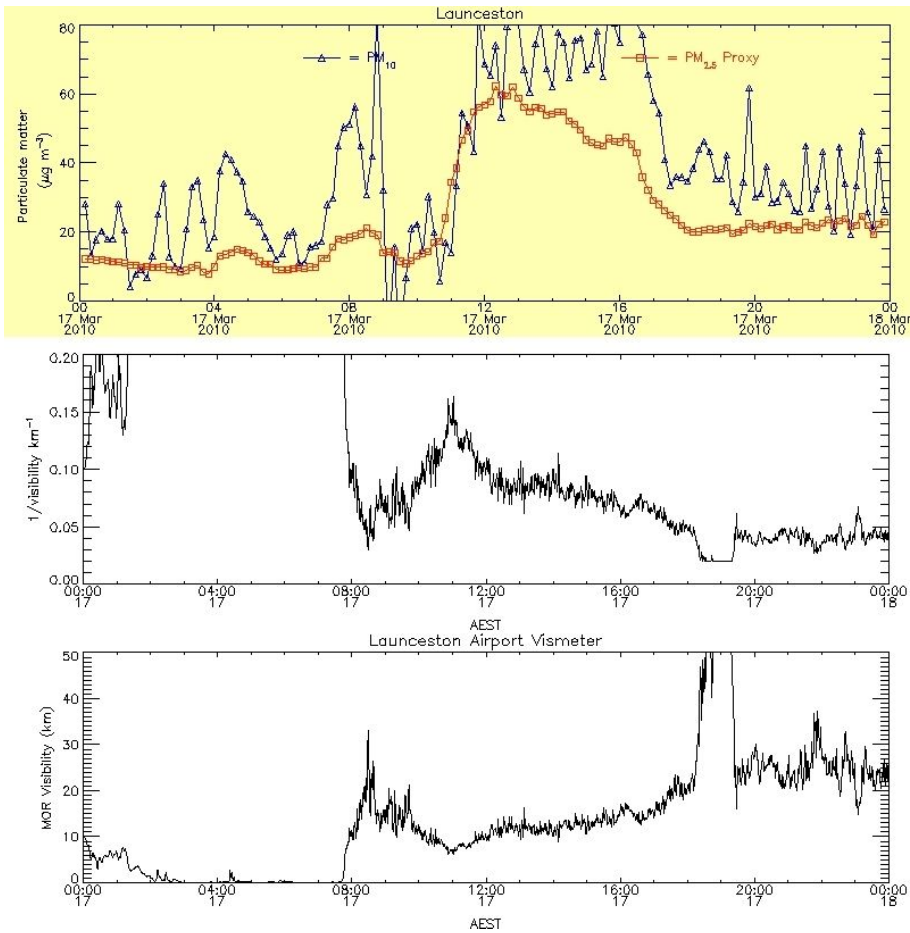

Figure 43: Upper panel: PM_{10} (blue line, square symbols) and $PM_{2.5}$ (red line, triangles); middle panel: Inverse visibility (i.e. the reciprocal of Meteorological Optical Range, MOR^{-1}), in km^{-1} measured at Launceston airport; lower panel: Meteorological optical range (visibility) in km at Launceston airport.

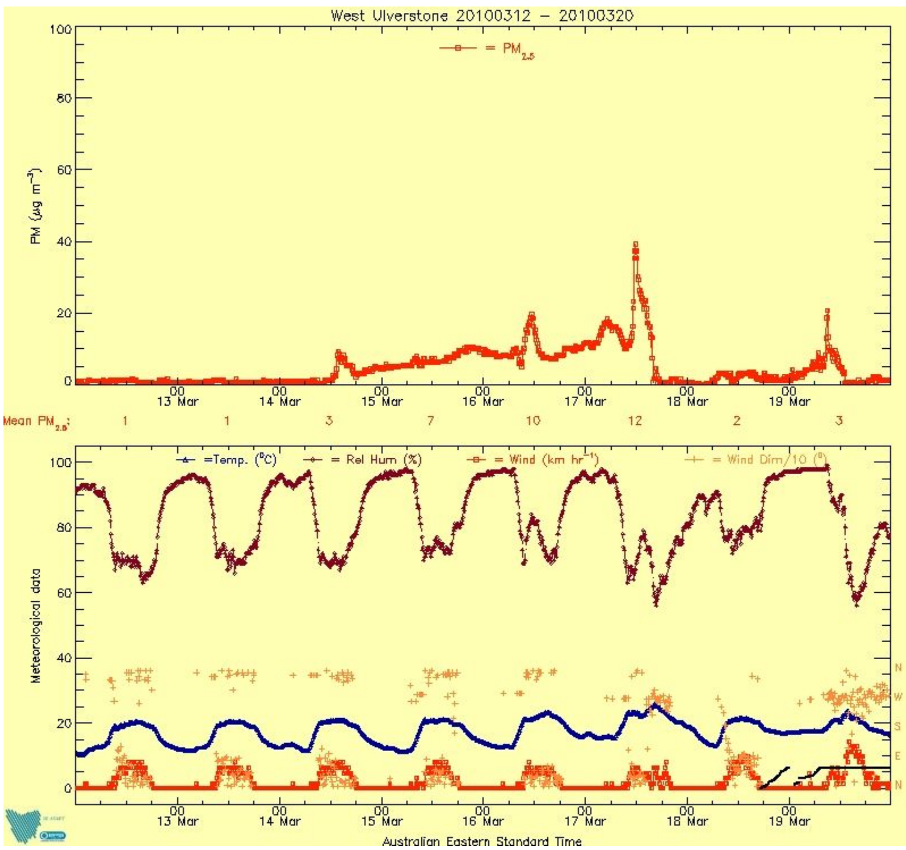

Figure 44: West Ulverstone BLANkET station data, 12th to 19th of March 2010. Upper panel: $PM_{2.5}$ (red line, triangles); lower panel: Meteorological data.

The BLANkET station at Emu River (about 6 km south of Burnie) shows a similar trend in $PM_{2.5}$ over this time, although here there is a clear pattern of katabatic winds at night.

5.3 Air Quality in Traralgon, Victoria, 16th - 17th March 2010

Very poor air quality at Traralgon, Victoria, was reported in the media around the 17th and 18th of March. The Victoria EPA was contacted, and supplied the hourly PM_{10} data shown in Figure 45. The Victoria EPA ascribed the poor air quality to smoke from planned burning. The peak signal of around 220μg m^{-3} occurred about 03:00 AEST on the 17th of March, around 6 hours before the first onset of the high $PM_{2.5}$ levels in the northern Tasmanian air stations. Elevated PM_{10} levels were observed for about 10 hours.

The magnitude, duration and even the time–profile of this event in Traralgon has some similarities to those seen in the northern Tasmanian air stations aroubnd six hours later. It is not known at present if this event was in anyway connected with the smoke that impacted on Tasmania.

It appears that Traralgon is the only Victorian EPA ambient air monitoring station outside the greater Melbourne metropolitan area, apart from a station at Geelong.

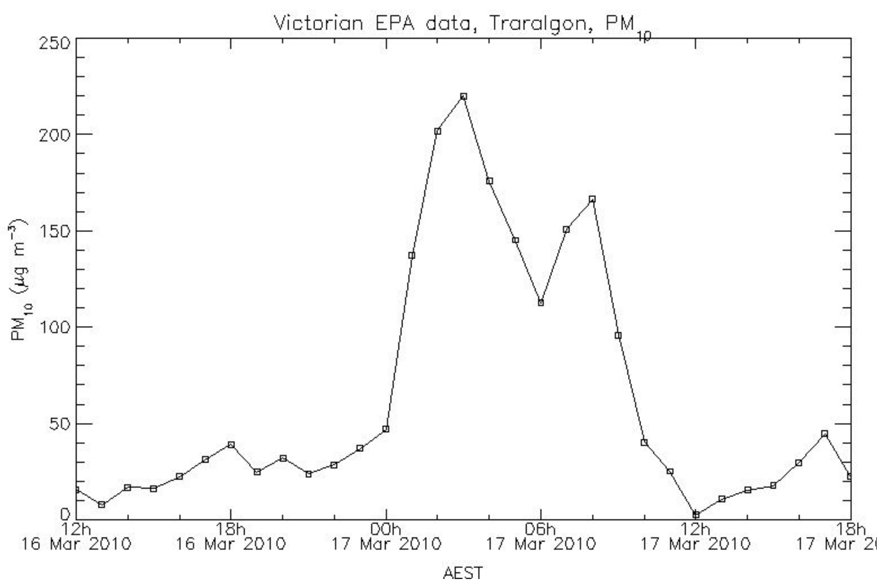

Figure 45: TEOM PM_{10} data from the Victorian EPA air quality station at Traralgon, Eastern Victoria, 16th–17th March 2010.

5.4 Historical example of smoke moving from Victoria to Tasmania - 24th April, 2008

Although not directly related to the 17th of March 2010 event, a clear example of smoke moving across Bass Strait from Victoria to Tasmania is provided by MODIS satellite images for the 24th of April 2008. Both the morning (Terra) and afternoon (Aqua) images are shown in Figure 46. The two images show a large apparent eddy south of Gippsland that slowly moves southward during the day. A clear wake in the clouds over the Ben Lomond plateau in eastern Tasmania is also seen in the afternoon image, demonstrating the presence of a general northerly wind over Tasmania. Although there are clearly fires burning in Tasmania on this day, a significant amount of smoke appears to have originated in Victoria.

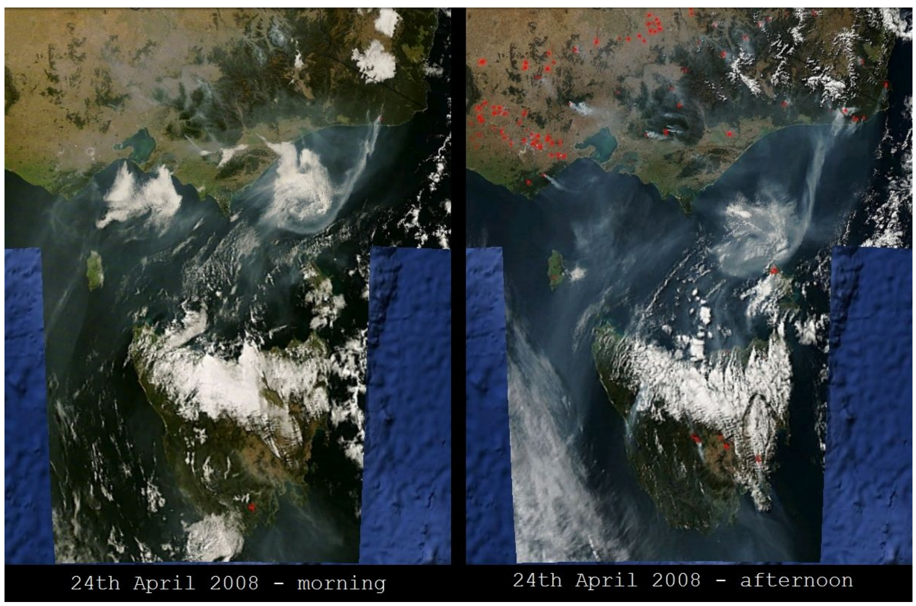

Figure 46: Archived MODIS images of south–eastern Australia for the morning (left) and afternoon (right) of 24th April 2008. Fire locations inferred by the NASA 'Rapid Response' automatic algorithms are shown as red polygons.

6 Discussion – Interpretation of the smoke event

The above analysis of data relating to the northern Tasmanian smoke event of the 17th of March leads to identifying smoke from Victoria fires as the most likely source. This smoke, which had been resident and building up in Bass Strait for several days – and had indeed reached parts of northern Tasmania at relatively low levels in the days before the 17th – moved in bulk to northern Tasmania on a northerly wind change during the early morning of the 17th of March.

It was noted earlier in this report (e.g. see Table 1) that while some moderate smoke concentrations were present at some stations from the early hours of the morning of the 17th of March, thick smoke was first measured at Scottsdale about 08:30 AEST, about 09:00 AEST at Lilydale and St Helens, near 10:00 AEST at George Town and Exeter, about 10:10 AEST at Rowella, near 10:20 AEST at Derby, and then, presumably after smoke moved up the Tamar, at Launceston city and Launceston airport near 11:00 AEST.

The interesting issues concern the delayed arrival at Derby, and the near simultaneous arrival at Exeter and George Town. The explanation to this may lie in the topography of northern Tasmania. It was reported by various first–hand accounts that the smoke moved in at a relatively low altitude. A 'birds–eye view' (via Google Earth) of north-eastern Tasmania, showing exaggerated vertical relief, is presented in Figure 47. Air monitoring stations are indicated by the red balloon symbols.

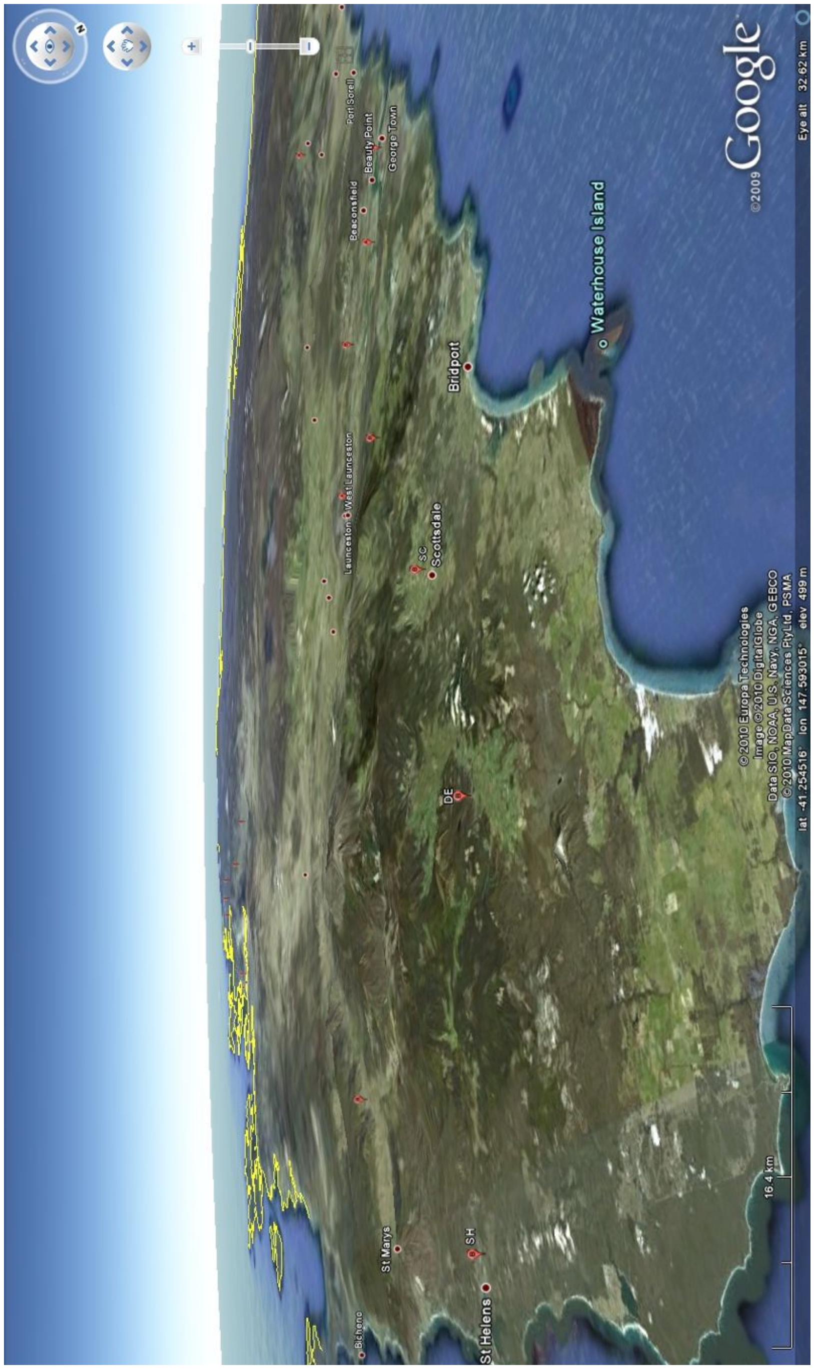

Figure 47: Oblique view (from Google Earth) of north–eastern Tasmania, with exaggerated vertical relief. Air monitoring stations are indicated by the red balloon symbols.

Air moving inland (i.e. on a northerly wind) at low–altitude off Bass Strait would have a (topographically) relatively straight–forward path to Scottsdale up the Brid River valley – which is in a broad, relatively shallow plain. Similarly for Lilydale, the Pipers River valley (and, to an extent, possibly the Pipers Brook valley) provides a direct route inland. Derby, located on the Ringarooma River, is much more 'land–locked'. The Ringarooma river near Derby flows in a relatively narrow valley, passing through a range of hills on the way to the coast, and skirting Mt Cameron (500 m), which itself could also provide a significant obstacle to air movement, depending on wind direction. The more complex topography around Derby, compared to Scottsdale and Lilydale, may be a contributory reason as to why Derby was one of the last of the northern Tasmanian air stations to be impacted by thick smoke on the 17th of March.

The near–simultaneous arrival of smoke at Exeter and George Town may have a similar topographical interpretation. The eastern side of the lower Tamar valley is flanked by the Tippogoree Hills and the Dismal Range. George Town would have a measure of protection from air (and smoke) moving from the north–east towards the coast due to the northern extension of these hills. The lowest elevations of these hills are the passes near East Arm Road and Dalrymple Road (Figure 48), marking the division between the Dismal Range and the Tippogoree Hills. It is conjectured that it may have been possible for air moving off Bass Strait, on a general northerly wind, up the Pipers River valley and reaching the vicinity of Lower Turners Marsh to then be topographically steered westwards towards Mt Direction and enter the middle Tamar through the pass at Dalrymple Road. This pass on the eastern side of the Tamar is nearly opposite Exeter station on the western bank. There are no independent data to support this conjecture. It is offered mainly as a hypothesis that could be worth investigating further in future.

Figure 48: Oblique view of part of the lower Tamar valley, Tasmania, with exaggerated vertical relief, showing the passes through the eastern Tamar hills of Dalrymple and East Arm Roads. The location of Exeter BLANkET station is indicated by the red balloon symbol at top–centre.

The first–hand reports note that smoke moved through Longford and Cressy on the morning of the 17th of March to Campbell Town (60 km south of Launceston), but did not reach Westbury (30 km west of Launceston). It is likely that smoke that had entered the Tamar on the northerly wind was carried into the wide Esk valley and moved southwards. It is possible the eastern escarpment of the Great Western Tiers also modified the wind flow (and hence the smoke movement), as was mentioned above. In this sense the escarpment may act under these conditions as a form of smoke corridor, controlling the movement of smoke. Such behaviour was possibly seen during the York Town (West Tamar) fire in January 2010, when Air Section officers noted, while returning to Hobart from Launceston on the 8th of January, that smoke from this fire had apparently moved southward along the foot of the tiers to the vicinity of Tunbridge (25 km south of Campbell Town).

Increasing smoke–concentrations were measured at West Ulverstone soon after 11:00 AEST, and, possibly, at reduced levels at Sheffield during the afternoon of the 17th, although the lack of data before 11:00 AEST at this station is a handicap to the analysis. First–hand accounts from Devonport did not seem to note any smoke other than from the green waste fire discussed above, although the presence of this local burn may have made the detection of another smoke source a more difficult task. The smoke at West Ulverstone appeared to move in, from Bass Strait, on a northerly (onshore) wind.

7 Conclusion

A consideration of the available data on the northern Tasmanian smoke event of the 17th of March leads to identifying smoke from Victorian fires as the most likely source. This is generally indicated by the times of onset of the smoke event at the various northern Tasmanian air stations, by the arrival of the smoke coincident with a northerly wind change (as seen in BLANkET and BoM wind data), from inspection of MODIS and JMS satellite images, and from the BoM trajectory analysis. A first–order calculation of the particle concentration in the smoke plume visible in Bass Strait on the 17th March MODIS Terra image, based on the expected particle production of the Victoria fires over the previous few days, produces a result consistent with observations. It was also noted that the burns in Tasmania carried out on the 16th of March could also have produced enough particles to account for the observed elevated levels across the north of the state, assuming the smoke was largely confined to the land area of north and north–east Tasmania and had not also extended out to sea. A plume from one or more of these Mersey burns passed over Launceston, apparently near 1500 m altitude, in the late afternoon of the 16th of March. However, the BoM trajectory analysis provides no evidence suggesting smoke from these plumes impacted on Launceston on the 17th of March.

Victoria is currently pursuing an active fuel–reduction burn program. It is very possible, given a recurrence of similar meteorological conditions in future burning seasons, that further smoke impacts from Victorian smoke could be experienced in Tasmania.

8 Acknowledgements

Many people and organisations have provided data and information for this report. We thank the Bureau of Meteorology for data and discussions. We thank Forestry Tasmania Mersey District office, the FIAT association member company, and the Tasmanian Fire Service who all provided information for this report. Information concerning the Victorian burns was kindly provided by the Victorian Department of Sustainability and Environment and the Victorian Country Fire Authority. The people who supplied first–hand accounts of the event are also thanked. BLANkET stations are sited at properties owned or operated by Ben Lomond Water, Break O'Day Council, Cradle Mountain Water, Dorset Council, Forestry Tasmania Huon District, Huon Valley Council, and West Tamar Council, all of whom are thanked for their assistance.

The MODIS images were obtained from the NASA/Goddard Space Flight Center 'MODIS Rapid Response' web site[2].

Satellite images from the Japanese Meteorological Satellite were originally produced by the Australian Bureau of Meteorology from the meteorological satellite MTSAT-1R operated by the Japan Meteorological Agency.

G. Stannus took the photo shown in Figure 41 (obtained from the Tasmanian Times website).

Report compiled by John Innis.

[2]http://rapidfire.sci.gsfc.nasa.gov/

9 Appendices

9.1 Air quality and meteorological data plots for northern Tasmania BLANkET stations for 17th March 2010

For the BLANkET stations the upper panel shows PM_{10} (blue squares) and $PM_{2.5}$ (red triangles). The lower panel shows meteorological data. Numerical values for relative humidity (solid red line), air temperature (solid blue line), wind speed (in km hr^{-1}), and daily total rainfall (if any) are read from the left–hand axis. Wind direction (degrees) divided by 10 (upright crosses) is also read from the left–hand axis. Hence a wind direction of 9 units on the plot means 90 degrees (a wind from due east), etc. Barometric pressure is indicated by the dash-dot line and is read off the right hand axis. For the main stations of George Town, Rowella, and Ti Tree Bend only air quality data are plotted.

9.1.1 Scottsdale

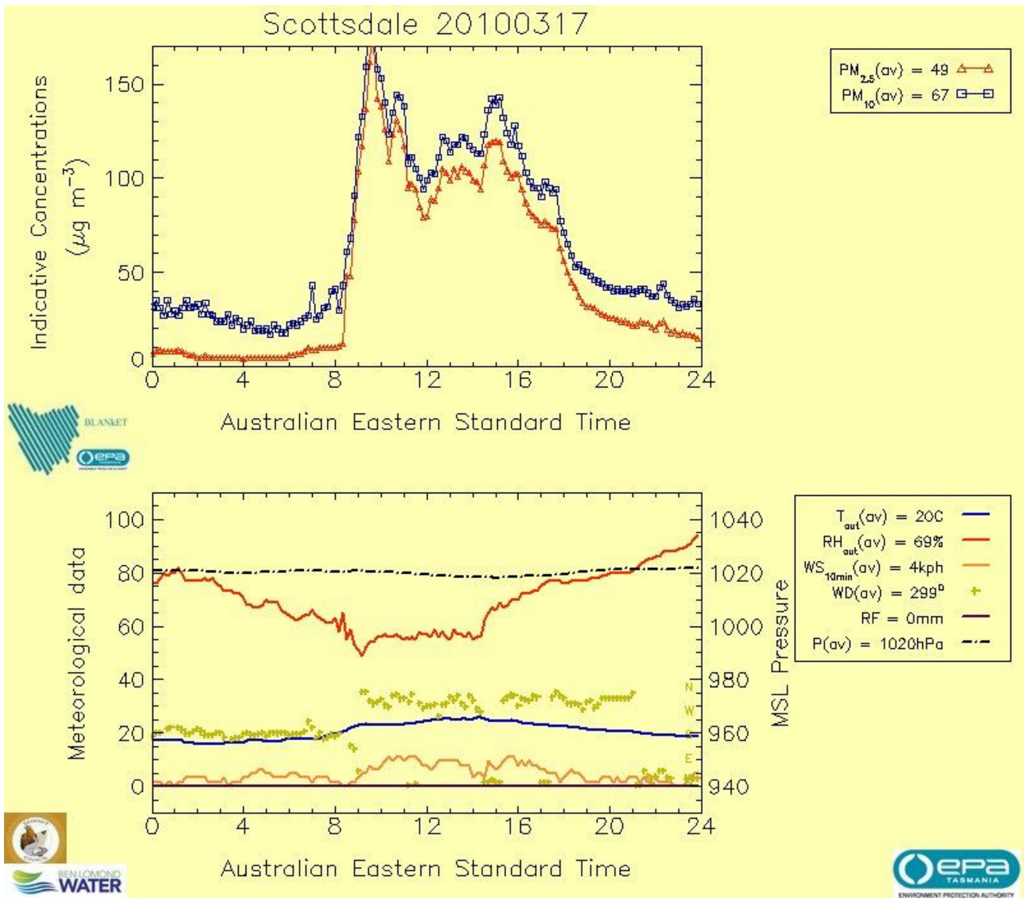

Figure 49: BLANkET station air quality data (top) and meteorological data (bottom) for Scottsdale for the 17th of March.

9.1.2 Lilydale

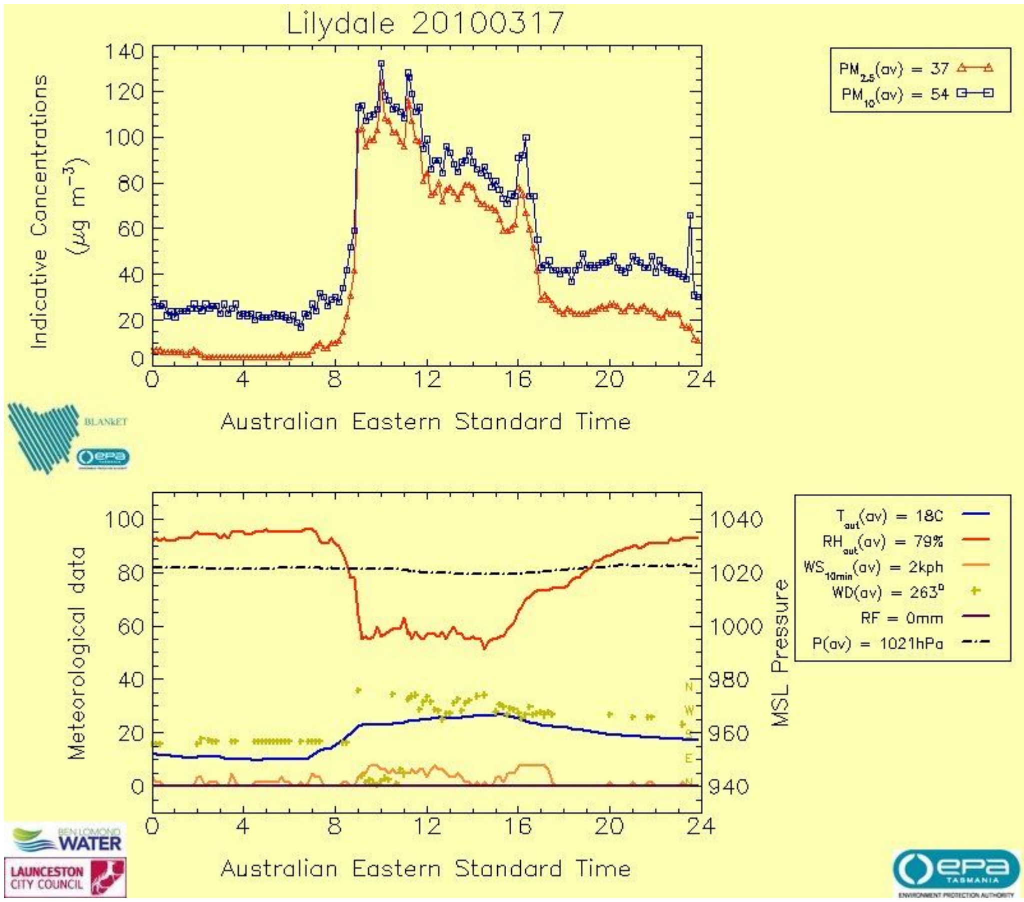

Figure 50: BLANkET station air quality data (top) and meteorological data (bottom) for Lilydale for the 17th of March.

9.1.3 Derby

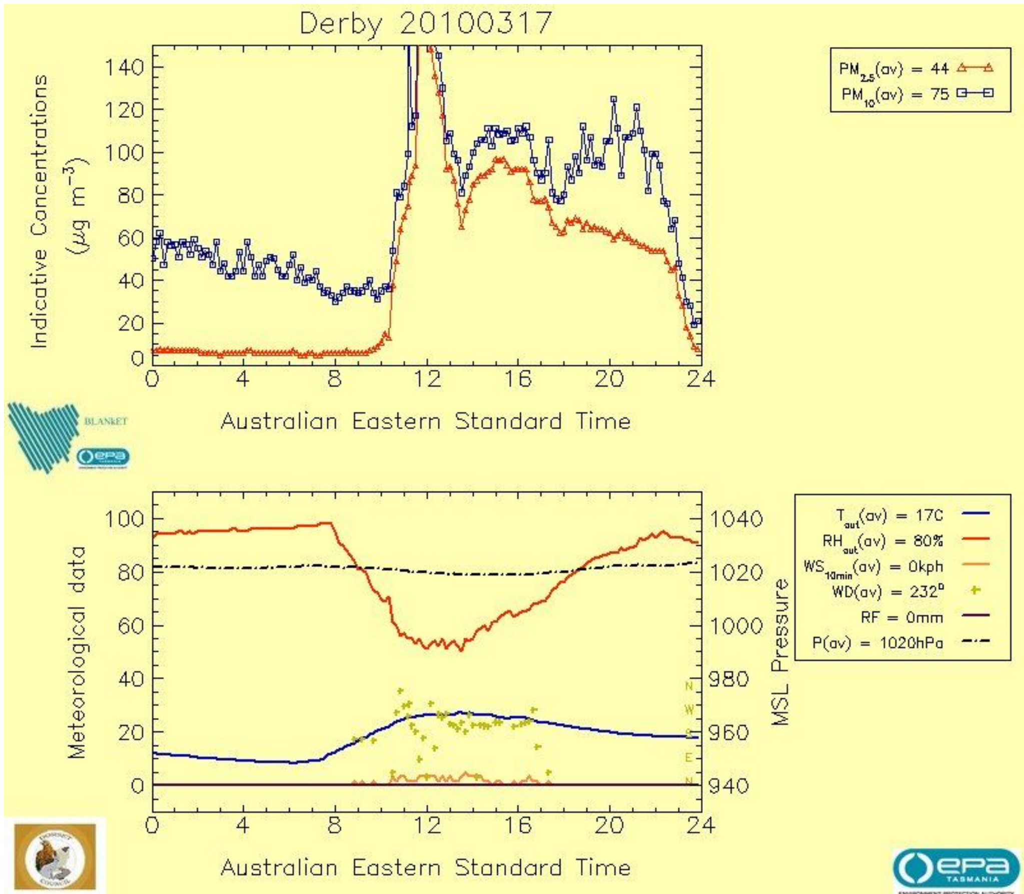

Figure 51: BLANkET station air quality data (top) and meteorological data (bottom) for Derby for the 17th of March.

9.1.4 Exeter

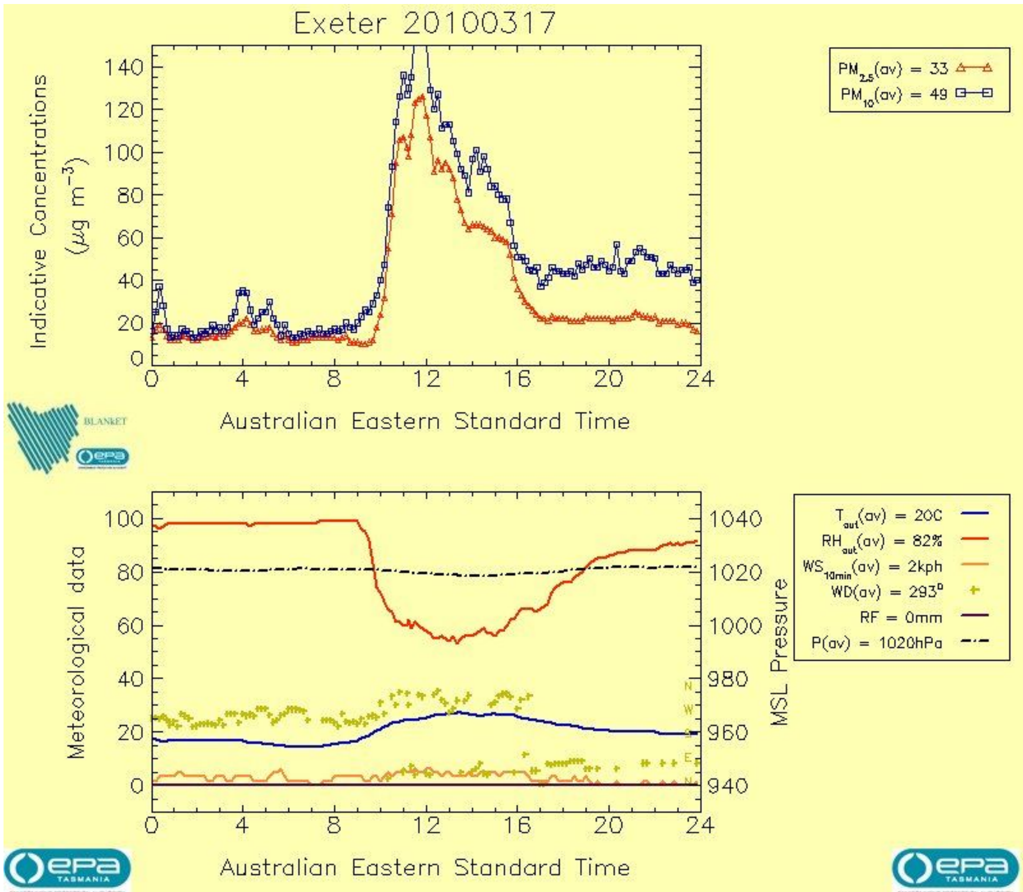

Figure 52: BLANkET station air quality data (top) and meteorological data (bottom) for Exeter for the 17th of March.

9.1.5 St Helens

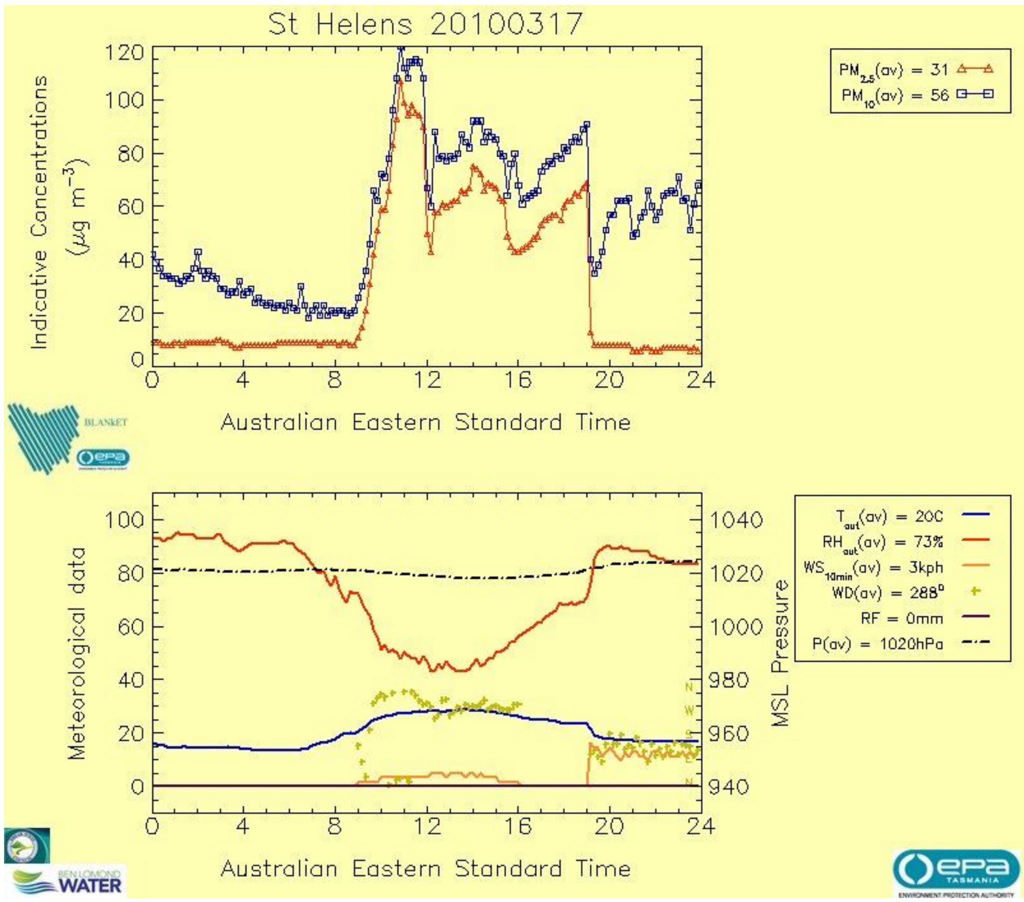

Figure 53: BLANkET station air quality data (top) and meteorological data (bottom) for St Helens for the 17th of March.

9.1.6 West Ulverstone

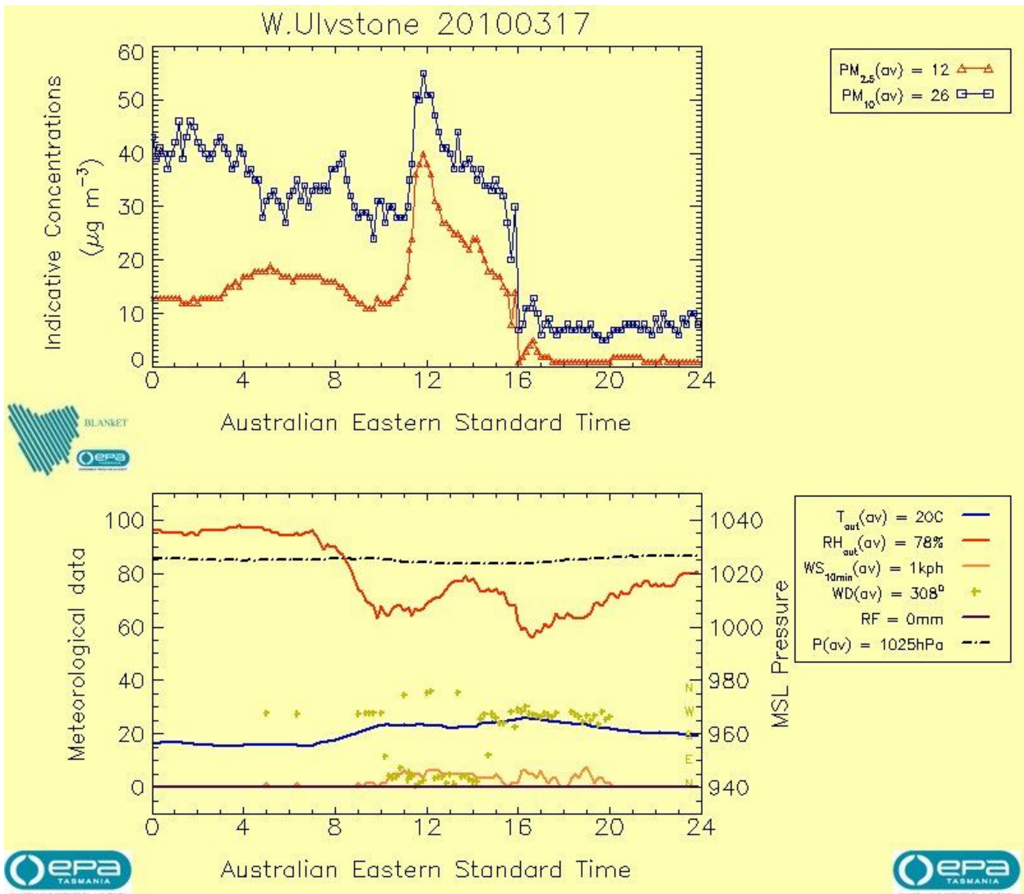

Figure 54: BLANkET station air quality data (top) and meteorological data (bottom) for West Ulverstone for the 17th of March.

9.1.7 Sheffield

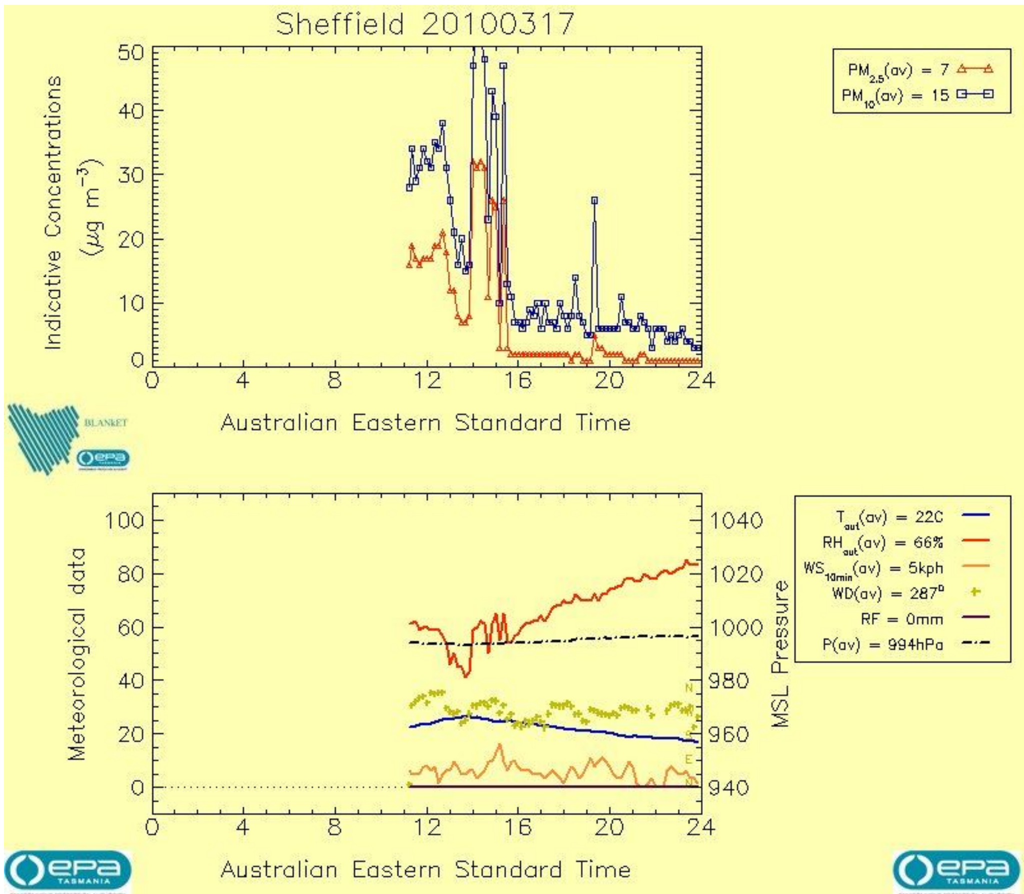

Figure 55: BLANkET station air quality data (top) and meteorological data (bottom) for Sheffield for the 17th of March.

9.1.8 Emu River (Burnie)

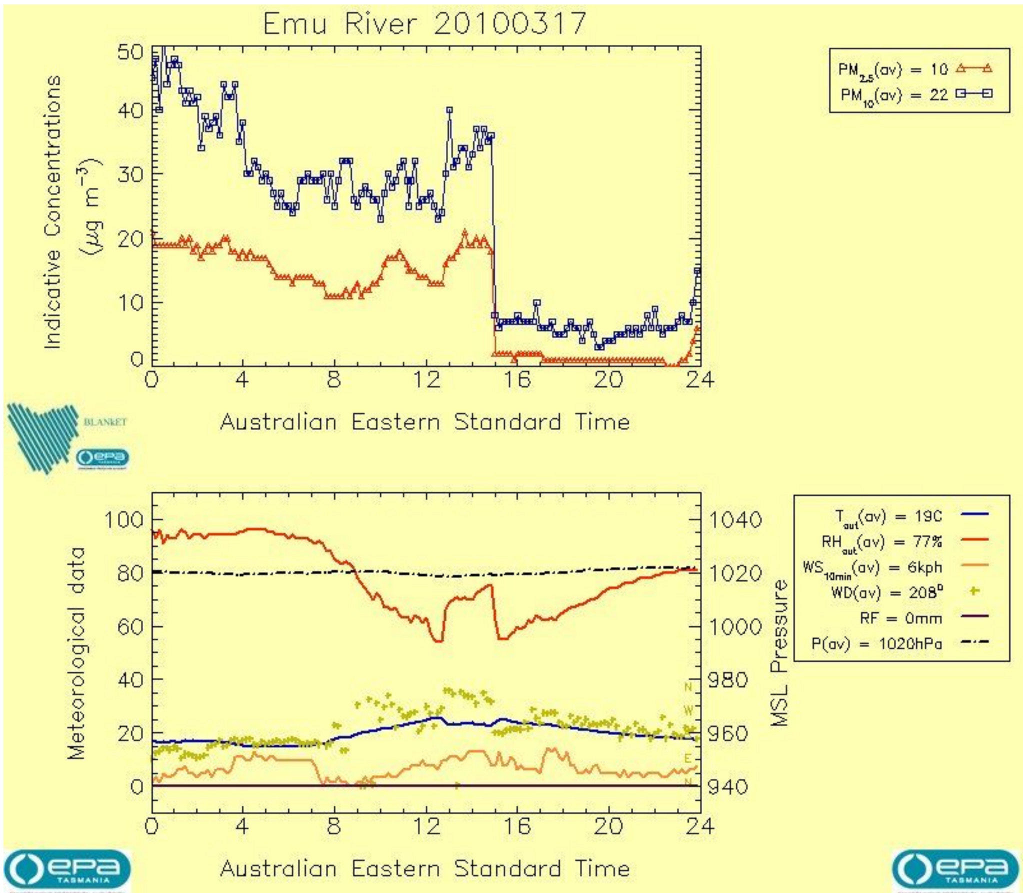

Figure 56: BLANkET station air quality data (top) and meteorological data (bottom) for Emu River for the 17th of March.

9.1.9 Fingal

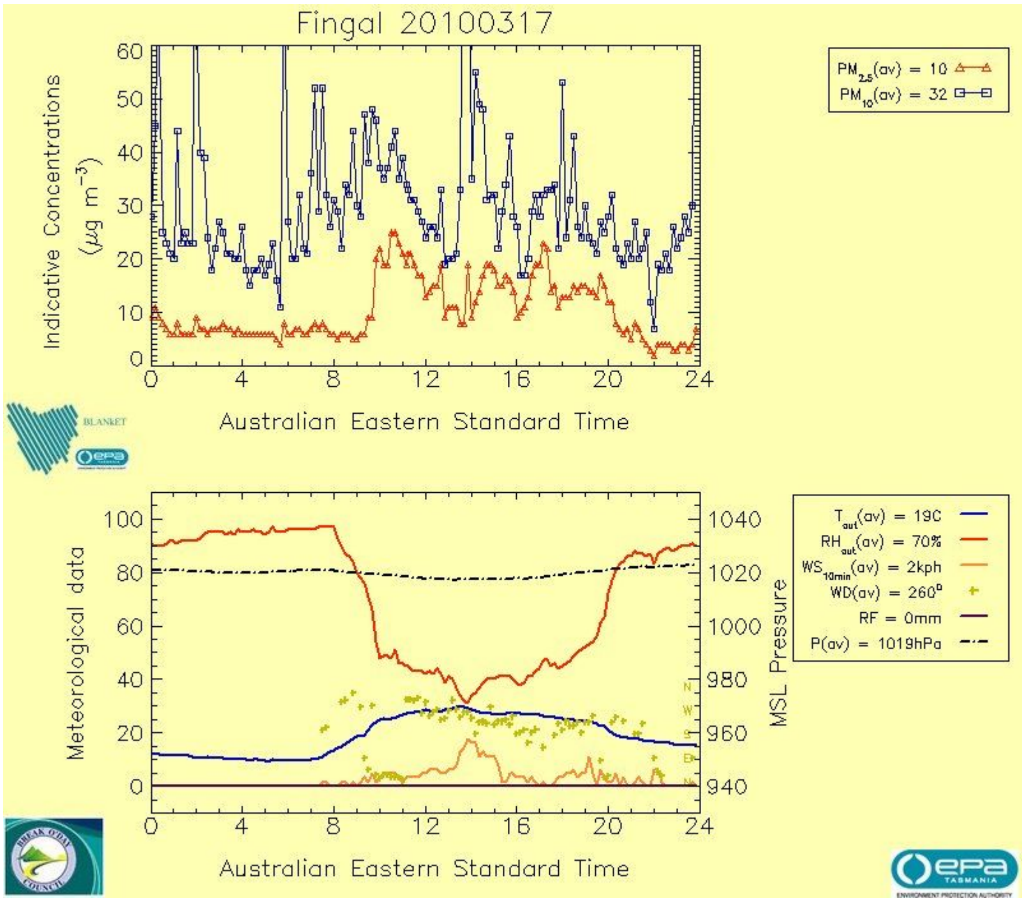

Figure 57: BLANkET station air quality data (top) and meteorological data (bottom) for Fingal for the 17th of March.

9.2 First–hand accounts of the 17th March 2010 smoke

1/ Officer at St Helens Ben Lomond Water – St Helens (recorded 18/3/2010)
The officer said there was a bit of smoke about, but it didn't worry him. The officer was asked about reports carried on ABC Radio Northern Tasmania that the smoke came in to St Helens at a low altitude. He confirmed this was the case, but no details were able to be obtained.

2/ Officer of the Air Section EPA Division (recorded on 23/3/2010)
The officer was on the 'Tamar run' - weekly filter changes at George Town and Tamar air stations – on the 17th of March. He was at Ti Tree Bend at 8 am. It was very foggy. On way to GT the fog lifted. He smelt smoke at GT at 11 am EDT = 10 am AEST. GRIMMs was reading high, PM2.5 $\sim 50\ \mu\text{g m}^3$. He crossed to west Tamar via Batman bridge, smoke seemed less intense there, looking across the river back to east Tamar it looked smokier. Some smoke at Beauty Point but not as bad as GT earlier. At Rowella it seemed less smoky, but the officer recalls the TEOM was reading up to $80\ \mu\text{g m}^3$ while he was there.

3/ Flinder Island Council officers, recorded 19/3
One officer could smell smoke when she awoke on the 17th, and 'we wondered were the fire was'. She had discussed it with co-workers.
The other officer reported it was hazy on the morning of the 17th, he couldn't smell smoke, he assumed 'we were in a fog'. It was only when other people said they could smell smoke that he realised it was a fire.

4/ Officer of Break O'Day Council (St Helens) recorded 23/3
The officer noticed smoke during morning about 10 am. She didn't notice which way it came in. Council rang FireCom to ask. She heard that there was a fire at Wesley Vale or near there, and maybe another on the mainland.

5/ Ben Lomond Water officer at Scottsdale, recorded 23/3
The smoke seemed to have moved in from Bridport, from NNW. Visibility was very poor in the smoke. 'The humidity seemed to drop, we were under a low cloud cover, the smoke was below that'. The officer lives 10 mins from Scottsdale along Lilydale Rd. He could smell smoke when he got up at 6 am (EDT). When asked, he didn't notice a sudden decrease in visibility at 9 am (EDT).

6/ Officer of Scottsdale council, recorded 23/3
The officer lives in Launceston. He noticed smoke in gullies as he drove to Scottsdale on Lilydale Rd, first noticed smoke near Golconda. It wasn't a wall of smoke, he was trying to work out how high the smoke was (in altitude) but had no reference points so he couldn't. There was a quick transition from clear air to smoke near Golconda.
He arrived at Scottsdale about 8 am EDT. He thought there was more smoke in the area of the council works depot in a valley East of the town than in the town itself.

It was choking, irritating thick smoke. It was structured, not non-homogeneous. The officer was at Bridport later that day, it was clearer there. At 3 pm he looked from Bridport towards Mt William over the plain, it was still hazy. He drove home over the Sideling ($\sim$600 m elevation) at about 5:30 pm. The air was clear on top. During the day the sun was pink at Scottsdale, the disk was visible, but it was too bright to look at directly.

7/ Officer of Northern Midlands Council (recorded 24/3)
The officer was in Longford and Cressy during the 17th. There was smoke in both places, at Cressy it looked smoky in every direction as far as he could see. Possibly it was mid morning when the smoke came in, he will check his diary and see if he can confirm this.

8/ Officer of Southern Midlands Council - recorded 24/3
There was no smoke in Oatlands. There may have been a haze in the distance. The officer's daughter lives in Launceston and said by phone it was smoky, he recalls saying to her it was not smoky in Oatlands.

9/ Officer of Meander Valley Council - recorded 24/3
The officer was in the Westbury area in the morning, in the field doing water sampling. She did not notice any smoke. She was inside in meetings in the afternoon. at 5 pm she left the office. There was no smell of smoke. It became hazy driving home from work in the Hadspen/Carrick area, and was very smoky/hazy going down the southern outlet to Launceston soon after.

10/ EPA Division officer based in Launceston, lives near Lilydale - by phone 25/3
The officer was at home on the morning of the 17/3. It was smoky when waking up at 7:30 am so she shut the windows of the house. She lives 2 km from Lilydale. She was at Lilydale at 10 am and it was smoky there, visibility about 1 km. The smoke was uniform from home to Lilydale. The smoke hung around all day. The officer reported: 'Forestry burns drift vertically all through the air column, this was different. This smoke was different, it came down the hillside into the valleys, but not all the way down. It wasn't 'local smoke'.
The officer was in Launceston for a 4 pm appointment at Invermay. The conditions in the Tamar were the same. Coming in on Lilydale Rd she thought 'why hasn't the smoke cleared?'.
The smell of the smoke was obvious during the day of the 17th, but she didn't smell it at night on the 16th/17th although they had the windows open. She said this 'probably it means it only came in about the time we woke'.

11/ Campbell Town Police officer - by phone 25/3
The officer was in Launceston on the night of the 16th and returned to Campbell Town during the afternoon of the 17th, arriving at about 3 pm. There was thick smoke all the way down the Midland Highway.

12/ Campbell Town Postmaster - by phone 25/3
There was thick smoke in Campbell Town on this day, possibly thicker after lunch. A family member commenced an afternoon shift outside at 2:30 pm EDT and reported the smoke was very thick about 3 pm EDT in Campbell Town.

13/ Property owner, residing about 10 km north of Campbell Town (co-operative BoM observer) - by phone 25/3
He noted the weather at 6 am EDT as NW wind at 5 knots, mist, 11 C. He first noticed smoke between 10 and 11 am EDT, about 1 hour after the mist had cleared. The smoke was coming from a N to NW direction, and appeared to be coming from a long way away. Between 10 am and 12 noon EDT the smoke spread out, appeared to be higher in altitude, moving on a NW wind. He departed his property for Hobart at noon, the smoke was coming from the N-NW.

14/ Resident near Nunamara - by email 26/3
'At 8:30am 17th March I received a message regarding Tamar valley was in smoke but there was none here at the time nor some time later. An hour or 2 later smoke had come from WNW around Mt Arthur and then engulfed Patersonia, 360 degrees, with thick smoke reducing visibility down to 100 m.'

9.3 BoM Launceston wind profiles

Wind speeds and directions at specified altitudes over Launceston airport are routinely sampled by a VHF (Very–High Frequency) radar operated by the Bureau of Meteorology. Figures 58 and 59 show these wind data from around 02:00 UT to 15:00 UT on the 16th of March and from 14:00 UT on the 16th to around 03:00 UT on 17th of March respectively. That is, from about 12:00 AEST on the 16th to 01:00 AEST on the 17th (Figure 58), and from about 00:00 AEST to 13:00 AEST on the 17th (Figure 59). At any given time (i.e. along any line drawn vertically on the plots) the wind speed (in knots) is indicated by the number of barbs on the line – a large bar represents 10 knots, a small bar represents 5 knots. Wind direction is indicated by the direction the line is pointing – a northerly wind (i.e. a wind moving air to the south) is represented by a line vertically downwards, hence with the wind speed barbs at the top. An westerly wind (i.e. air moving to the east) is represented by a line pointing to the right – hence with the wind speed barbs on the left–hand end. Altitude is given in feet (left–hand axis) and in pressure units (right–hand axis). An altitude of 5000 feet is close to 1500 metres, and 6600 feet is close to 2000 metres.

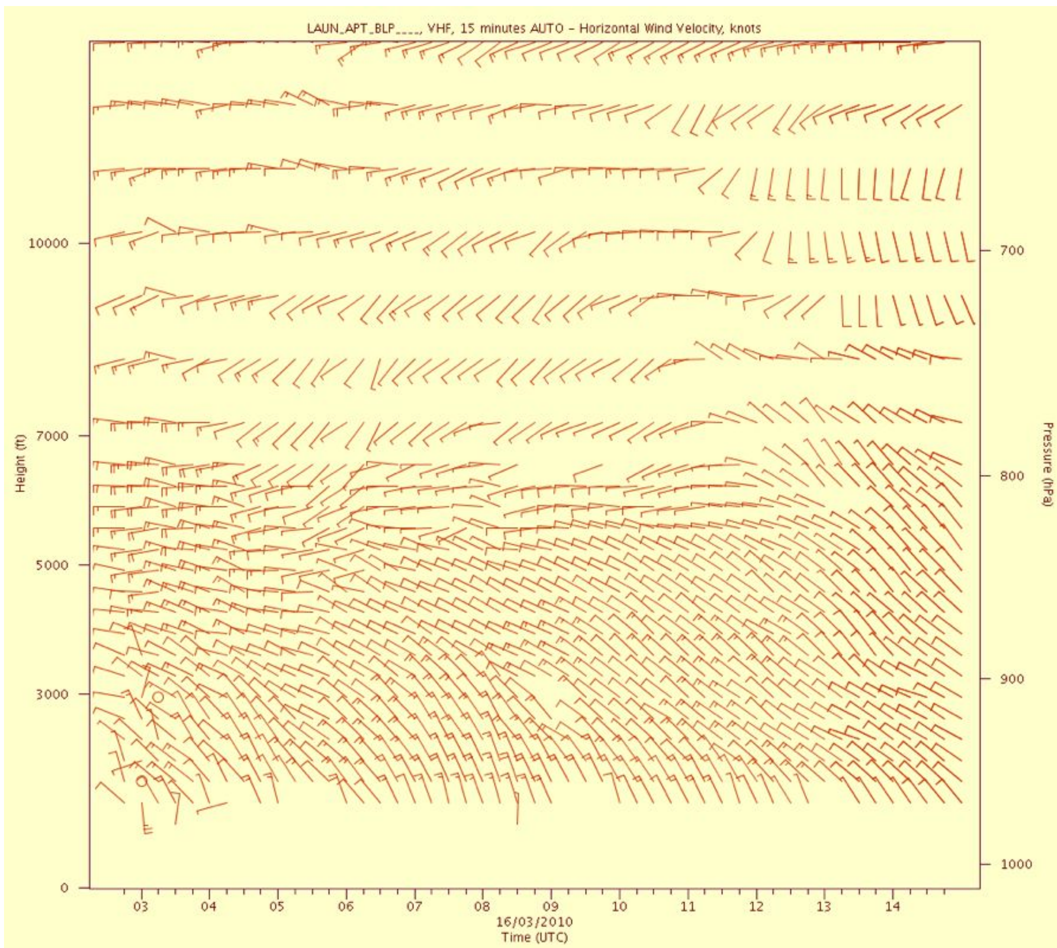

Figure 58: Launceston airport wind profiler (VHF radar) data for the 16th of March 02:00 to 15:00 UT. The interval shown corresponds approximately to 12:00 AEST 16th of March to 01:00 AEST on the 17th of March.

During the late afternoon of the 16th in Tasmania (e.g. around 17:00 AEST = 07:00 UT, Figure 58) the wind was north–north–westerly (i.e. directed to a little south of east) at 5000 feet (1500 metres), and was westerly (i.e. directed to the east) at 6600 feet (2000 metres). This is also shown in the trajectory analysis for Launceston shown earlier in this report (e.g. in Figure 35). The wind profiler data are assimilated into the traajectory analysis, so a large measure of agreement is not unexpected.

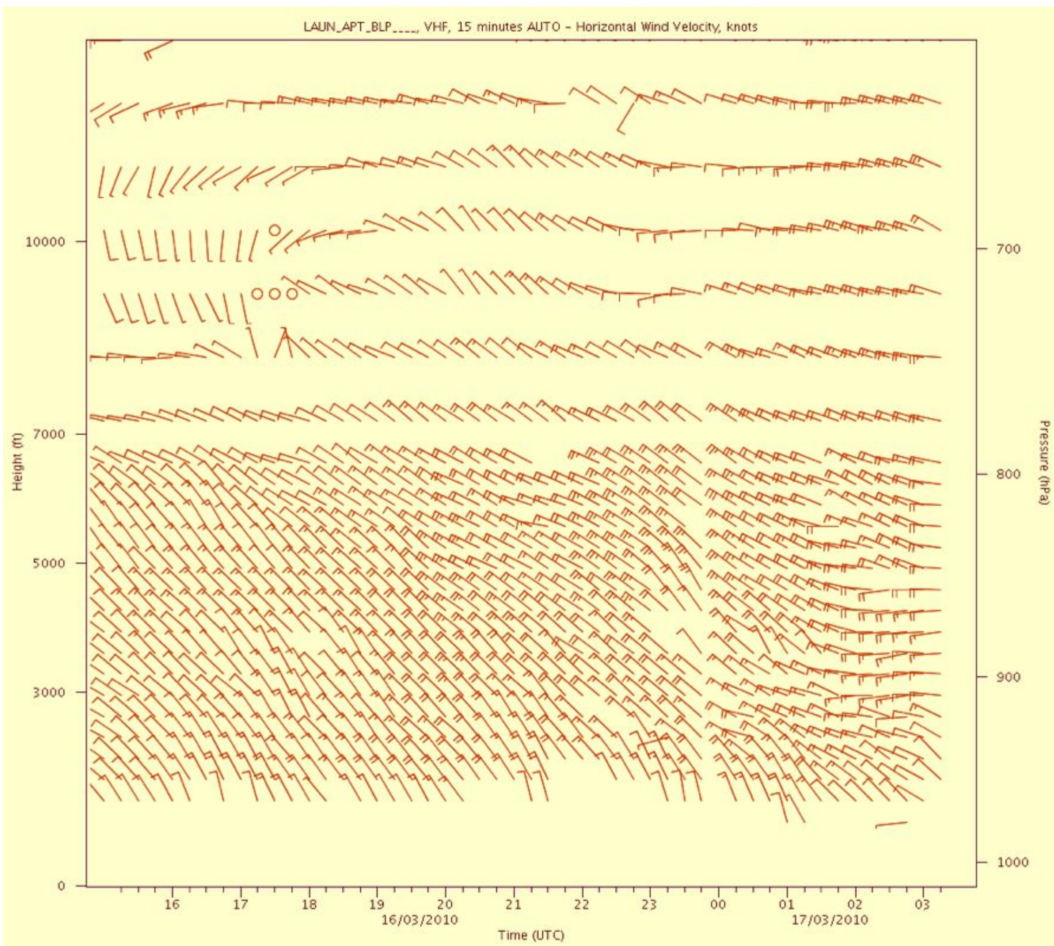

Figure 59: Launceston airport wind profiler (VHF radar) data for the 16th and 17th of March (UT date and time given in the figure). The interval shown corresponds approximately to 00:00 to 13:00 AEST on the 17th of March.

9.4 Raw MODIS images

Raw MODIS full–colour images are available from:
http://rapidfire.sci.gsfc.nasa.gov/realtime/

The images shown here have 2 km spatial resolution. Higher–resolution images are available on the above website. The images used in the main part of the report were of nominal resolution of 250 metres. The raw image swaths are geometrically corrected for off–nadir viewing angles and stitched together to make the processed images used above.

Processed true–colour images for Tasmania are available at:
http://rapidfire.sci.gsfc.nasa.gov/subsets/?subset=Tasmania

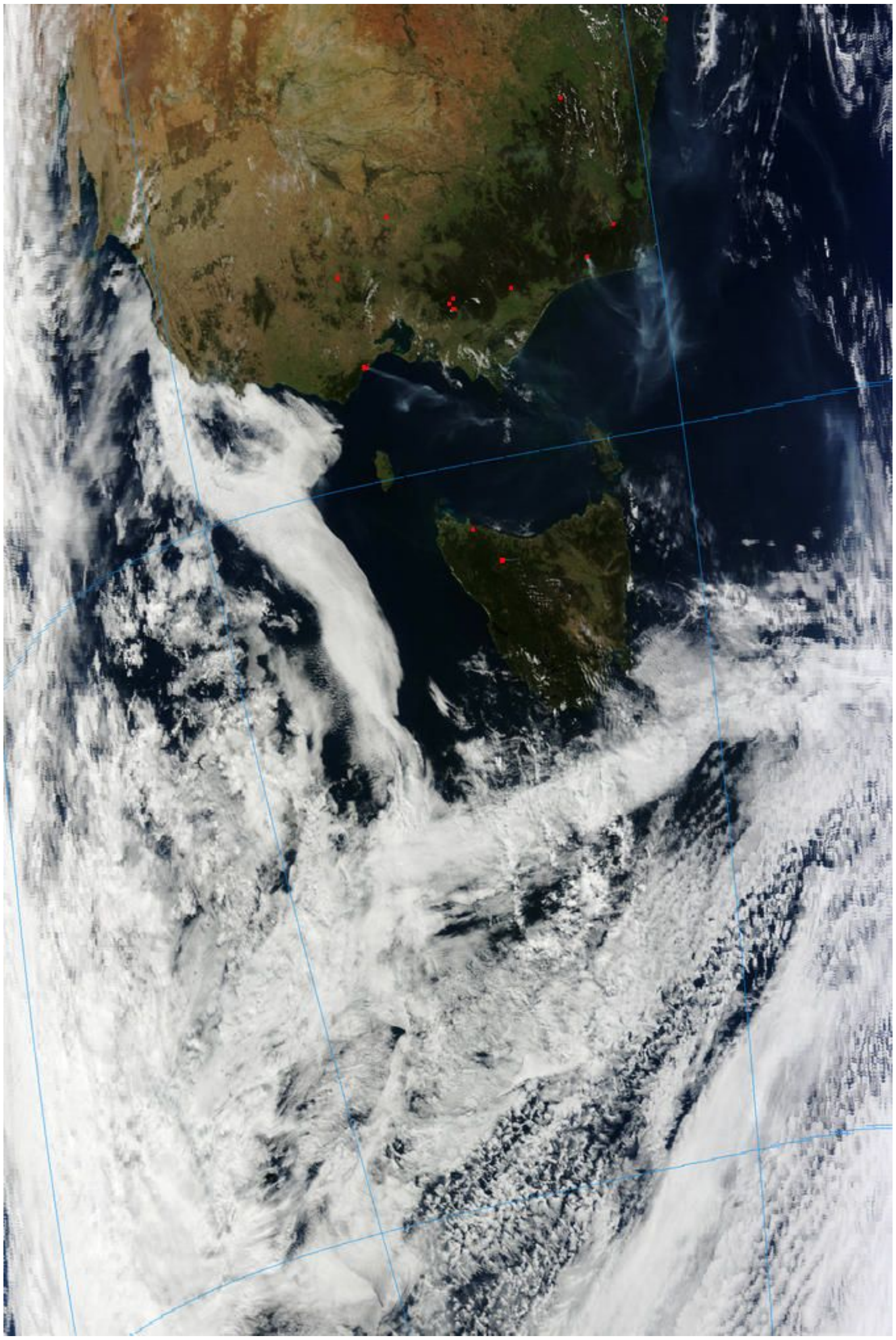

Figure 60: Raw MODIS swath (Terra satellite) for the morning of the 16th of March.

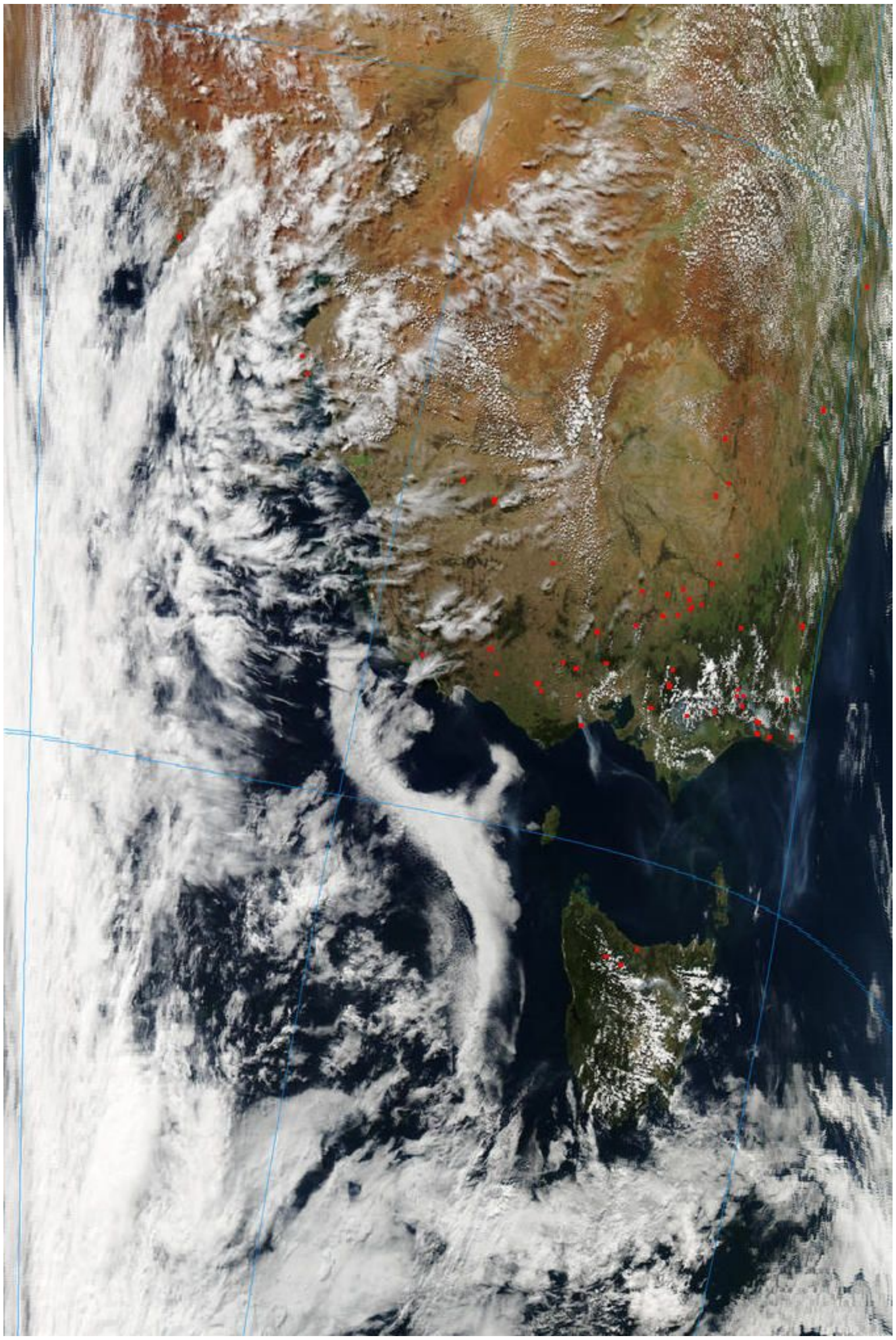

Figure 61: Raw MODIS swath (Aqua satellite) for the afternoon of the 16th of March.

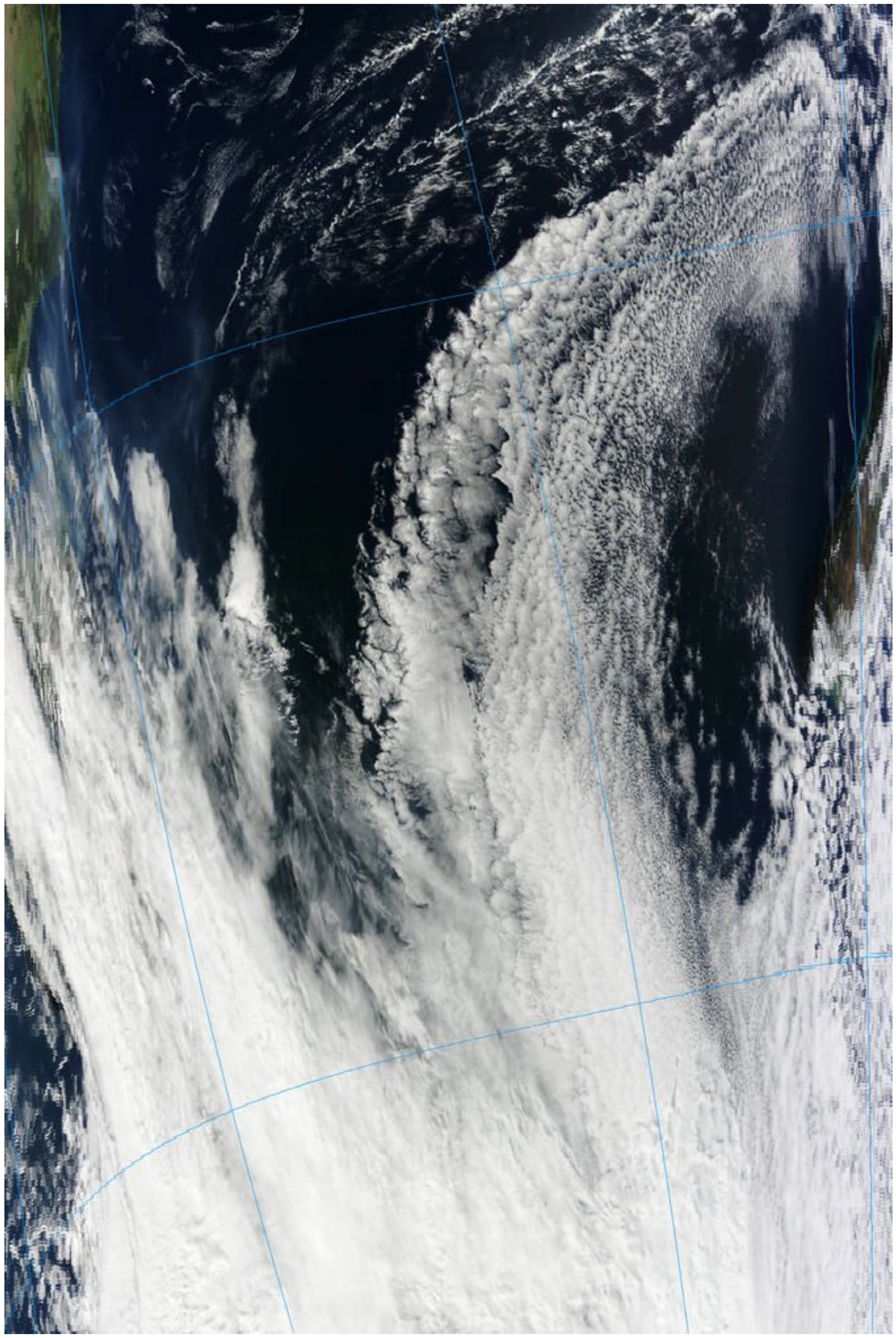

Figure 62: Raw MODIS swath (Terra satellite) for the morning of the 17th of March.

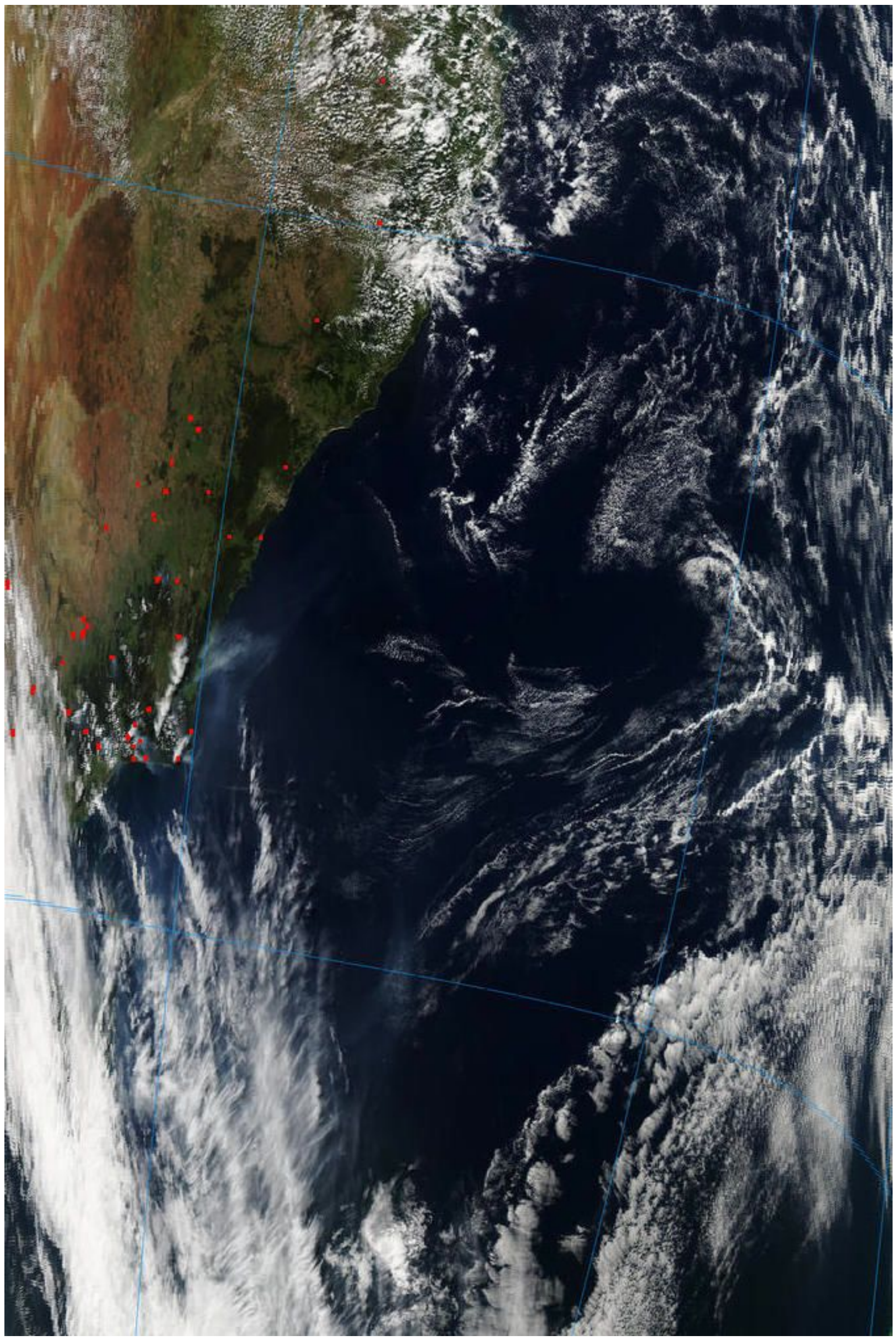

Figure 63: Raw MODIS swath (Aqua satellite) for the afternoon of the 17th of March.

Note: The hotspot near Stanley in the Terra image for the morning of the 16th of March (Figure 60) is shown in a detailed view in Figure 64. This is currently an unidentified burn.

Figure 64: Detail of the MODIS Terra image for 16th of March, showing a detected 'hot spot' near Stanley.

9.5 Japanese Meteorological Satellite images

Figure 65: JMS image for 15th March 19:30 UT (16th March 05:30 AEST).

The monochrome images from the Japanese Meteorological satellite MTSAT-1R are often of low–contrast and are often not well reproduced on a printed page.

Images obtained prior to dawn and after dusk are usually completely black. Some example images of this are included here to show that all available usable images for the 16th and 17th of March 2010 have been inspected.

Figure 66: JMS image for 15th March 20:30 UT (16th March 06:30 AEST).

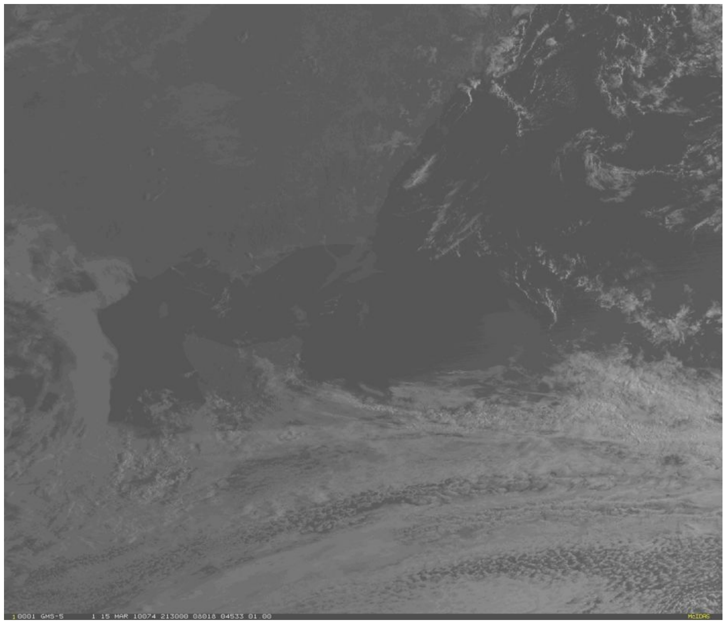

Figure 67: JMS image for 15th March 21:30 UT (16th March 07:30 AEST).

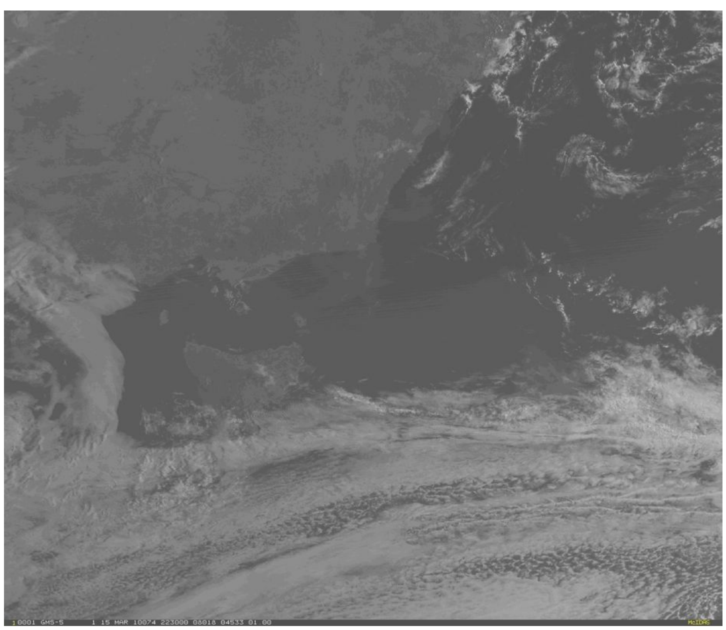

Figure 68: JMS image for 15th March 22:30 UT (16th March 08:30 AEST).

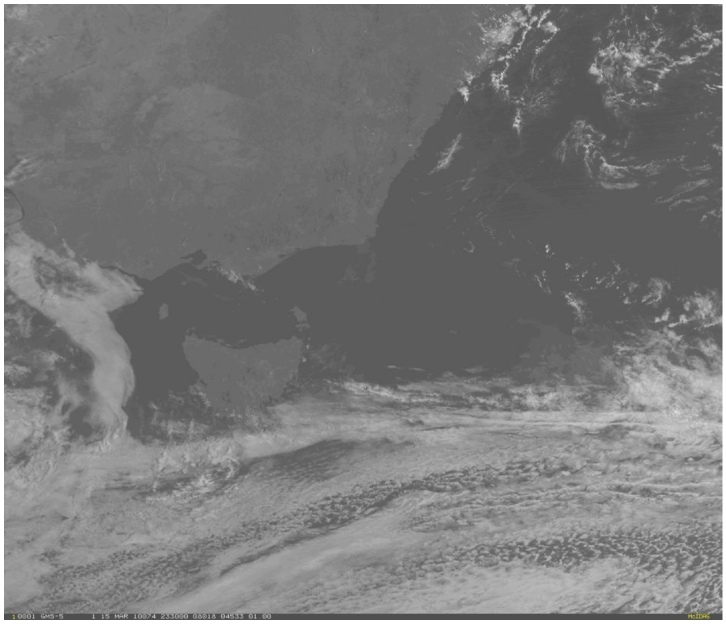

Figure 69: JMS image for 15th March 23:30 UT (16th March 09:30 AEST).

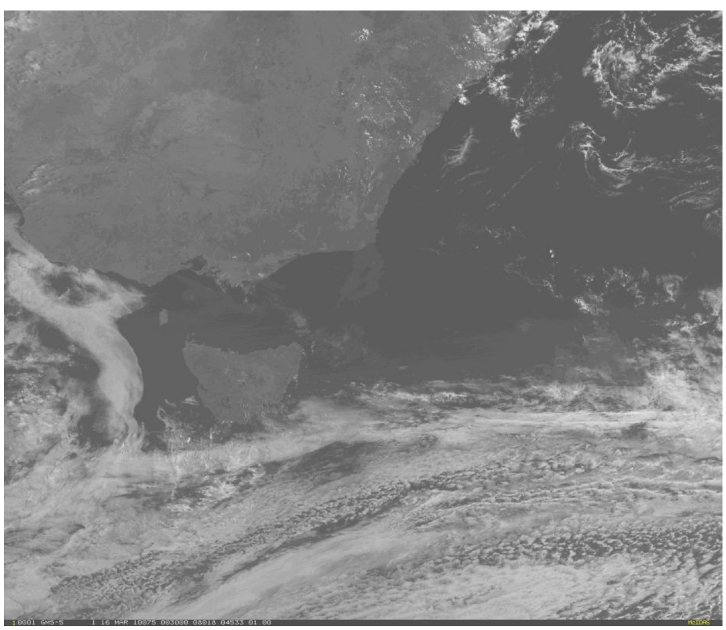

Figure 70: JMS image for 16th March 00:30 UT (16th March 10:30 AEST).

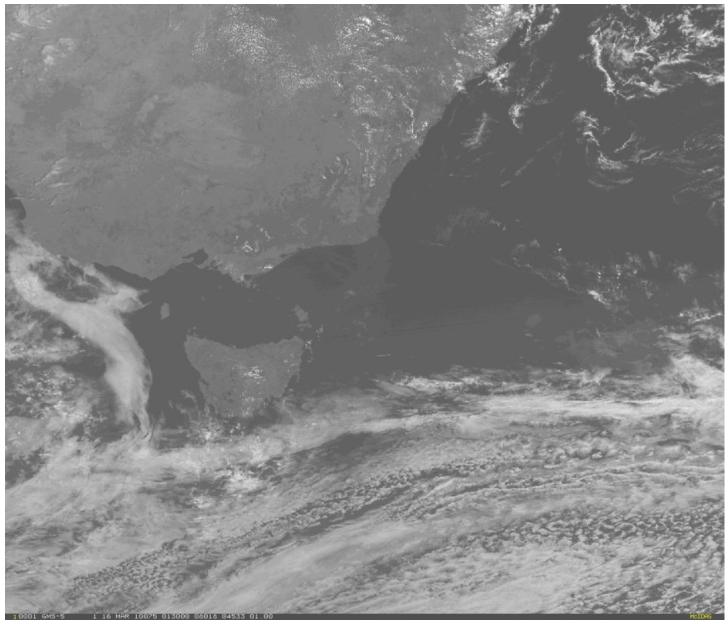

Figure 71: JMS image for 16th March 01:30 UT (16th March 11:30 AEST).

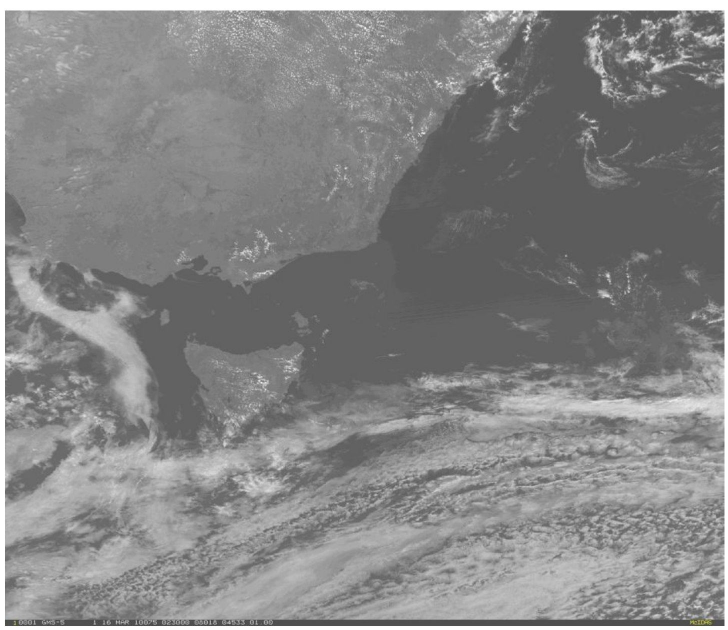

Figure 72: JMS image for 16th March 02:30 UT (16th March 12:30 AEST).

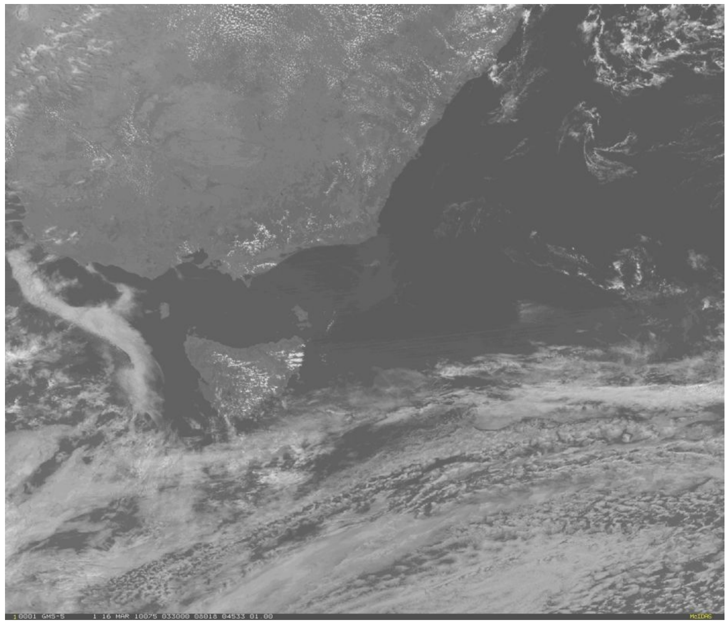

Figure 73: JMS image for 16th March 03:30 UT (16th March 13:30 AEST).

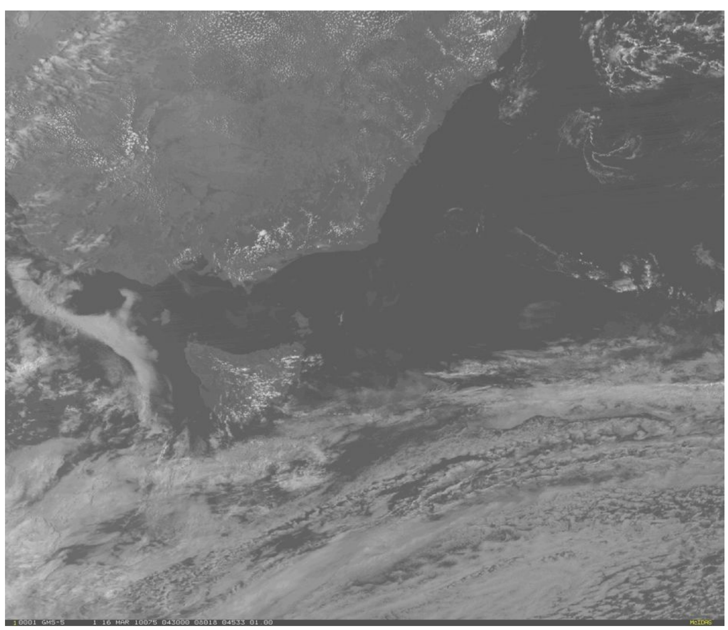

Figure 74: JMS image for 16th March 04:30 UT (16th March 14:30 AEST).

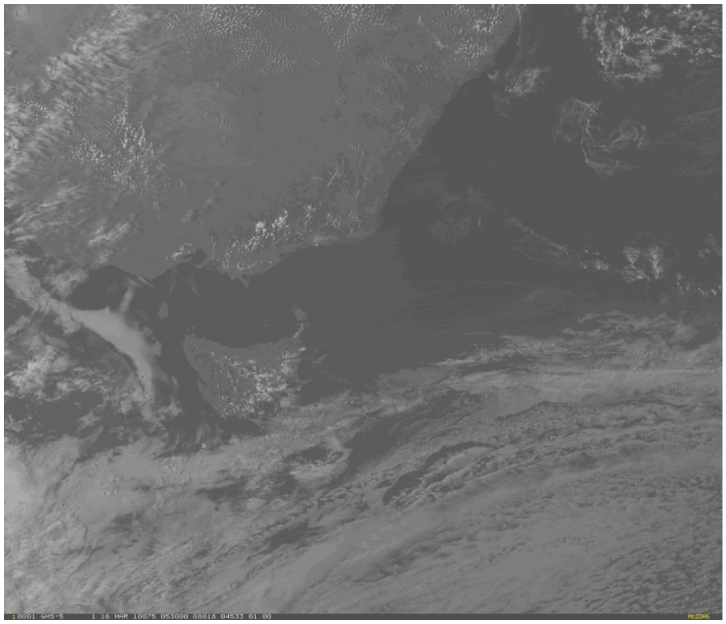

Figure 75: JMS image for 16th March 05:30 UT (16th March 15:30 AEST).

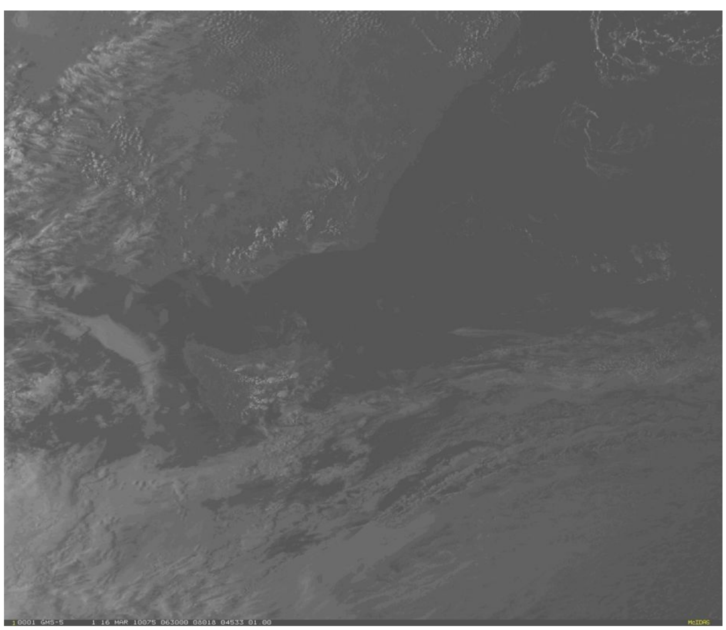

Figure 76: JMS image for 16th March 06:30 UT (16th March 16:30 AEST).

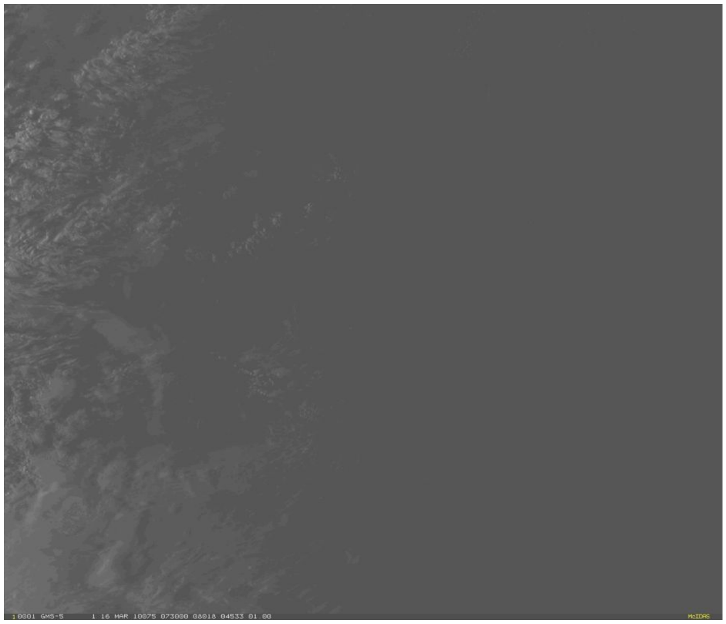

Figure 77: JMS image for 16th March 07:30 UT (16th March 17:30 AEST).

Figure 78: JMS image for 16th March 08:30 UT (16th March 18:30 AEST).

Figure 79: JMS image for 16th March 19:30 UT (17th March 05:30 AEST).

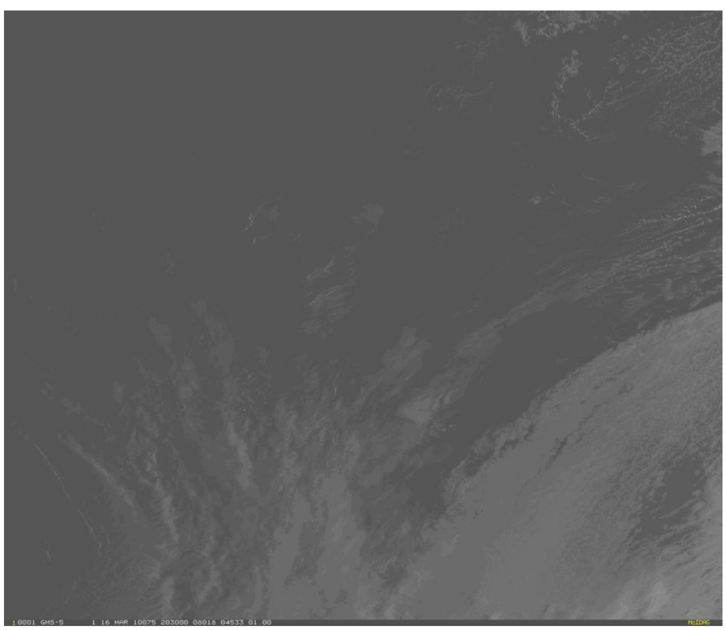

Figure 80: JMS image for 16th March 20:30 UT (17th March 06:30 AEST).

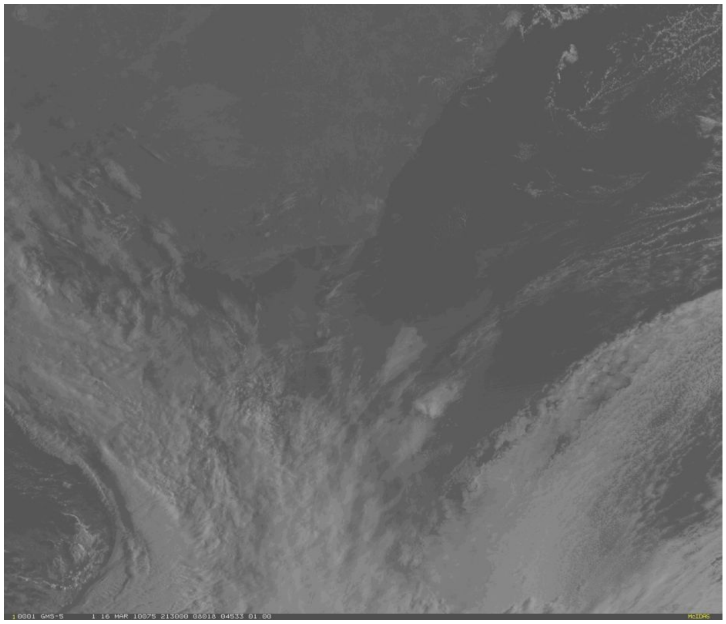

Figure 81: JMS image for 16th March 21:30 UT (17th March 07:30 AEST).

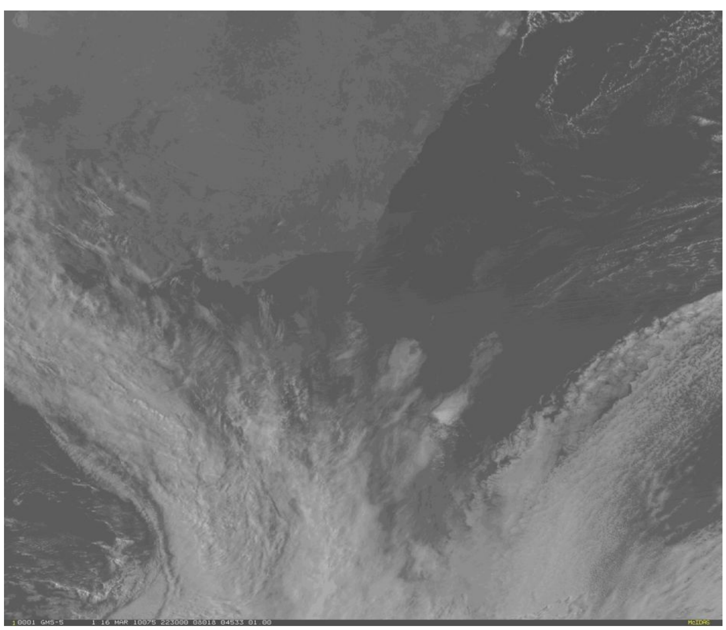

Figure 82: JMS image for 16th March 22:30 UT (17th March 08:30 AEST).

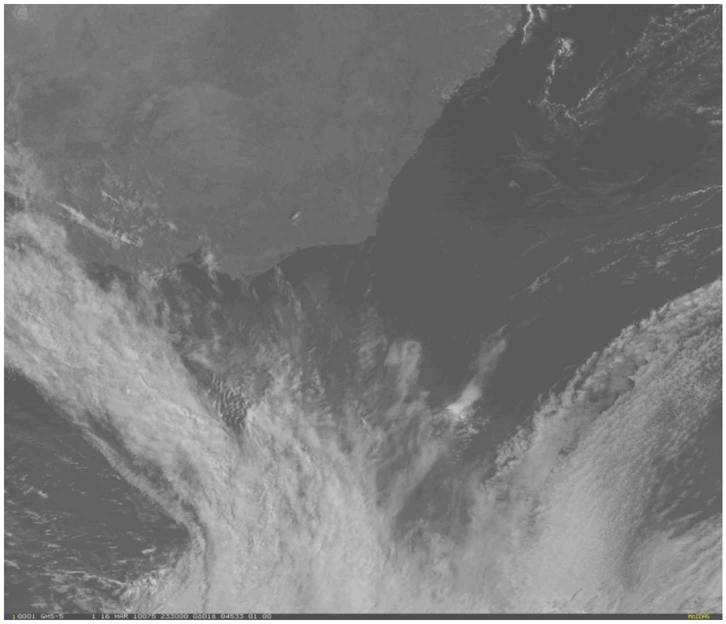

Figure 83: JMS image for 16th March 23:30 UT (17th March 09:30 AEST).

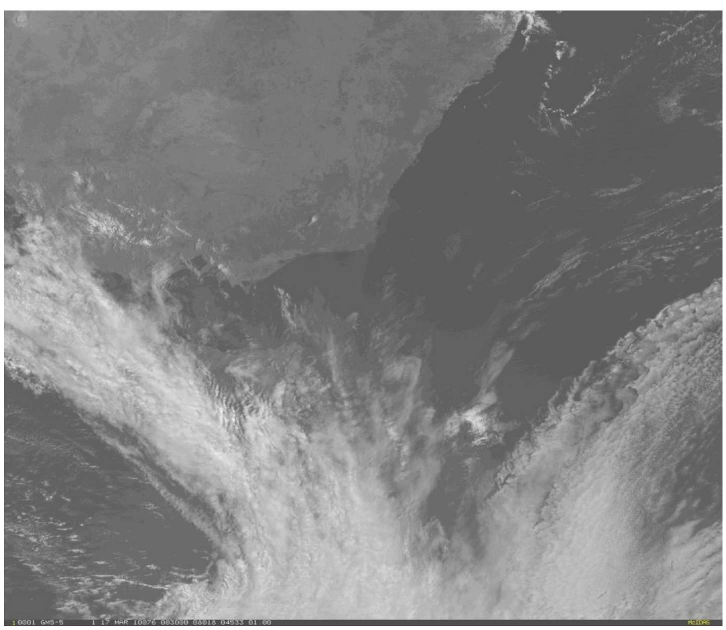

Figure 84: JMS image for 17th March 00:30 UT (17th March 10:30 AEST).

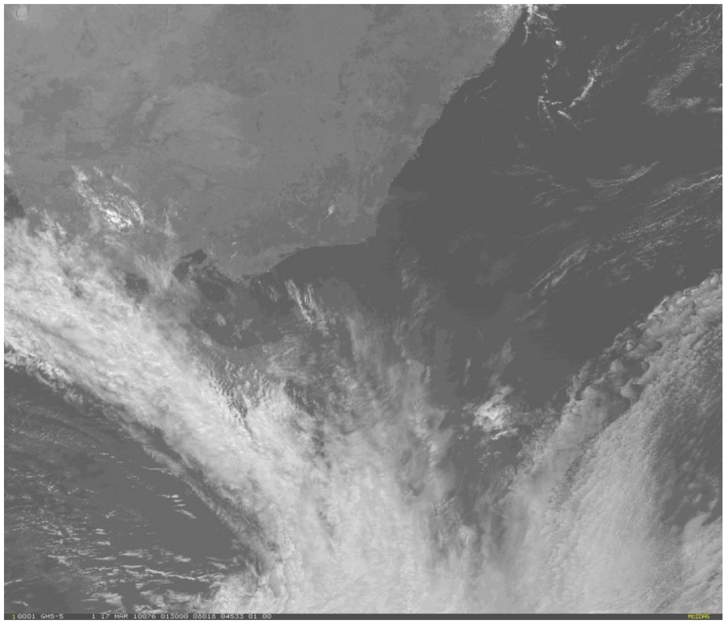

Figure 85: JMS image for 17th March 01:30 UT (17th March 11:30 AEST).

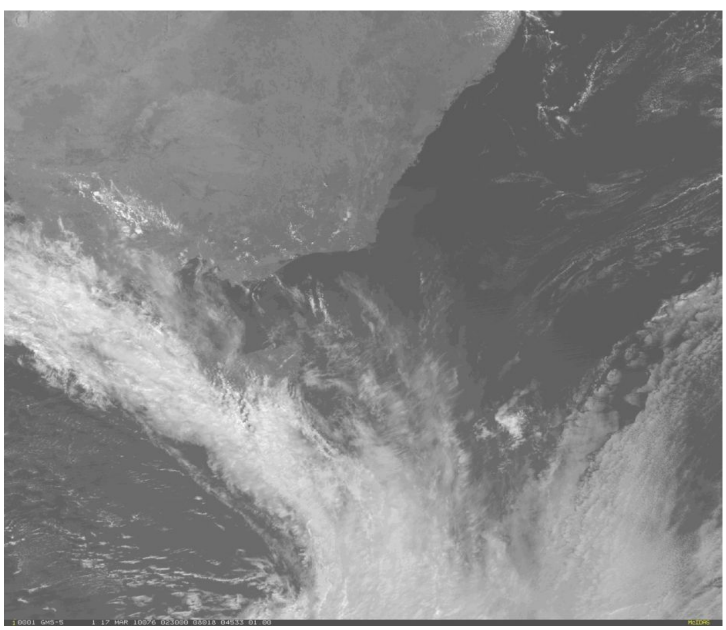

Figure 86: JMS image for 17th March 02:30 UT (17th March 12:30 AEST).

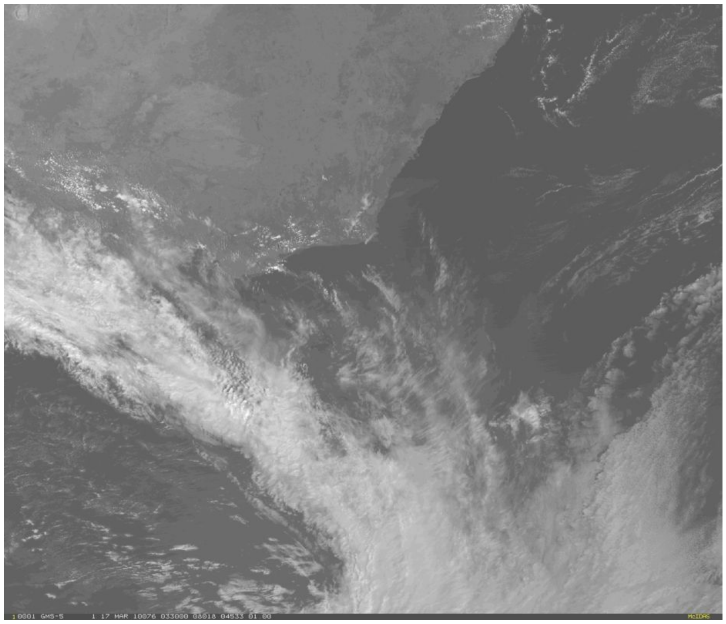

Figure 87: JMS image for 17th March 03:30 UT (17th March 13:30 AEST).

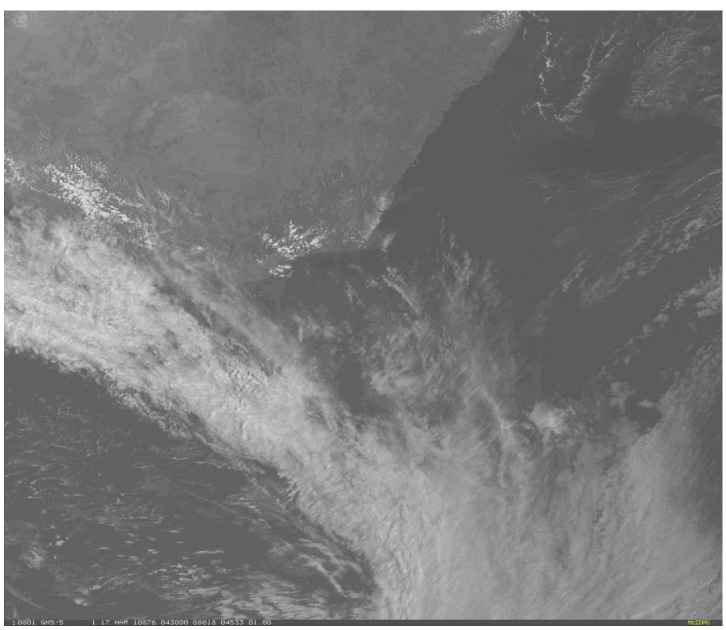

Figure 88: JMS image for 17th March 04:30 UT (17th March 14:30 AEST).

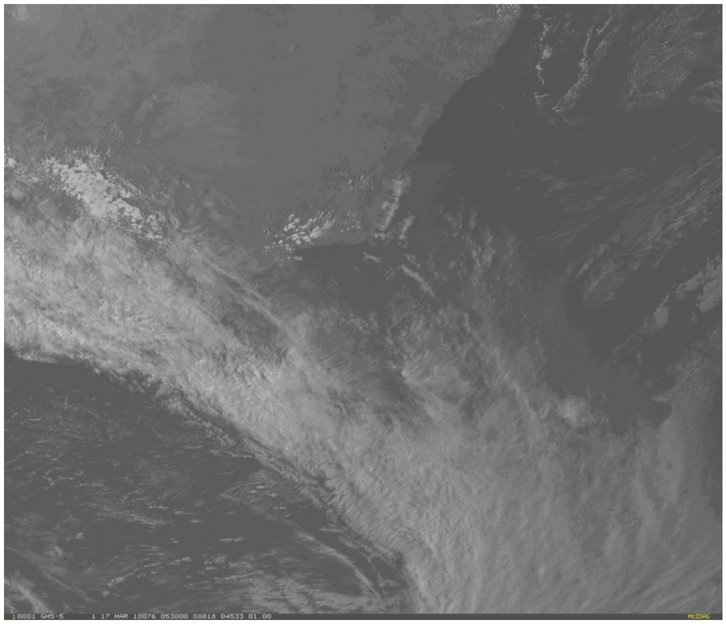

Figure 89: JMS image for 17th March 05:30 UT (17th March 15:30 AEST).

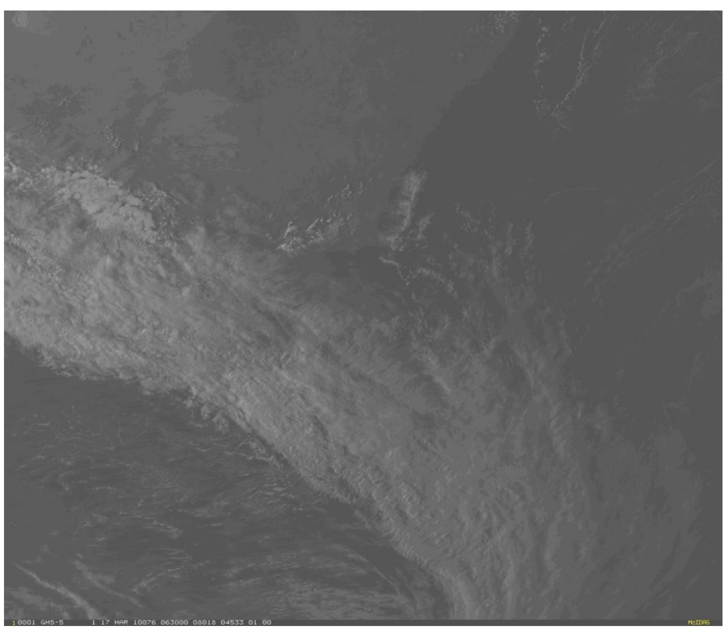

Figure 90: JMS image for 17th March 06:30 UT (17th March 16:30 AEST).

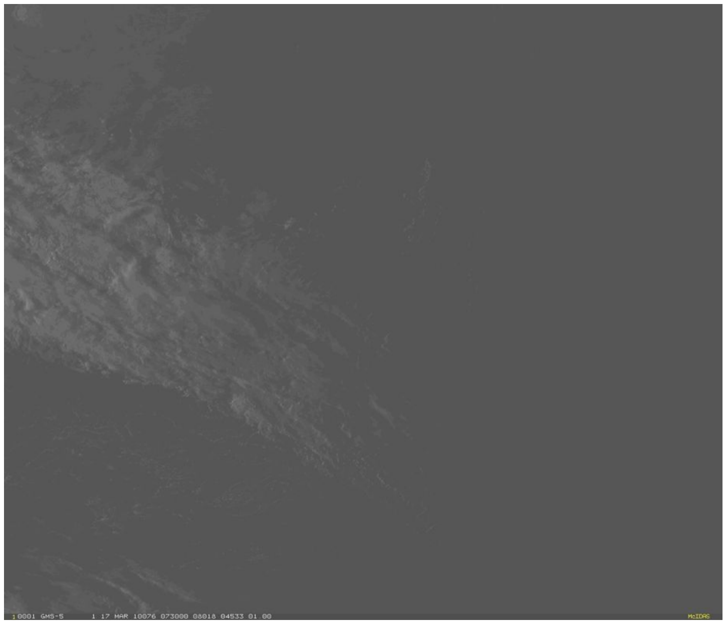

Figure 91: JMS image for 17th March 07:30 UT (17th March 17:30 AEST).

Figure 92: JMS image for 17th March 08:30 UT (17th March 18:30 AEST).