Supplementary material

Ambient air quality in the Surat Basin, Queensland

Final data summary: January 2017 - February 2018

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Appendix A

A.1 Measurement details

A.1.1 Summary of measurement techniques undertaken by Ecotech

Table A. 1 Details of measurements made by Ecotech at ambient air monitoring stations

Parameter	Instrument/s	Method/s	Description
Nitric oxide (NO) Nitrogen dioxide (NO_2) Nitrogen oxides (NO_x)	Ecotech Serinus 40 or Ecotech EC9841T	Australian standard method AS 3580.5.1-2011	Methods for sampling and analysis of ambient air. Method 5.1: Determination of nitrogen oxides – chemiluminescence method
		Ecotech laboratory method	In-house method 6.1 Nitrogen oxides by chemiluminescence
Carbon monoxide (CO)	Ecotech Serinus 30 or Ecotech EC9830T	Australian standard method AS 3580.7.1-2011	Methods for sampling and analysis of ambient air. Method 7.1: Determination of carbon monoxide - direct reading instrumental method
		Ecotech laboratory method	In-house method 6.3 Carbon monoxide by gas filter correlation spectrophotometry
Ozone (O_3)	Ecotech Serinus 10	Australian standard method AS/NZS 3580.6.1-2011	Methods for sampling and analysis of ambient air. Method 6.1: Determination of ozone – Direct reading instrumental method
		Ecotech laboratory method	In-house method 6.7 Ozone by UV photometry
TVOC	Baseline 9000	Australian standard method AS 3580.11.1-2013	Methods for sampling and analysis of ambient air. Method 11.1 Determination of volatile organic compounds – Methane and non-methane volatile organic compounds – Direct reading instrument method

		Ecotech laboratory method	In-house method 6.6 Hydrocarbons –methane, non-methane, total by flame ionization detection (FID)
TSP, PM10, PM2.5 (Fidas)	Fidas 200	Ecotech laboratory method based on Fidas instrument manual	In-house method 7.7 – PM10 and PM2.5 Particles – Light Scattering Method Using Palas Fidas® 200 Series Monitors
Carbon dioxide/methane	Picarro G2301 or LGR GGA	Ecotech laboratory methods	Methane and Carbon dioxide by Cavity Ring-Down Spectroscopy (CRDS). Laser absorption spectroscopy method.
Meteorology measurements (continuous sampling/insitu analysis)			
Vector Wind Speed (Horizontal)	RM young 85000	Australian standard method AS 3580.14-2014	Methods for sampling and analysis of ambient air. Method 14: Meteorological monitoring for ambient air quality monitoring applications
		Ecotech laboratory method	In-house method 8.1 Wind speed (Horizontal) by anemometer (ultrasonic)
Vector Wind Direction	RM young 85000	Australian standard method AS 3580.14-2014	Methods for sampling and analysis of ambient air. Method 14: Meteorological monitoring for ambient air quality monitoring applications
		Ecotech laboratory method	In-house method 8.3 Wind direction by anemometer (ultrasonic)
Temperature	MetOne 062MP	Australian standard method AS 3580.14-2014	Methods for sampling and analysis of ambient air. Method 14: Meteorological monitoring for ambient air quality monitoring applications
		Ecotech laboratory method	In-house method 8.4 Temperature ambient by thermoelectric techniques
Relative Humidity	Vaisala HMP155	Australian standard method AS 3580.14-2014	Methods for sampling and analysis of ambient air. Method 14: Meteorological monitoring for ambient air quality monitoring applications
		Ecotech laboratory method	In-house method 8.5 – Relative humidity by hygrometer

Rain	Hydrological Services TB6	Australian standard method AS 3580.14-2014	Methods for sampling and analysis of ambient air. Method 14: Meteorological monitoring for ambient air quality monitoring applications
		Ecotech laboratory method	In-house method 8.7 – Rainfall by tipping bucket rain gauge
Solar and net radiation	Middletone Solar Pyranometer SK-01-D2	Australian standard method AS 3580.14-2014	Methods for sampling and analysis of ambient air. Method 14: Meteorological monitoring for ambient air quality monitoring applications
		Ecotech laboratory method	In-house method 8.6 – Global solar radiation and Net radiation by pyranometer and net pyradiometer

A.1.2 Ambient air quality station measurement specifications and uncertainty

Table A. 2 Details of measurement specifications and uncertainty for measurements made at ambient air quality stations

Site	Parameter	Units	Resolution	Uncertainty	Measurement Range
H, M, C	NO, NO_x	ppb	1 ppb	±14 ppb K factor of 2.01	0 to 500 ppb
H, M, C	NO_2	ppb	1 ppb	±16 ppb K factor of 2.01	0 to 500 ppb
B, T	NO, NO_x	ppb	1 ppb	± 10 ppb K factor of 2.00	0 ppb to 250 ppb
B,T	NO_2	ppb	1 ppb	± 12 ppb K factor of 2.01	0 ppb to 250 ppb
H, M, C	CO	ppm	0.1 ppm	±1.1 ppm K factor of 2.00	0 to 50 ppm
B	CO	ppm	0.001 ppm	±0.002 ppm	1 to 5 ppm
H, M, C, B, T	O3	ppb	1 ppb	± 16 ppb between 0 - 125 ppb K factor of 2.02	0 ppb to 500 ppb
H, M, C	CH_4 (VOC1000)	ppm	0.1 ppm	4% of reading at span value K factor = 2	1 to 2000 ppm
H, M, C	NMHC (VOC1000)	ppm	0.1 ppm	4% of reading at span value K factor = 2	1 to 2000 ppm
H	CO_2 [a] (Picarro G2301)	ppm	0.1 ppm	0.05 ppm	0 to 1000 ppm
H	CH_4 [a] (Picarro G2301)	ppm	0.1 ppm	0.001 ppm	0 to 20 ppm
M, C	CH_4[a] (LGR GGA)	ppm	0.1 ppm	<1% without calibration	0.1-100 ppm

M, C	CO_2[a] (LGR GGA)	ppm	0.1 ppm	<1% without calibration	200-20000 ppm
H, M, C	Vector Wind Speed	m/s	0.1 m/s	±0.22 m/s or 3 % of reading (whichever is greater) K factor of 1.96	0 to 20 m/s
H, M, C	Vector Wind Direction	°	1°	±4° K factor of 2.11	0 to 360° Starting threshold: 0 m/s
H, M, C	Solar Radiation	W/m2	1 W/m2	±5 % of reading or ±32 W/m² or whichever is greater K factor of 1.96	0 to 1100 W/m2
H, M, C	Rainfall	mm	0.2 mm	±0.60 mm or 7.5 % of reading, whichever is the greater K factor of 2.14	Rainfall rates of 0 to 80 mm/hr
H, M, C	Ambient Temperature	°C	0.1 °C	±0.25 °C K factor of 2.01	0 to 50 °C
H, M, C	Relative Humidity	%	1 %	±5 % K factor of 2.31	0-100 %
H, M, C	TSP, PM_{10}, PM_4, $PM_{2.5}$, PM_1 (Dust)[b]	µg/m³	0.1 µg/m³	PM_{10} 91.% of reading at 50 µg m^{-3} $PM_{2.5}$ 16.8% of reading at 30 µg m^{-3}	0 to 10,000 µg/m³

a) Measurement of carbon dioxide and methane by cavity ring-down spectroscopy is not covered by Ecotech's NATA scope of accreditation. Manufacturer instrument manuals are followed for recommended calibration intervals (see A.4.2). Instrument response was checked using overnight spans and zeroes and against methane measurements from another co-located instrument using a different measurement technique. Specifications are taken from manufacturer Specifications sheet

b) Measurement of ambient TSP, PM_{10}, PM_4, $PM_{2.5}$, PM_1 using the Fidas 200 (optical light scattering spectroscopy) is not covered by Ecotech's NATA scope of accreditation. Instrument performance was determined via a comparison against a reference method at the Miles Airport site (see A.2)

H=Hopeland, M=Miles Airport, C=Condamine, T=Tara, B=Burncluith

A.2 Data removal/low data capture and use of indicative data

A.2.1 **Reasons for data capture <75%**

Data capture rates of <75% for a month are due to missing data, or because some of the data collected have been assessed as being invalid. Data which has been assessed as invalid are not presented in this report. Reasons for missing data has been divided into 6 categories. Table A.3 below shows the categories, a description of the issue and actions taken to resolve issues and maximise data capture.

Table A. 3 Description of invalid data categories

Category	**Description of issue**	**Actions taken to resolve issue and maximise data capture**
a) Power outage	Instruments cannot run without power. Due to the remoteness of this sites, power was sometimes unreliable, particularly in the summer.	Electricity supplier contacted; local technicians contacted to visit site and investigate issue. Due to the remoteness of the sites, there were sometimes delays in accessing the sites for assessment, diagnosing the cause of the power outage and resolving the issue.
b) Instrument fault	Fault – failure of a component, performance outside of specifications, unrealistic readings as instrument stabilising following a power outage, calibration or service	Diagnosing and resolving the instrument fault was initially performed remotely. If the problem couldn't be identified or resolved, a technician was sent to the site. Servicing was mostly performed on site; occasionally instruments had to be removed and sent to the manufacturer for repair.
c) Instrument commissioned during month	Data capture for month is low when instrument was initially installed/commissioned mid-way through one month	N/A
d) Air conditioning failure	Enclosure gets too hot which can result in instrument failure and damage	Instruments are shutdown automatically (via safety switch) or manually to avoid heat damage to instruments. A local technician was contacted to visit site and reset or repair the air conditioner unit. Servicing of heat damaged instruments was mostly performed on site; occasionally instruments had to be removed and sent to the manufacturer for repair.
e) Calibration out of tolerance	Overnight zeroes and spans not within acceptable tolerance; the calibration system itself fails; multipoint calibrations fail.	Diagnosing and resolving the calibration issue was initially performed remotely. If the problem couldn't be identified or resolved, a technician was sent to the site. Servicing was mostly performed on site; occasionally instruments had to be removed and sent to the manufacturer for repair.
f) Communication/logger failure	Data from instrument can be noisy, corrupt or lost	Diagnosing and resolving the instrument fault was initially performed remotely. If the logger couldn't be remotely access, a technician was sent to the site to regain communications. If logger was faulty, it replaced. Where possible data not able to be remotely collected was able to be recovered from the logger or instrument during the site visit.
g) Station decommissioned		

A.2.2 **Indicative data**

Some data which has been used in this report does not comply with Australian standard measurement methods. This indicative data has been assessed as being of acceptable quality for use in this report using instrument checks, calibrations, and comparing data obtained with other co-located or nearby instruments.

While ozone, oxides of nitrogen and carbon monoxide methods used in this study are compliant with Australian standards, there are some occasions during the study period when the data was not compliant, due to all requirements of the Australian Standard method not being met. Examples are provided in Table A2.

The $PM_{2.5}$ and PM_{10} method used in this study is a European certified method but not an Australian standard method. This instrument has been run according to the manufacturer's operating procedures. CSIRO deployed a system based on beta attenuation which produces data equivalent to Australian Standard Methods (AS/NZS 3580.9.11.2008 (PM_{10}) and AS/NZS 3580.9.12:2013 ($PM_{2.5}$)). See Section A.3 for details of particle method comparison.

The TSP measurement in this study provides an indicative TSP concentration and has been run according to the manufacturer's operating procedures. However this cannot be considered an equivalent method to the Australian Standard gravimetric method AS/NZS 3580.9.3:2015. This is discussed further in A.3.

The methane and carbon dioxide measurements using cavity ring down technique were not run using an Australian Standard method, which became available in 2016. This instrument has been run according to the manufacturer's operating procedures.

A summary of the specific reasons why data was indicative/not compliant with Australian Standards is given below, as well as indicators used to assess that indicative data was of acceptable quality (Table A.4).

Table A. 4 Reasons that some data did not meet requirements of Australian Standards, and indicators used to assess whether data was acceptable quality for use in this study

	Reasons for indicative data/data not meeting Australian standard requirements	Indicators of acceptable data quality (where applicable)
Ozone	Calibrations not carried out within the specified time or at frequency required by the Australian Standard	Daily and spans and zeros are within scope Data correlates with other nearby sites Subsequent reference photometer check passed without adjustment or overnight response check within tolerance
	Suspected calibrator fault. Automatic span calibrations out of tolerance	
	Shelter above 30°C (outside recommended range)	
	Overdue annual siting audit	Previous siting audits passed
$PM_{2.5}$, PM_{10}	Method not covered by an Australian Standard	Instrument operation follows manufactures instructions including recommended zero and span checks Method comparison for PM2.5 and PM10 between this technique and another technique which produces data equivalent to Australian Standard Methods (AS/NZS 3580.9.11.2008 (PM10) and AS/NZS 3580.9.12:2013 (PM2.5)) will be presented in final report (see A.2)
	Calibration out of tolerance (isolated event)	
	Verification with caldust not performed at interval recommended by manufacturer	Subsequent caldust verification pass without adjustment
	Overdue annual siting audit	Previous siting audits passed
Methane and carbon dioxide	Cell pressure outside tolerance	Methane data correlates with co-located instrument (TVOC/CH4 monitor) and methane data from nearby sites
	Overnight span was not triggered/did not occur (isolated events)	Subsequent overnight span check within tolerance
	Calibrations not undertaken at required frequency required by AS/NZS 3580.17-2017	Subsequent calibration not needing adjustment. Overnight span check within tolerance.
	Overdue annual siting audit	Previous siting audits passed
Oxides of nitrogen	No valid overnight calibrations for several nights	Subsequent overnight span and check within tolerance
	Multipoint calibration failed (isolated event)	
	Overdue proficiency audit or converter efficiency check	

	Shelter above 30°C (outside recommended range) Overdue annual siting audit	Subsequent converter efficiency check or proficiency audit within tolerance Previous siting audits passed
Carbon monoxide	Suspected calibrator fault. Automatic span calibrations out of tolerance (isolated event) Overdue proficiency audit Shelter above 30°C (outside recommended range) Chassis temperature out of tolerance (isolated event) Overdue annual siting audit	Subsequent overnight span check within tolerance Subsequent proficiency audit within tolerance. Previous siting audits passed
Total VOC	Overnight span was not triggered/did not occur Overdue proficiency audit or multipoint calibration Shelter above 30°C (outside recommended range)Overdue annual siting audit Overdue annual siting audit	Subsequent overnight calibration check pass without adjustment Subsequent proficiency audit or calibration within tolerance Previous siting audits passed

A.3 Particle instrument method comparison

A.3.1 **Background and reason for method comparison**

The PM instrumentation (Fidas – see A.1) deployed at the Gas field sites was selected because it provided a cost effective means of simultaneously measuring real-time TSP, $PM_{2.5}$ and PM_{10}. The Fidas uses an optical technique and is a European and UK certified equivalent method for measurements of $PM_{2.5}$ and PM_{10} according to the standards VDI 4202-1 (2010), VDI 4203-3 (2010), EN 12341 (1998), EN 14907 (2005), Guide to Demonstration of Equivalence of Ambient Air Monitoring Methods (2005), EN 15267-1 (2009), EN 15267-2 (2009). The Fidas PM_{10} and $PM_{2.5}$ measurement method also meets the more recent standard BS EN 16450:2017 (2017).

While the Fidas it is not an Australian Standard Method for $PM_{2.5}$ and PM_{10}, it has shown good agreement with Standard methods in four European and UK urban locations (TUV 2015). However, because measurements using optical techniques such as the Fidas may be influenced by the composition of particles in the environment it is measuring, it was desirable to test the performance of the Fidas in Australian rural conditions relevant to this study.

As such, CSIRO made independent measurements of $PM_{2.5}$ and PM_{10} alongside the existing particle instrumentation (Fidas) at the Miles Airport site for 6 months in 2017. CSIRO deployed a Teledyne-API dual channel Model 602 BetaPLUS Particle Measurement System based on beta attenuation (herein called BAM) which produces data equivalent to Australian Standard Methods (AS/NZS 3580.9.11.2008 (PM_{10}) and AS/NZS 3580.9.12:2013 ($PM_{2.5}$)).

Note that a method comparison for TSP was not undertaken, as this was assessed to be a lower priority for a method comparison than PM_{10} and $PM_{2.5}$. TSP includes PM_{10} and $PM_{2.5}$ plus additional particles greater than 10 µm in diameter. As such, the method comparison for PM_{10} and $PM_{2.5}$ reported here covered the smaller particle component of TSP which are criteria air pollutant in the NEPM (NEPM 2016) and can cause adverse health affects (10 µm and less). However the method comparison reported here did not include the larger particle component of TSP (particles greater than 10 µm). These larger particles are of concern mainly for localised nuisance effects when deposited and can impact land-use activities and amenity values and cause visual impacts (MFE 2016). A further reason that a method comparison was not undertaken for TSP is due to the particle diameter size ranges sampled and measured by the Fidas (up to 18 µm) and the Australian Standard method (up to 100 µm) (AS/NZS 3580.9.3:2015) being non-equivalent. As such, the TSP data from this study can only be considered indicative and cannot be considered equivalent to Australian Standard Method (AS/NZS 3580.9.3:2015).

In this section a comparison of PM_{10} and $PM_{2.5}$ data obtained using the Fidas and the BAM is provided, and implications discussed.

A.3.2 **Details of comparison location, period**

The CSIRO method comparison ran from 1st March 2017 until the 6th August 2017 at the Miles Airport ambient air quality station. This provided approximately 23 weeks or just under 6 months of Fidas and BAM measurements side by side. The method comparison period finished on the 6th

August when power supply issues occurred at the Miles Airport station. Power issues at this site were ongoing until mid-September.

24 hour average concentrations from the Fidas and BAM were reported at Australian standard temperature and pressure (STP) conditions.

The Fidas was housed inside the ambient air quality station while the BAM was deployed in a separate air conditioned shelter approximately 6m to the north of the station. The inlet of the BAM was approximately 3m high and the Fidas inlet was approximately 3.5 m high.

A.3.3 **Fidas methods**

The Fidas was operated by Ecotech according to Ecotech's In-house method 7.7 – PM_{10} and $PM_{2.5}$ Particles – Light Scattering Method Using Palas Fidas® 200 Series Monitors.

The Fine Dust monitoring and Ambient air measuring System (FIDAS) simultaneously concentrations of PM_1, $PM_{2.5}$, PM_4, PM_{10}, total suspended particles (TSP) at one minute intervals. The resolution of the instrument is 1 µg m-3 and the measurement range is 0 to 10,000 µg m-3.

A sample stream at a flow rate of 4.8 l m^{-1} is passed through a heated inlet to remove water bound to particles, which can adversely affect the determination of particle size. The temperature of the heated inlet is controlled depending on the ambient temperature and humidity, measured by the weather station attached to the sampler. The heated inlet "intelligent aerosol drying system" has three operating modes: (1) switched off, (2) remove volatile / moisture compensation (dynamic heating modus); and (3) remove volatile and semi-volatile (heated to 90 °C to evaporate all liquid particles and components). For the duration of the study the heated inlets at each site were set to (2) remove volatile / moisture compensation, where the temperature is dynamically adjusted if the relative humidity is greater than 60%.

The particle size and number in the sample stream are determined using an optical aerosol spectrometer, which measures scattering of light by the particles. Each particle generates a scattered light impulse which is detected at an angle of 85° to 90°. The number of light impulses within the sample volume is used to determine the number of particles per unit volume and the intensity of scattered light is used to determine the size of each particle, ranging from 180 nm to 18 µm in diameter. Conversion of the particle size distribution into mass distribution requires application a conversion algorithm. The algorithm depends on the size and chemical composition of the aerosol, which can be comprised of particles from sources such as fossil fuel combustion, smoke, soil, sea salt, pollen, etc. The algorithm used for this study was the one verified in European and UK ambient conditions (TUV 2015).

The particle sensor sensitivity is calibrated by measuring the scattered light signal from a dust (MonoDust 1500) that contains latex particles of a known diameter (~1.26 µm). The manufacturer recommends monthly particle sensor sensitivity verification and 3-montly sample flow verification. These procedures were applied to instruments at each site, using the same calibration dust and flow meters. The measured expanded uncertainty for PM_{10} is ± 7.2% of the reading (K factor of 2.0) and for $PM_{2.5}$ is ± 10.2% of the reading (K factor of 2.0). The Fidas logs the real-time status of the channel calibration, sensor flow, particle coincidence, pump suction, LED temperature and environmental conditions and generates flags if these fall outside control limits.

The default algorithm verified in the TUV (2015) report was used to determine particle mass size distribution for concentrations of TSP, PM_{10} and $PM_{2.5}$. The appropriateness of applying this algorithm for determining PM_{10} and $PM_{2.5}$ in the Surat region was tested by comparison of the Fidas against an independent mass measurement technique for a period of 6 months at the Miles Airport site. The appropriateness of this algorithm for Fidas TSP mass concentration could not be compared to an Australian standard method AS/NZS 3580.9.3:2015 because both techniques do not measure the same TSP size range. The Fidas TSP measures particles with a diameter of 18 µm or less whereas high volume TSP samplers used in method AS/NZS 3580.9.3:2015 measure particles with a diameter of 100 µm or less.

A.3.1 **BAM methods**

The BAM sampled PM_{10} and $PM_{2.5}$ simultaneously on two 47 mm Whatman glass fibre filters. Air is drawn into the instrument using two independently controlled flow lines at a volumetric flow rate of 16.7 l min^{-1} and a sampling height of 3m above ground through a US EPA louvered PM_{10} inlet on line A and through a BGI $PM_{2.5}$ very sharp cut cyclone attached to a PM_{10} pre impactor on line B. The instrument measures ambient and filter temperatures, barometric and filter pressures, filter % relative humidity and volumetric flow rate. The instrument contains a sample line heater with water trap on each inlet line and was set to activate at 40% relative humidity and deactivate at 30% relative humidity. At the end of each 24 h sampling cycle, mass collected on the filter was measured using the beta attenuation method with compensation for filter density, beta intensity variation and humidity effects on the sample filter. The instrument was housed in an air-conditioned shelter set at 25 ^{o}C and each inlet line was insulated inside the shelter. The instrument has built-in flow transfer standards for automatic flow span checks and automatic leak checks which occur before each sample analysis. The instrument also contains two reference filter foils which are automatically used to do a beta span test at the beginning of every operation cycle.

The BAM has US EPA Equivalent Method Certification for PM_{10} and $PM_{2.5}$ and was operated following to the Australian equivalent method AS/NZ 3580.9.11:2016. Before sampling the instrument was calibrated using 7 different calibration foils and a multipoint precision check was performed. Reference foil 1 had an error of 0.8% at 3.365 mg cm^{-2} and reference foil 2 had an error of -0.5% at 6.730 mg cm^{-2}. A volumetric air flow, temperature and barometric audit check was carried out using a Bios Defender 520 volumetric primary flow standard. Line A had a flow rate error of 1.0%, the temperature difference was of 0.5 ˚C and the pressure difference was 0.6 kPa. Line B had a flow rate error of 1.2%, the temperature difference was 0.5˚C and the pressure difference was 0.6 kPa. A zero check was also performed on the BAM with Line A having a zero level of 0.1 µg m^{-3} and line B a zero level of 0.3 µg m^{-3}. The measured uncertainty at 95% based on variation in the zero levels for 24 hours was ±1.2 µg m^{-3}. The logged temperature was also checked against NATA accredited temperature measurements made on site using MetOne 062MP temperature sensors located at heights of 2 m and 10 m.

A.3.2 **Suitability of ambient concentrations during method comparison**

The concentration of PM_{10} and $PM_{2.5}$ measured by the Fidas during the method comparison is shown in Table A. 5. Concentrations during the method comparison were well below air quality

objectives, with no exceedances of the $PM_{2.5}$ or PM_{10} air quality objectives during the method comparison. The average ratio of $PM_{2.5}/PM_{10}$ measured by the Fidas during the method comparison was 0.4, with a standard deviation of 0.1, and range of 0.2 – 0.7. This indicates that the particle mass was mostly in the coarse size fraction during the method comparison ($PM_{2.5}$-PM_{10}), and was likely to be composed mostly of non-combustion sources including wind-blown dust.

Table A. 5 24 hour average concentrations of PM_{10} and $PM_{2.5}$ as well as average ratio of $PM_{2.5}/PM_{10}$ during the method comparison from the 1 March 2017 – 6th August 2017 at the Miles Airport site. Concentrations shown were measured by the Fidas instrument.

	PM_{10} (µg m³)	$PM_{2.5}$ (µg m³)	$PM_{2.5}/PM_{10}$ ratio
Average	8.5	2.9	0.4
Standard deviation	5.0	1.3	0.1
Minimum conc (day)	1.9 (05/08/2017)	0.9 (20/07/2017)	0.2 (02/05/2017)
Maximum conc (day)	27.7 (02/08/2017)	9.2 (17/05/2017)	0.7 (17/05/2017)

There is currently no Australian standard for comparing the equivalency of scattered light spectrometry (Fidas Model 200 S, Palas, Karlsruhe Germany) against an Australian reference equivalent method for measurement of PM_{10} and $PM_{2.5}$. However there are Australian standards for comparing PM_{10} and $PM_{2.5}$ BAM instruments (AS/NZS 3580.9.11:2016; AS/NZS 3580.9.12:2013). These Australian standards specify that when comparing particle concentrations from different techniques at least 40 sets of paired observation points are required from each technique, with the concentrations within a certain range.

Table A. 6 below shows the number of paired Fidas and BAM observations required in each concentration range as specified by each Australian Standard. This shows that during the 6-month method comparison for PM_{10} concentrations, there was a sufficient number of paired observations <10 µg m^{-3}, in the range 10-50 µg m^{-3} but no observations >50 µg m^{-3} for comparison. As such the concentration range of PM_{10} during the comparison was reasonable but not optimal for undertaking a comparison of two measurement methods. The average concentration of PM_{10} measured by the Fidas 8.5 µg m^{-3} (range 1.9 – 27.7 µg m^{-3}) and for the BAM it was 9.9 µg m^{-3} (range 1.8 – 38.6 µg m^{-3}).

During the 6-month method comparison for $PM_{2.5}$ concentrations, there was a sufficient number of paired BAM and Fidas observations <5 µg m^{-3}, but an insufficient number of Fidas observations with concentrations between 5 and 25 µg m^{-3} and no Fidas concentrations >25 µg m^{-3}. There were a sufficient number of BAM concentrations between 5 and 25 μg^{-3} but all were below 9 µg m^{-3} except for one observation of 12.3 µg m^{-3} (Table A. 6). The average concentration of $PM_{2.5}$ measured by the Fidas was 2.9 µg m^{-3} (range 0.9 – 9.2 µg m^{-3}) and for the BAM it was 3.6 µg m^{-3} (range -2.0 – 12.3 µg m^{-3}). Given that 80% of BAM and Fidas were <5 µg m^{-3}, the concentration range during the method comparison was too small to undertake a complete method comparison of the Fidas and BAM techniques.

Table A. 6 The number of paired Fidas and BAM observations required in each concentration range as specified by Australian Standards, and the number of paired observations in each concentration range for this study

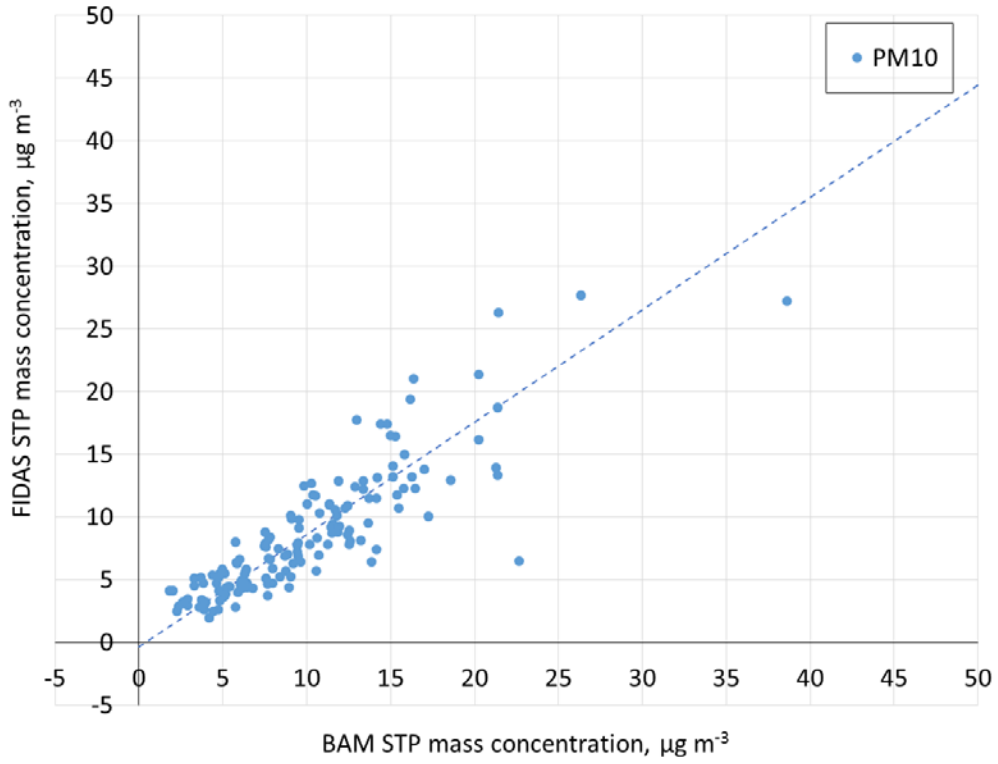
	PM_{10}[a]			$PM_{2.5}$[b]		
Concentration range µg m^{-3}	<10	10-50[a]	>50[a]	<5	5-25	>25
Number paired observations required	5	30	5	5	30	5
Number BAM observations within concentration range	81	63	0	97	47	0
Number FIDAS observations within concentration range	98	46	0	134	10	0

***number of paired observations calculated using BAM concentrations**

[a] AS/NZS 3580.9.11:2016 PM10 beta attenuation monitors; [b] AS/NZS 3580.9.12:2013 PM2.5 beta attenuation monitors;

A.3.3 Method comparison results

The average 24-hour paired concentration data from the Fidas and BAM are shown below.



An orthogonal (Deming) regression was used to assess whether there were systematic or proportional differences between the two measurement techniques at a confidence interval of 95%. Table A. 7 shows the concentration range for paired Fidas and BAM 24 hour observations for the PM_{10} comparison, the orthogonal (Deming) regression slope, intercept and coefficient of determination (R^2) and the uncertainties in the slope and intercept at a 95% confidence interval.

For PM_{10} the relationship between the Fidas and BAM concentrations was significant, with a coefficient of determination (R^2) of 0.74, indicating a reasonable correlation. The slope (0.90) and intercept (-0.37) were within the measurement uncertainty at 95% confidence for both methods. This means there was no systematic or proportional differences between the two PM_{10}

measurement methods. One caveat with this determination of equivalence between the methods is that there were no 24-hour periods during the 6 month comparison where PM_{10} exceeded the standard of 50 µg m^{-3}.

Table A. 7 Concentration range of the Fidas for PM_{10}, the number of paired Fidas and BAM 24 hour observations for the PM_{10}, deming regression the slope, intercept and coefficient of determination (R^2) of the relationship between Fidas and BAM data, and significance of the regression at a 95% confidence interval.

	BAM Average (range) µg m^3	Fidas Average (range) µg m^3	n	Deming Slope	Deming intercept	Slope U95% lower – upper	Intercept U95% lower – upper	R^2
PM_{10}	9.9 (1.8 – 38.6)	8.5 (1.9 – 27.7)	144	0.90	-0.37	0.73 – 1.06	-1.76 – 1.02	0.74

Thus the 6 month measurement comparison shows equivalency between Fidas and BAM PM_{10} measurement methods and strong agreement within the concentration range of 1.8 to 38.6 µg m^{-3}. There were insufficient $PM_{2.5}$ observations greater than 5 µg m^{-3} to assess the equivalency of the methods over the concentration range of 5 to 25 µg m^{-3}. BAM and Fidas data from this comparison is available via https://data.qld.gov.au/.

A.3.4 Findings compared to other studies

DSITI Brisbane study

In 2016-2017 the Queensland Department of Science Information Technology and Innovation (DSITI), now Department of Environment and Science (DES) undertook a method comparison study which compared the same type of instrument used in this study – the Fidas – with two techniques – an Australian Standard Reference method (Partisol 2025 monitors) and an USEPA Equivalent method, a Dichotomous Tapered Oscillating Element Microbalance (TEOM) (Torr 2017). The study was undertaken at Cannon Hill, an urban site in Brisbane which is situated next to a rail line which is used to transport coal to the Port of Brisbane.

Table A. 8 summarises the method comparison results for DSITI's study at Cannon Hill and the results from this study for comparison. The average concentration and concentration range, number of observations, slope, intercept and R^2 are shown.

Concentrations of PM_{10} and $PM_{2.5}$ at Cannon Hill were low and there were no exceedances of air quality objectives. The average concentrations of PM_{10} and $PM_{2.5}$ and concentration ranges were similar between Miles Airport and Cannon Hill during the different method comparison studies. The ratio of $PM_{2.5}/PM_{10}$ were on average 0.4 at both sites, indicating that the PM_{10} was predominantly coarse fraction. While the $PM_{2.5}/PM_{10}$ ratio and concentration range at the Miles Airport and Cannon Hill sites are very similar, Miles Airport is a predominantly rural site while Cannon Hill is an urban site with potential influence of coal dust, and as such the composition of the particles at these two sites is likely to differ.

DSITI found reasonable agreement between PM_{10} measured using the Fidas and the reference method with a strong correlation of 0.92 and a slope of 0.68. Overall DSITI found that PM_{10} measured with the Fidas was somewhat lower than reference equivalent methods, with the Fidas measuring lower by ~30% and 40% respectively at the Cannon Hill site (DSITI – Partisol and TEOM).

DSITI found that the range of concentrations of $PM_{2.5}$ at Cannon Hill during the method comparison were too low to be able to undertake a reliable comparison of methods and found weak correlations between techniques, which was due at least in part to the low ambient concentrations. As mentioned previously, low ambient concentrations of $PM_{2.5}$ at Miles Airport also meant that a method comparison for $PM_{2.5}$ could not be carried out in this study. European and UK equivalence testing of uncorrected Fidas $PM_{2.5}$ against a gravimetric reference method measured an orthogonal regression slope and intercept of 1.060 and -0.210, respectively, with an expanded uncertainty of 14.43% (TUV, 2015).

Table A. 8 Fidas method comparisons in Australia undertaken in this this study and DSITI (Cannon Hill, Brisbane)

	Study	Instruments	n obs	Average (range) µg m³	Orthogonal regression		R^2
					Slope	Intercept	
PM10	CSIRO (Miles Airport)	Fidas v BAM	144	8.5 (1.9 – 27.7)	0.90	-0.37	0.74
	DSITI (Cannon Hill)	Fidas v Partisol	53	8.4 (1.8 - 21.1)	0.68	-3.08	0.92
		Fidas v TEOM*	362	8.4 (4.5-27.5)	0.60	-0.85	0.58
PM2.5	CSIRO (Miles Airport)	Fidas v BAM	144	2.9 (0.9 -9.2)	NA#	NA#	NA#
	DSITI (Cannon Hill)	Fidas v Partisol	57	4.5 (1.0 -12.8)	2.2	-3.6	0.20
		Fidas v TEOM*	373	4.5 (0.7 – 15.8)	0.41	2.1	0.36
PM2.5/PM10 ratio	CSIRO (Miles Airport)	Fidas	144	0.4 (0.2 – 0.7)	n/a	n/a	n/a
	DSITI (Cannon Hill)	Partisol	76	0.4 (0.3 – 0.9)	n/a	n/a	n/a

*original uncorrected and unfiltered data

GISERA Impacts of Hydraulic Fracturing study

The equivalency of the Fidas PM_{10} and $PM_{2.5}$ methods to reference methods was measured in a 2017 monitoring campaign to measure the air, surface water groundwater and soil impacts of hydraulic fracturing of gas production wells in the Surat Basin, Queensland https://gisera.csiro.au/project/air-water-and-soil-impacts-of-hydraulic-fracturing-phase-2/. The location of the campaign was a rural property approximately 90 km north west of the Miles Airport site which was likely influenced by similar regional sources of particles.

Fidas instruments were used at two sites located approximately 2 km apart. At one site, a Fidas was co-located with an aerosol sampler fitted with a PM_{10} impactor head that collected aerosol mass onto a filter for 12-hour periods. The aerosol mass concentrations were gravimetrically determined, providing 94 paired observations with 12-hour average Fidas PM_{10} observations. The gravimetric sampler used is an EU approval for use reference method and was operated following Australian Standard Methods.

At a second site a Fidas was co-located with an 'Esampler' instrument (Met One, Oregon USA) fitted with a $PM_{2.5}$ impactor head that has a nephelometer to measure scattering of light at 5-minute intervals and a filter cassette to collect aerosol for gravimetric measurement. The

'Esampler' was calibrated using the gravimetric mass of $PM_{2.5}$ collected on filters. The 24-hour average calibrated Esampler $PM_{2.5}$ observations were compared to 24-hour average Fidas $PM_{2.5}$ observations. Direct comparison of the Fidas $PM_{2.5}$ to gravimetric $PM_{2.5}$ mass concentration was undertaken for eight observations.

The concentration range of PM_{10} and $PM_{2.5}$ during the particle method comparison was higher than during the Miles Airport method comparison and was reasonable for undertaking a comparison of two measurement methods for both PM_{10} and $PM_{2.5}$.

Provisional data from this comparison indicates a good agreement between methods for both PM_{10} and $PM_{2.5}$ including the direct comparison of the Fidas $PM_{2.5}$ to gravimetric $PM_{2.5}$ mass concentration.Final method comparison data from this study will be available in a final report published in late 2018.

A.3.5 **Summary and Implications for particle measurements in this study**

The method comparison at Miles Airport site found good agreement between PM_{10} measured with the Fidas, (which measures particles at the 3 gas field sites), and the BAM, which produces data equivalent to Australian Standard methods.The two measurement techniques agreed within their stated uncertainties at the 95 % confidence level. Thus the 6 month measurement comparison shows equivalency between Fidas and BAM PM_{10} measurement methods and strong agreement within the concentration range of 1.8 to 38.6 µg m^{-3}. There were insufficient $PM_{2.5}$ observations greater than 5 µg m^{-3} to assess the equivalency of the Fidas and BAM methods over the concentration range of 5 to 25 µg m^{-3}.

The PM_{10} findings from this study are comparable to the findings from another recent Queensland study by DSITI (Torr 2017) which compared a Fidas instrument with two other techniques (Partisol – a reference method, and TEOM) in an urban Australian environment. DSITI found the Fidas agreed reasonably well with the reference method, but that the Fidas concentrations were lower concentrations than the other two techniques. Also similar to this study, the $PM_{2.5}$ concentrations were too low during the DSITI study to undertake a method comparison for $PM_{2.5}$.

Overall this method comparison shows good agreement between Fidas and BAM and supports the use of the Fidas for measuring PM_{10} in this study. The suitability of the Fidas for measuring $PM_{2.5}$ could not be assessed due to low concentrations during the study period, an issue also found in a similar recent Queensland study. However provisional data from another recent study in the Surat Basin found good agreement between techniques for $PM_{2.5}$ and details of this comparison and final results will be made available at the end of 2018.

A method comparison for TSP was not undertaken, as this was assessed to be a lower priority for a method comparison than PM_{10} and $PM_{2.5}$. This is because the method comparison for PM_{10} and $PM_{2.5}$ reported here covered the smaller particle component of TSP which are criteria air pollutant in the NEPM (NEPM 2016) and can cause adverse health affects (10 µm and less). A further reason that a method comparison was not undertaken for TSP is due to the particle diameter size ranges sampled and measured by the Fidas (up to 18 µm) and the Australian Standard method (up to 100 µm) (AS/NZS 3580.9.3:2015) being non-equivalent. As such, the TSP data from this study can only

be considered indicative and cannot be considered equivalent to Australian Standard Method (AS/NZS 3580.9.3:2015). It is likely that for very localised dust events with large airborne particles >10 µm, the Fidas would have measured a lower concentration of TSP than would have been measured by the Australian standard method. As such is possible that there were some 24 hour concentrations of TSP which were below the TSP guildine when measured with Fidas, but would have exceeded the guideline if measured by the Austalian Standard Method. Many such events would have been captured by the protocol of investigating TSP events which were >80% of the nuisance dust guideline (MFE 2016).

A.3.6 **References**

AS/NZS 3580.9.11.2008 (2008) Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM10 beta attenuation monitors, Standards Australia

AS/NZS 3580.9.12:2013 (2013) Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM2.5 beta attenuation monitors, Standards Australia

BS EN 16450:2017 Ambient air. Automated measuring systems for the measurement of the concentration of particulate matter (PM10; PM2.5)

EN 12341 (1998) Air Quality - Determination Of The Pm 10 Fraction Of Suspended Particulate Matter - Reference Method And Field Test Procedure To Demonstrate Reference Equivalence Of Measurement Methods. CEN, Brussels, 1998, 24 pp. Superseded by EN 12341:2014.

EN 14907 (2005) Ambient Air Quality – Reference gravimetric measurement method for the determination of the PM2.5 mass fraction of suspended particulate matter in ambient air. CEN, Brussels, 2005. 32 pp. Replaced by EN 12341:2014.

EN 15267-1 (2009), Air quality. Certification of automated measuring systems. General principles, 20 pp.

EN 15267-2 (2009) Air Quality - Certification of Automated Measuring Systems Part 2: Initial Assessment of the ams Manufacturer's Quality Management System and Post Certification Surveillance for the Manufacturing Process, 20 pp

Guide to Demonstration of Equivalence of Ambient Air Monitoring Methods (2005), Report by an EC Working Group on Guidance for the Demonstration of Equivalence January 2010 http://ec.europa.eu/environment/air/quality/legislation/pdf/equivalence.pdf

MFE (2016) *Good Practice Guide for Assessing and Managing Dust.* Wellington: Ministry for the Environment. November 2016. Publication reference number ME1277. ISBN: 978-0-908339-73-0, 78 pp http://www.mfe.govt.nz/publications/air/good-practice-guide-assessing-and-managing-dust

Torr, S., (2017) Comparison of PM10 and PM2.5 ambient measurements from a Palas Fidas 200 particle monitor against an equivalent and reference particle method at an urban site, Brisbane. Conference paper, 23rd Biennial International Clean Air Society of Australia and New Zealand, Brisbane, 15-18 October 2017, Brisbane, Australia.

TUV. (2015) the Report on supplementary testing of the Fidas 200 S respectively Fidas 200 measuring system manufactured by PALAS GmbH for the components suspended particulate matter PM10 and PM2.5. TUV-report 936/21227195/A, Cologne, 9th March 2015.

Report: http://chtechusa.com/Manuals/Fidas_200-Report.pdf

Certificate: http://www.qal1.eu/15267/0000040212_04_palas_Fidas200S_en.pdf

VDI 4202-1 (2010), Performance Criteria For Performance Tests Of Automated Ambient Air Measuring Systems - Point-Related Measurement Methods For Gaseous And Particulate Air Pollutants, Verlag des Vereins Deutscher Ingenieure. 31 pp. Superseded by VDI 4202-1:2018

VDI 4203-3 (2010) Testing Of Automated Measuring Systems - Test Procedures For Point-Related Ambient Air Measuring Systems For Gaseous And Particulate Air Pollutants. Verlag des Vereins Deutscher Ingenieure, 91 pp. Superseded by VDI 4203-3:2017

A.4 Event investigations - Fire Hotspot data

Hotspots referred to in Section 6 are derived from satellite-born instruments that detect light in the thermal wavelengths. The satellite data are processed with a specific algorithm that highlights areas with an unusually high temperature.

Two different satellite products were used to investigate the presence of fires in the study area in this report – Sentinel Hotspots and NASA Worldview.

Sentinel Hotspots - Sentinel is an Australian bushfire monitoring system that provides information about fire hotspots. Sources – MODIS sensor aboard NASA Terra and Aqua satellites, AVHRR (Advanced Very High Resolution Radiometer) night time imagery from NOAA satellites, VIIR on the Suomi-NPP satellite. © Commonwealth of Australia (Geoscience Australia) 2018.

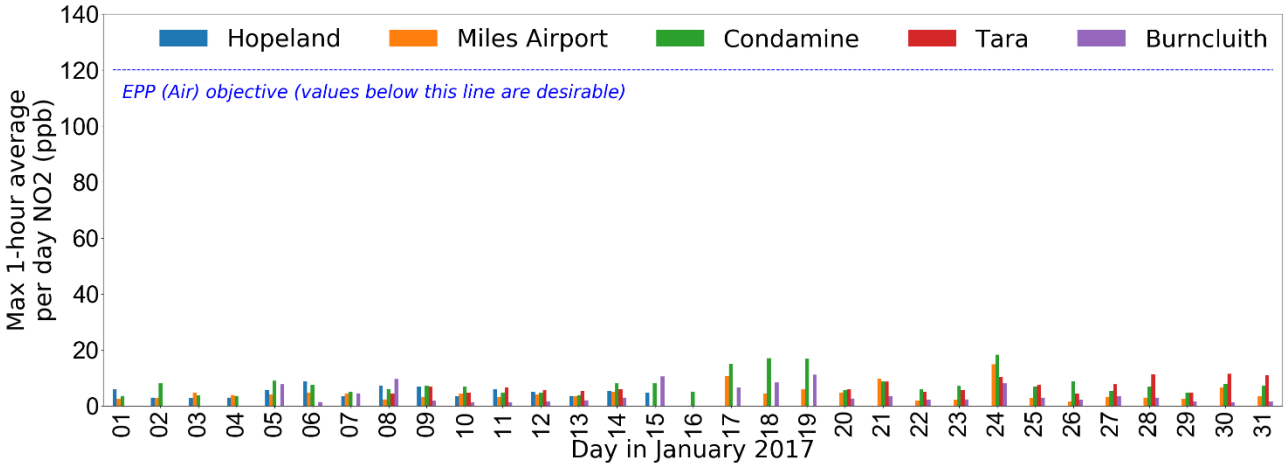
NASA Worldview is a component of the NASA Earth Observing System Data and Information System (EOSDIS). The Worldview tool from NASA's Earth Observing System Data and Information System (EOSDIS) provides the capability to interactively browse historical fire data. FIRMS (Fire Information for Resource Management System) can be used to download the historical data. NASA Worldview provides fire products from the Moderate Resolution Imaging Spectroradiometer (MODIS) (MCD14DL) and the Visible Infrared Imaging Radiometer Suite (VIIRS) 375 m (VNP14IMGTDL_NRT))

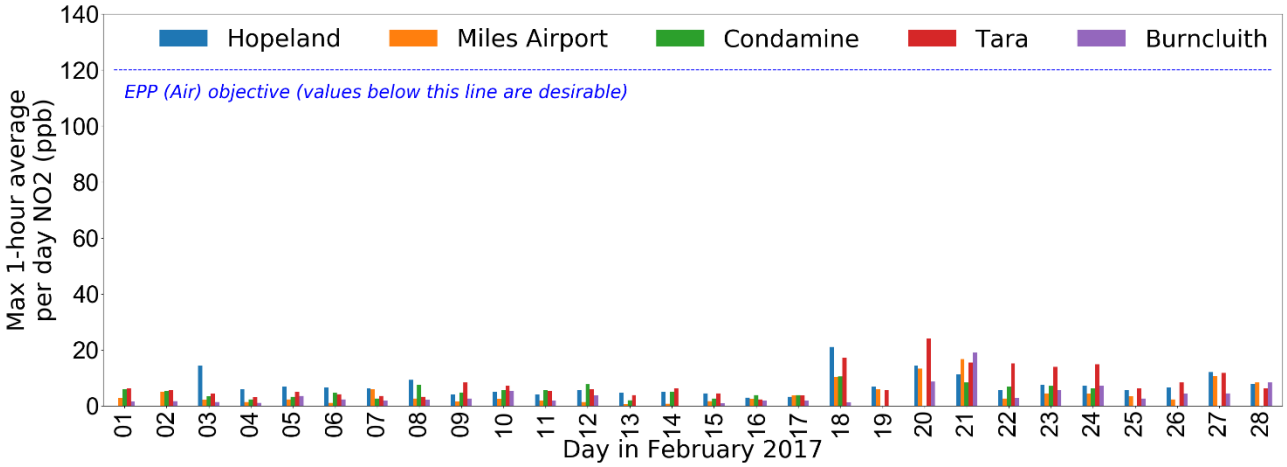
The smoke plumes are observed in NASA Worldview using corrected reflectance from Suomi NPP / VIIRS, Aqua /MODIS and /or Terra / MODIS.

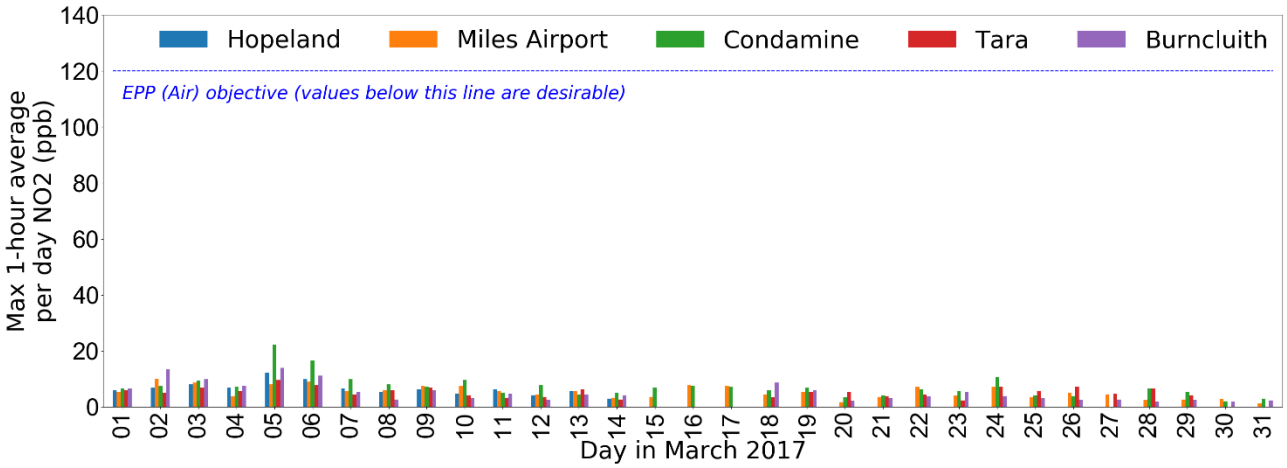
We acknowledge the use of data and imagery from LANCE FIRMS operated by the NASA/GSFC/Earth Science Data and Information System (ESDIS) with funding provided by NASA/HQ.

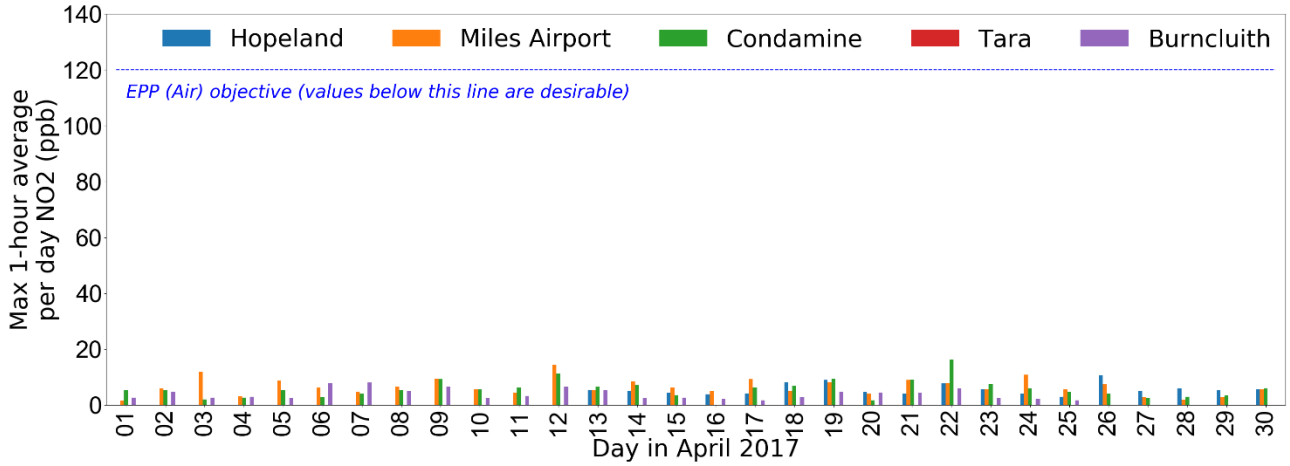
A.5 Daily data summary Plots

A.5.1 **Nitrogen dioxide- maximum 1 hour average from January 2017 – February 2018**





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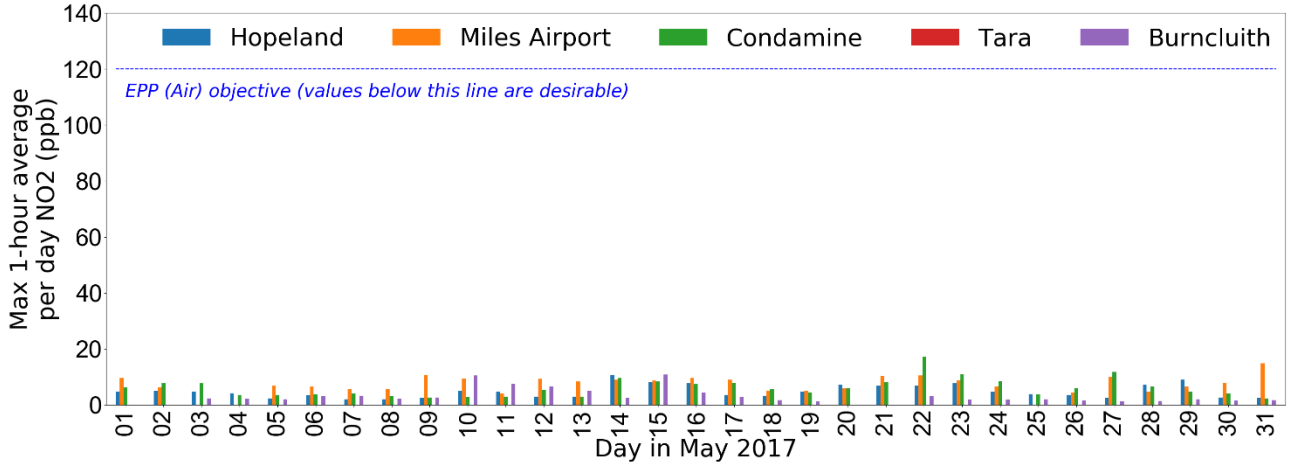
Max 1-hour average per day NO2 (ppb)
Day in April 2017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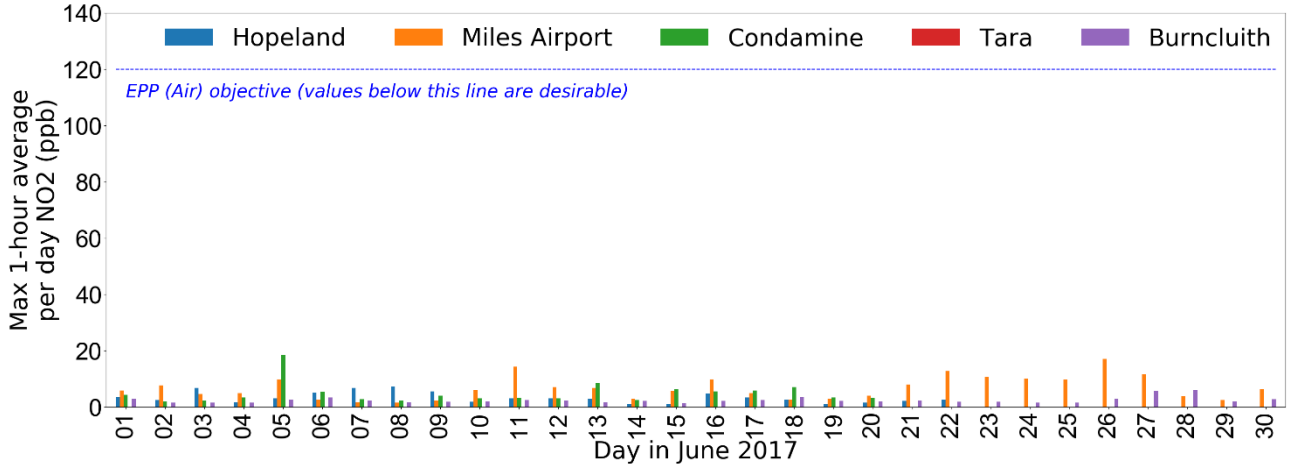
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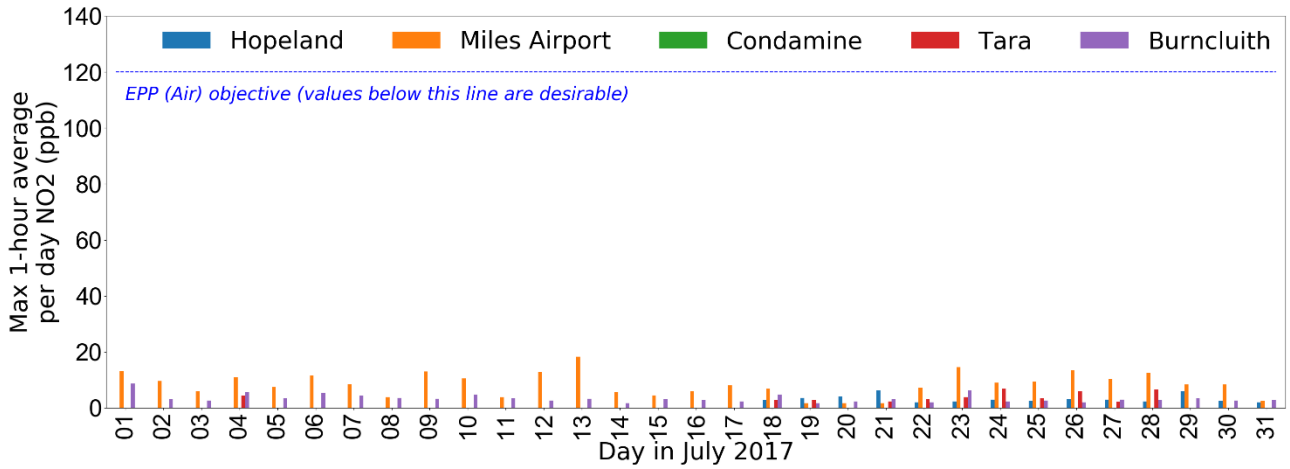
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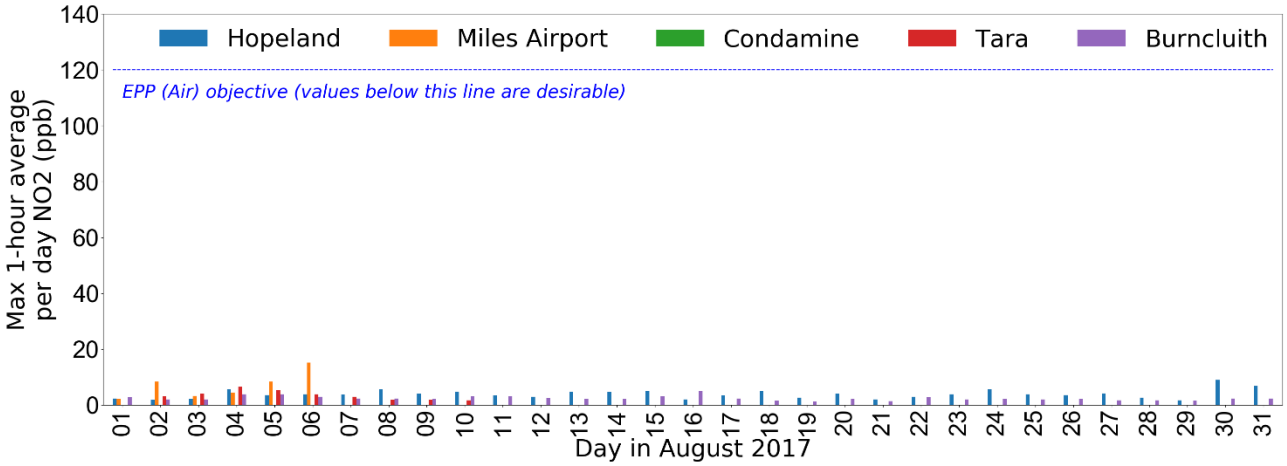
Day in July 2017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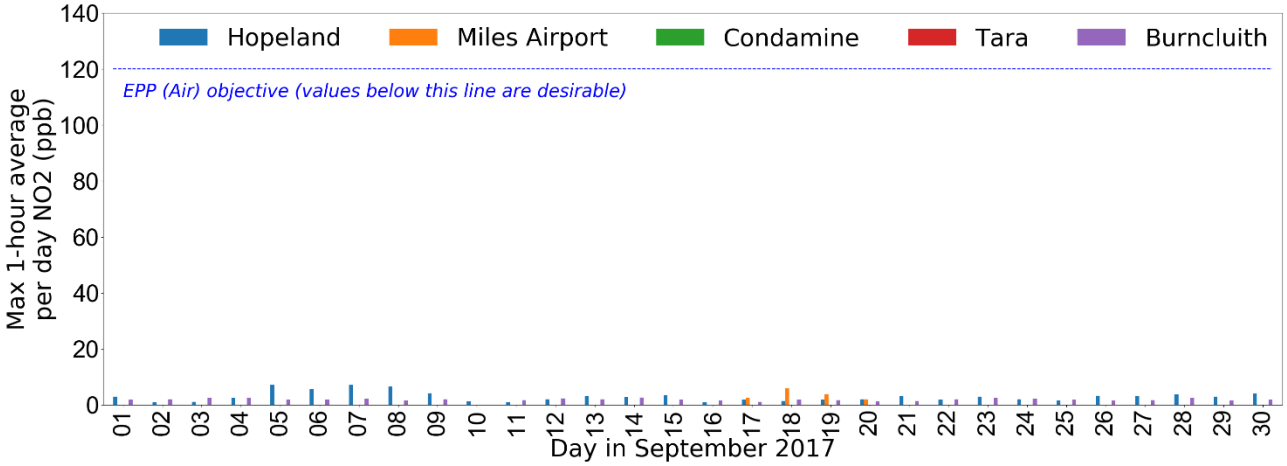
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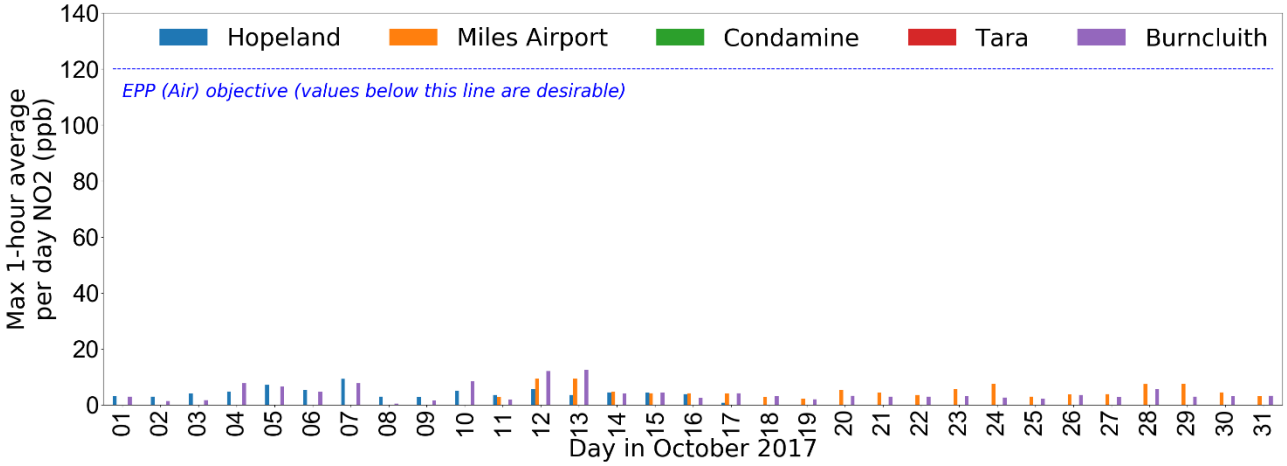
Day in September 2017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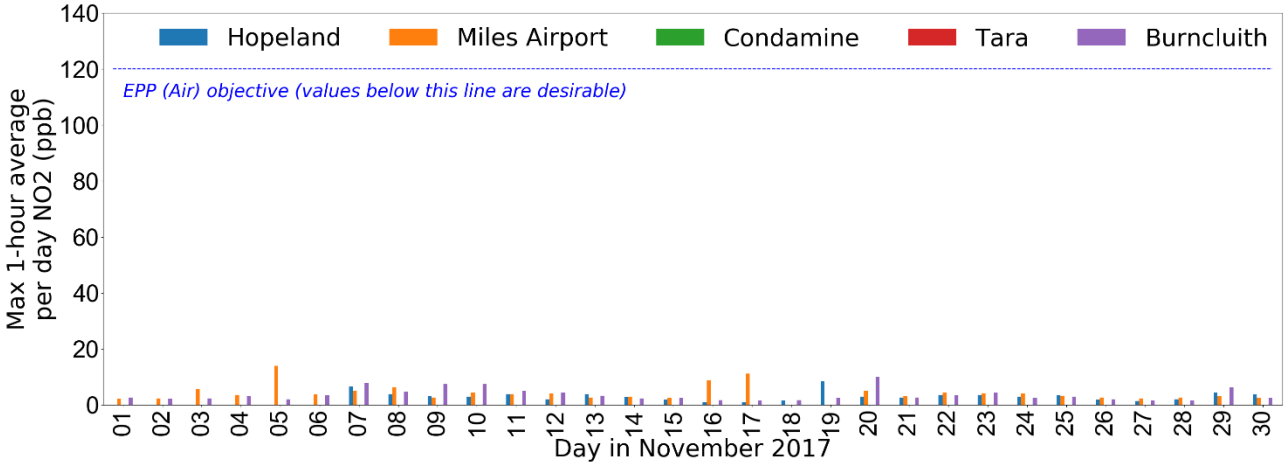
Day in October 2017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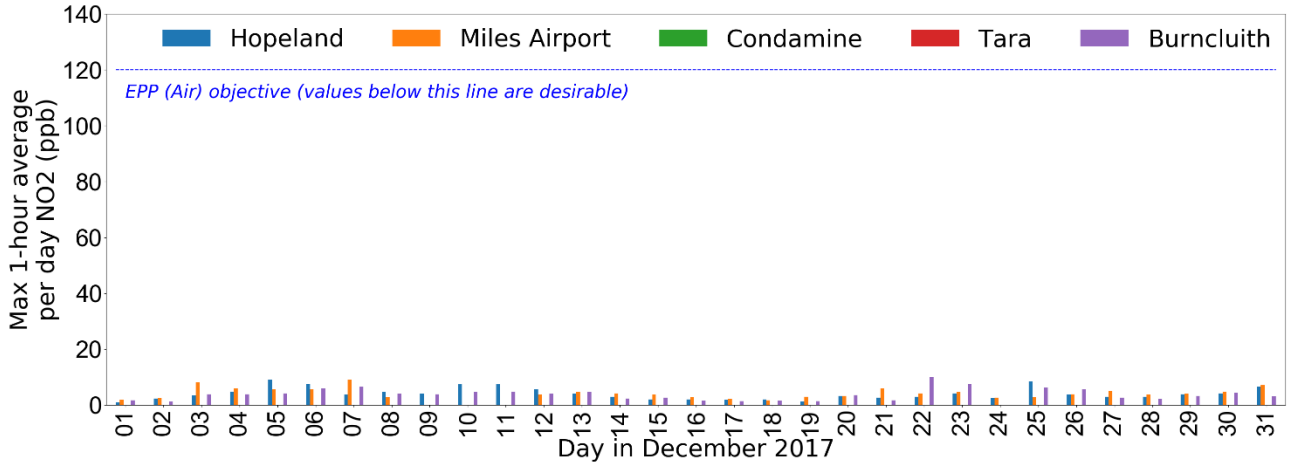
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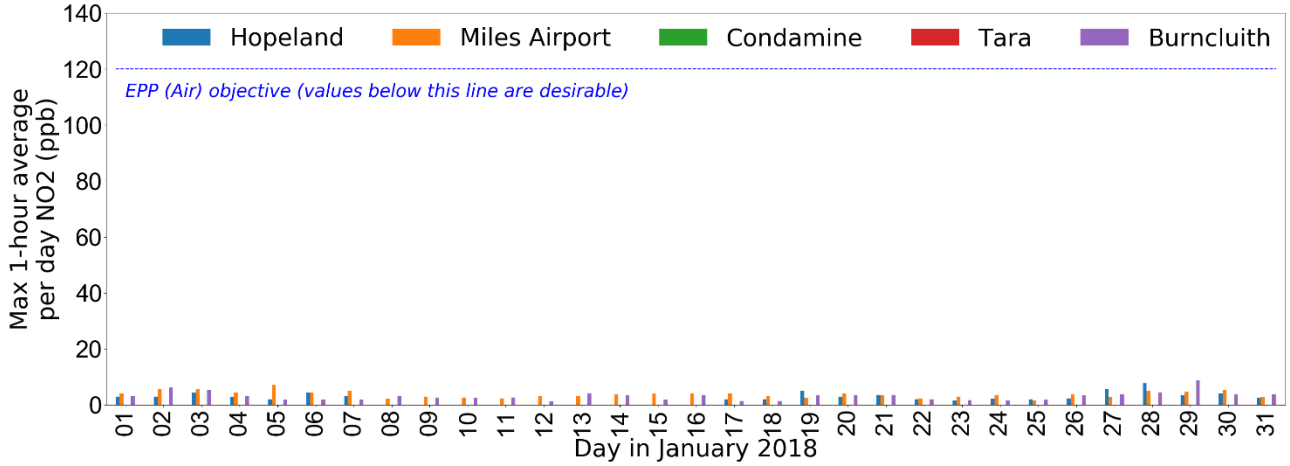
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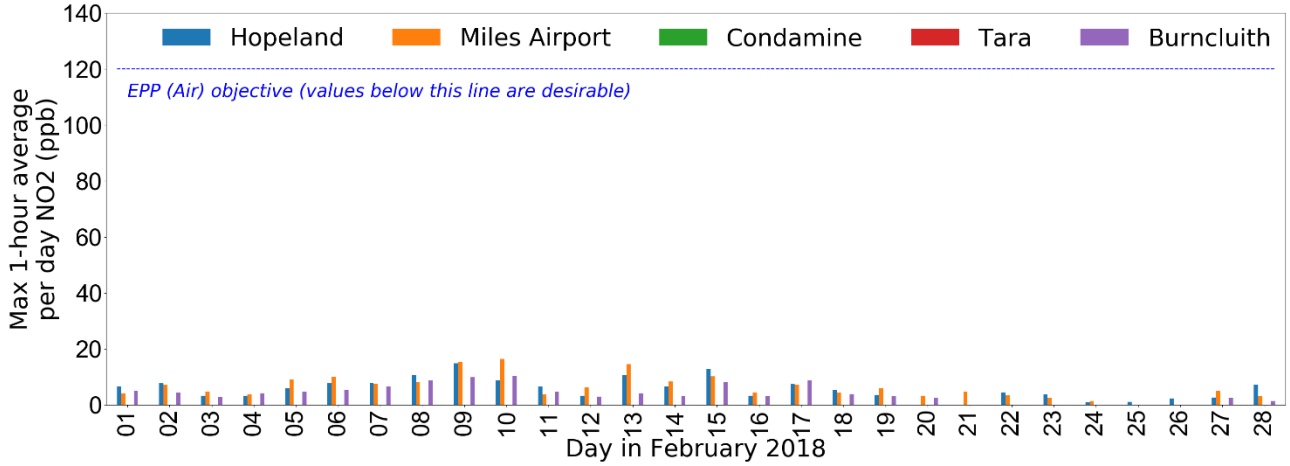
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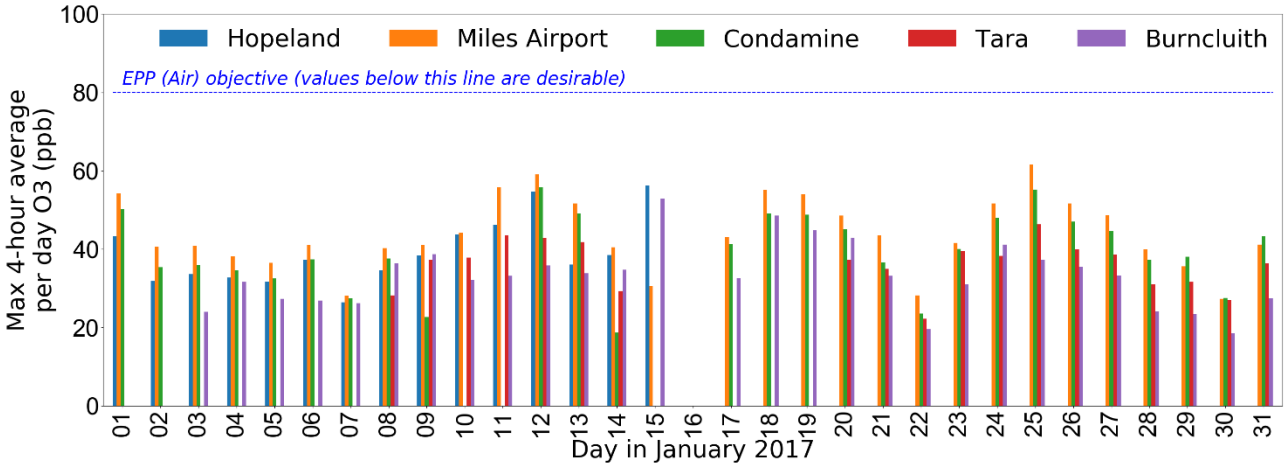
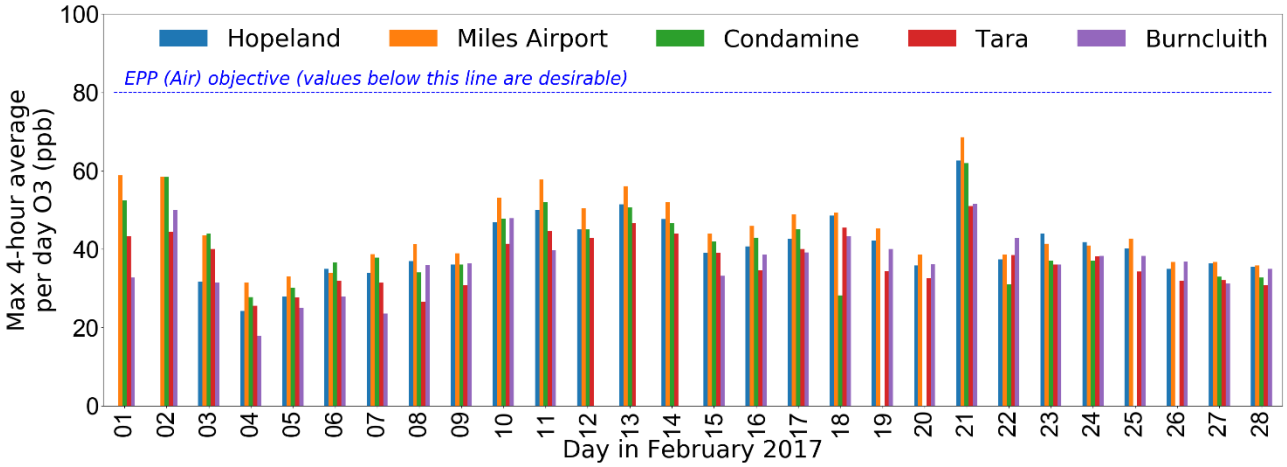
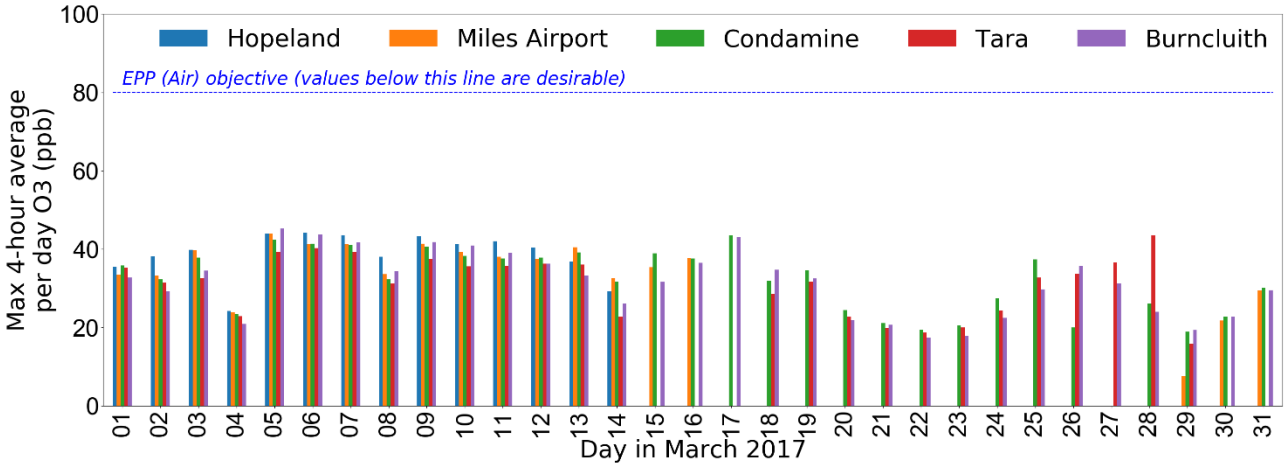
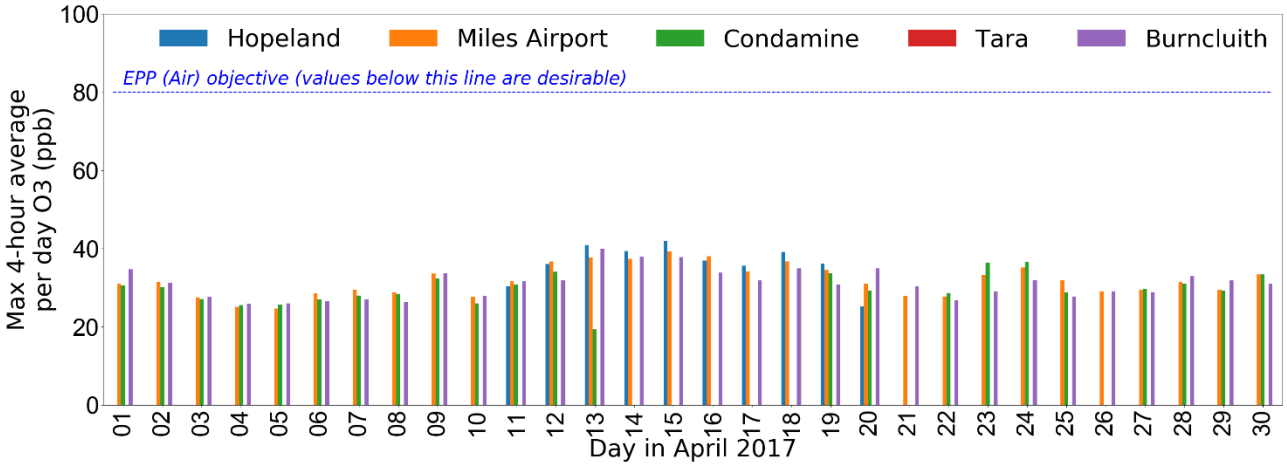
Day in February 2018

A.5.3 **Ozone - maximum 4-hour concentration for all sites, for January 2017 – February 2018**





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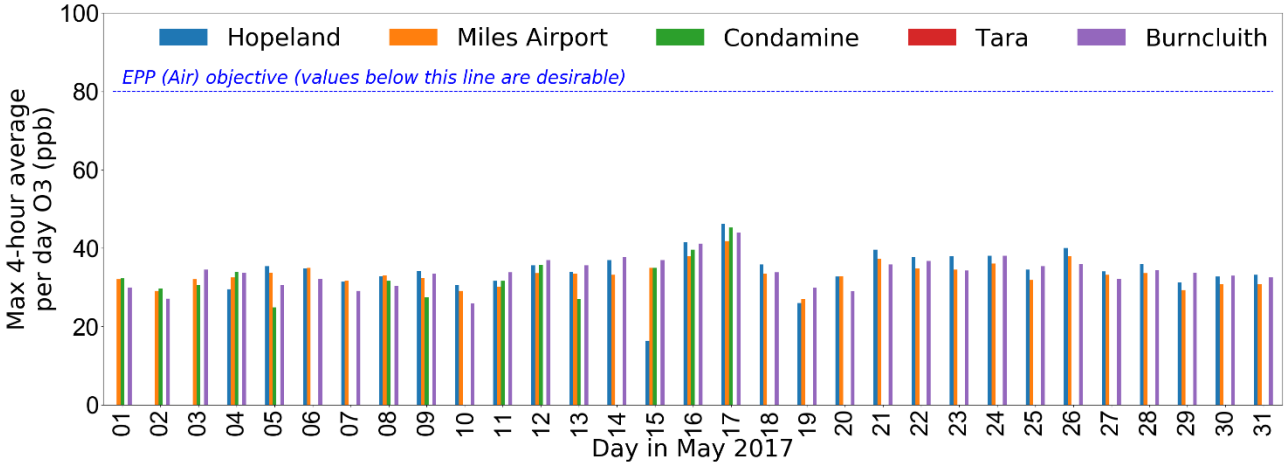
Day in April 2017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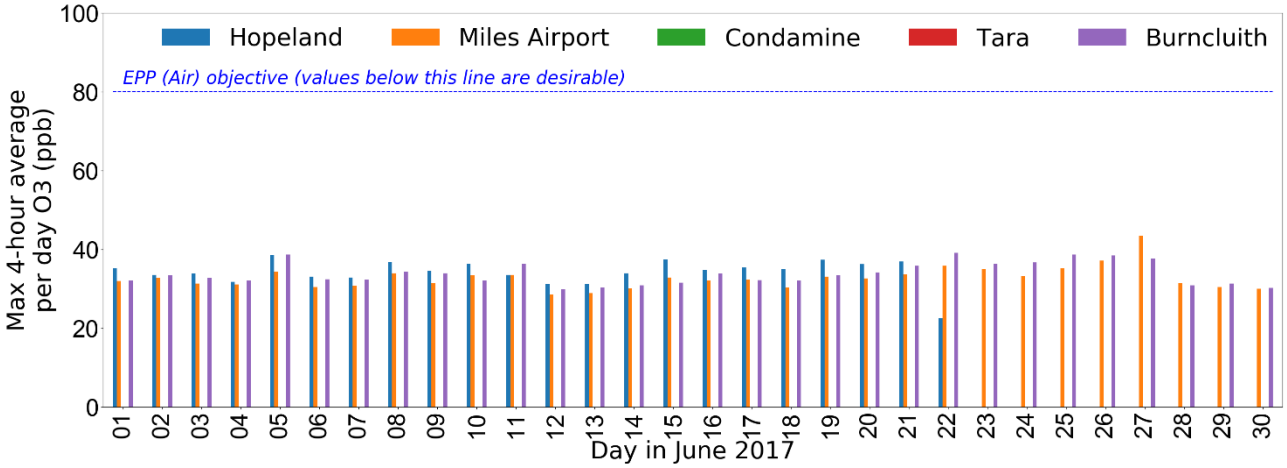
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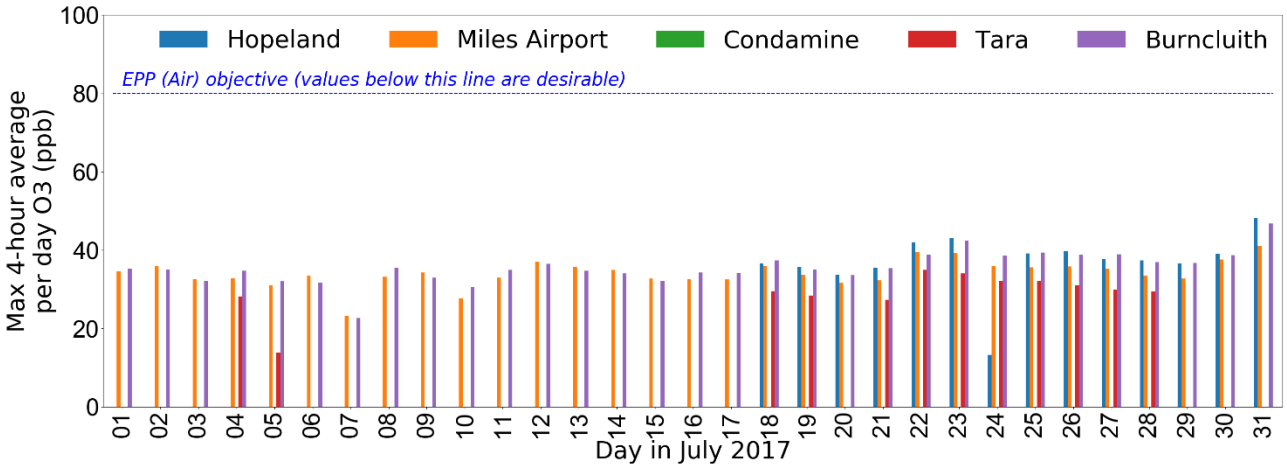
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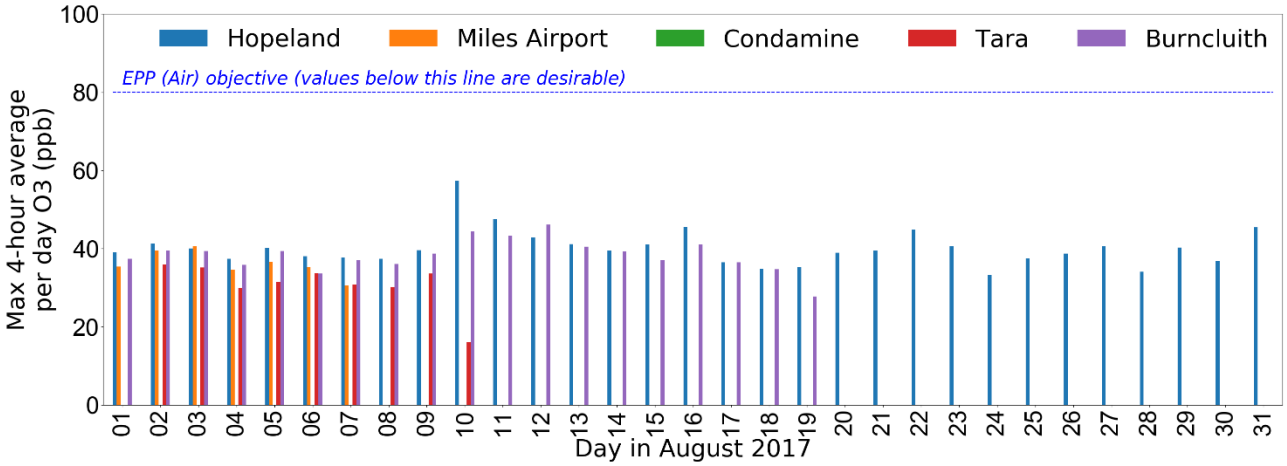
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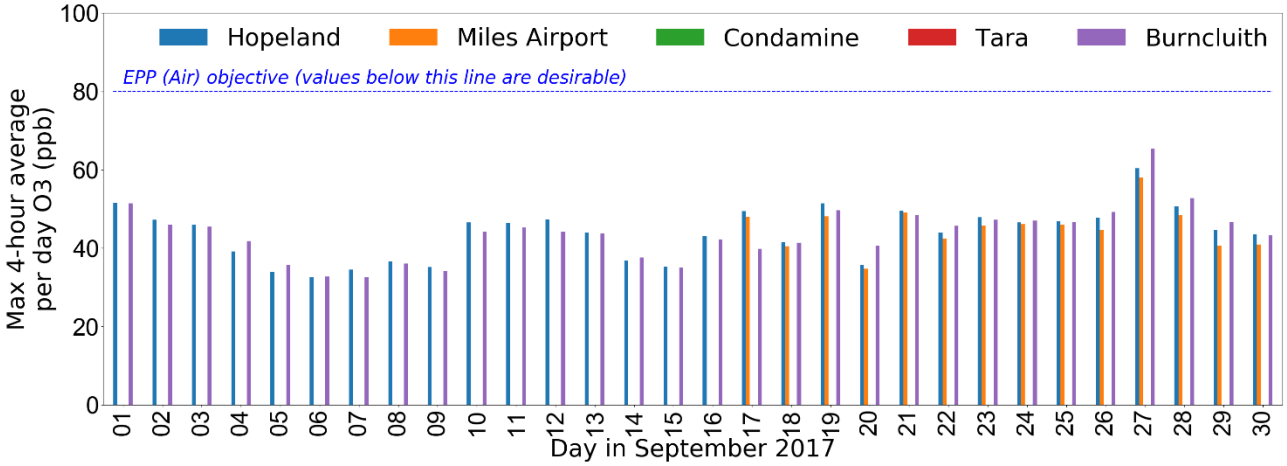
Day in August 2017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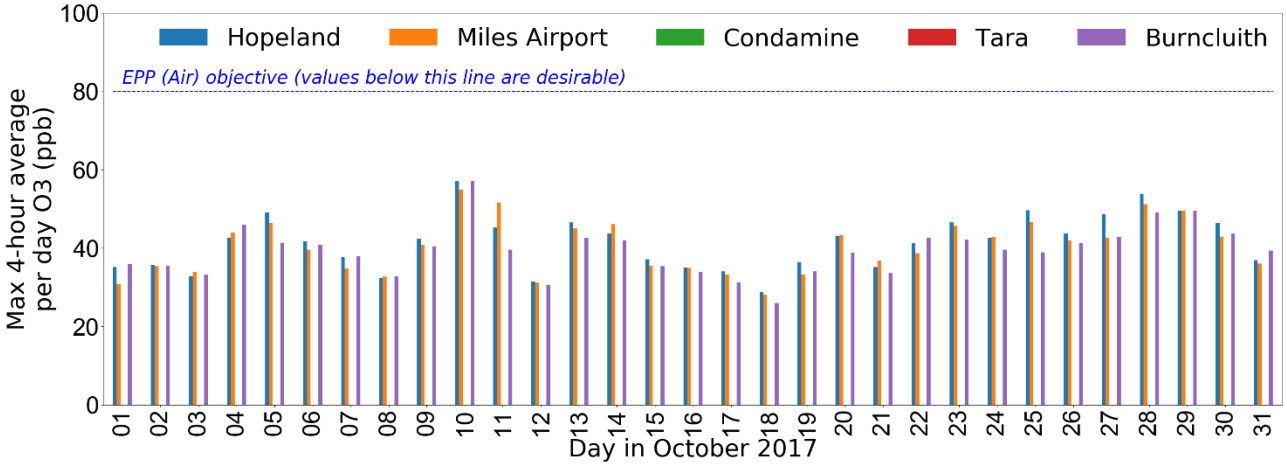
Max 4-hour average per day O3 (ppb)
Day in September 2017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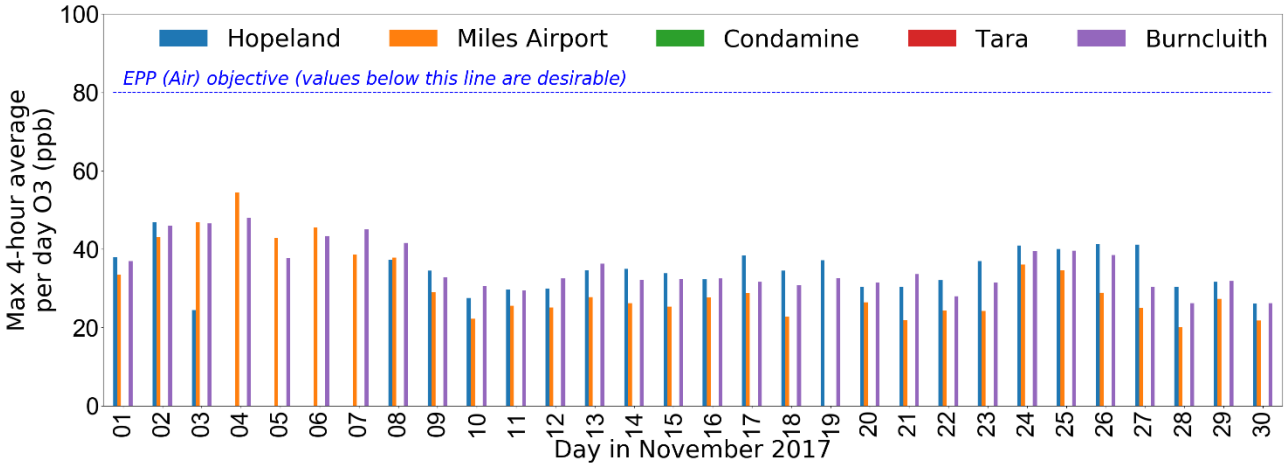
EPP (Air) objective (values below this line are desirable)
Max 4-hour average per day O3 (ppb)
Day in October 2017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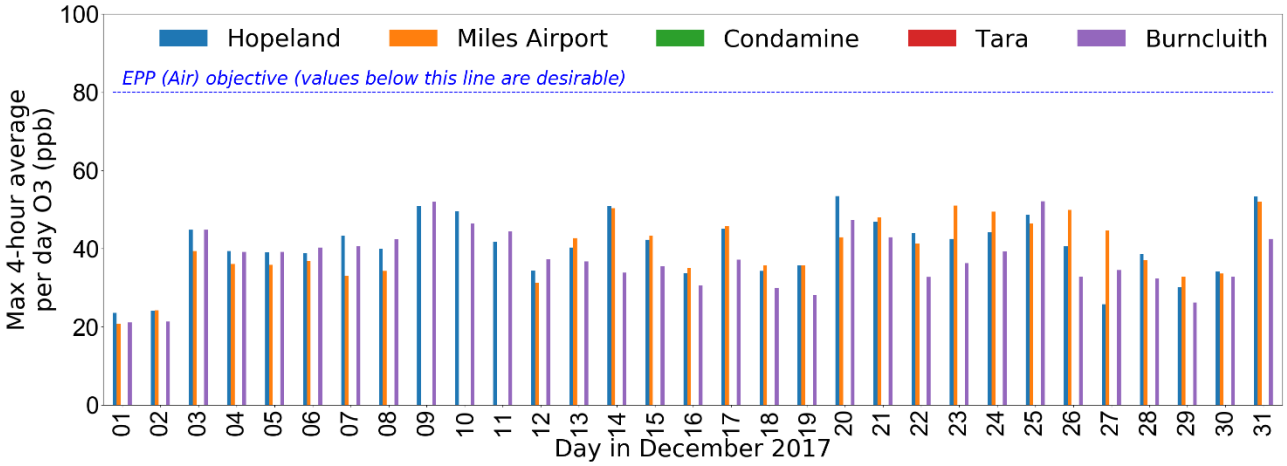
EPP (Air) objective (values below this line are desirable)
Max 4-hour average per day O3 (ppb)
Day in November 2017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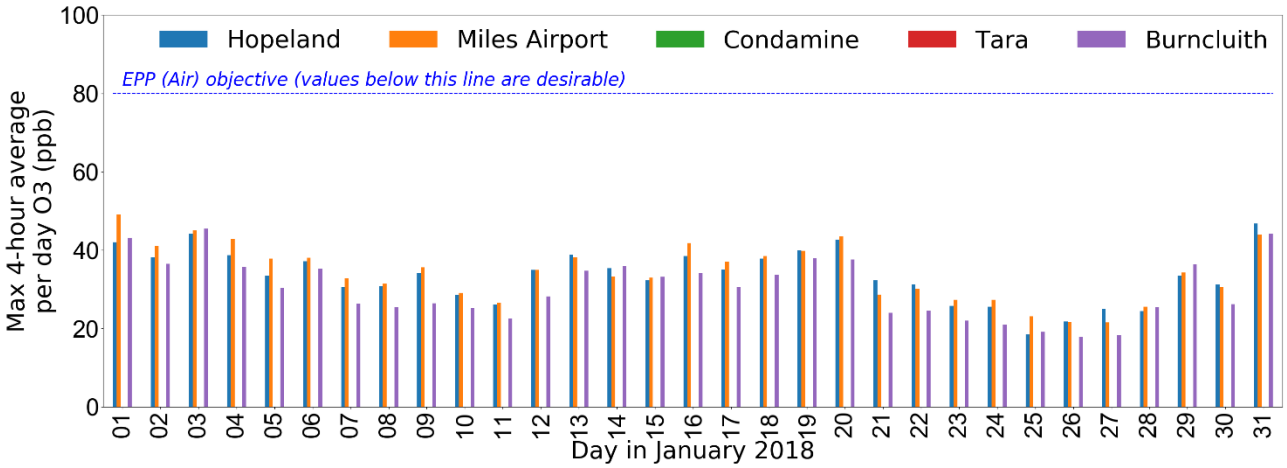
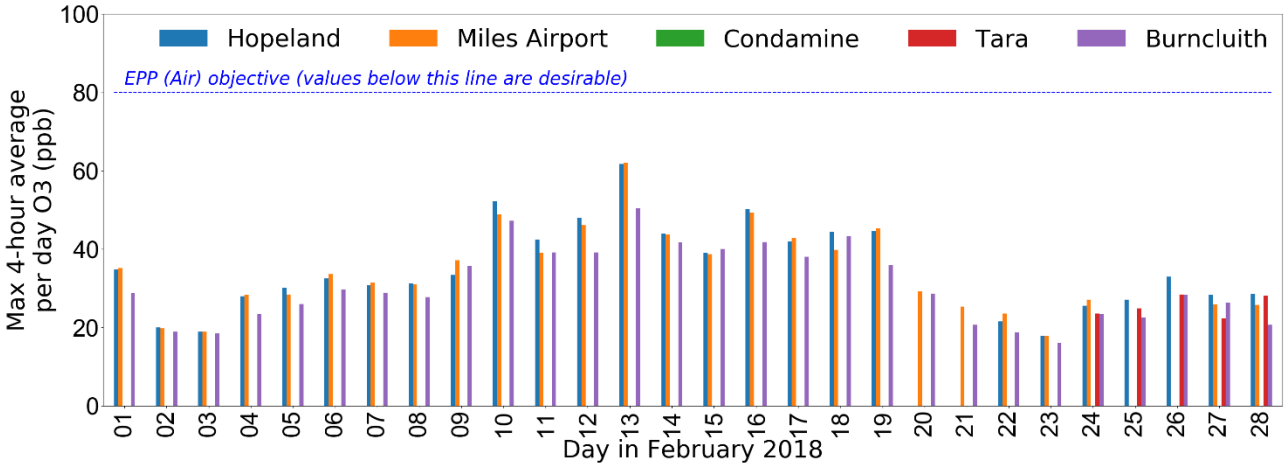
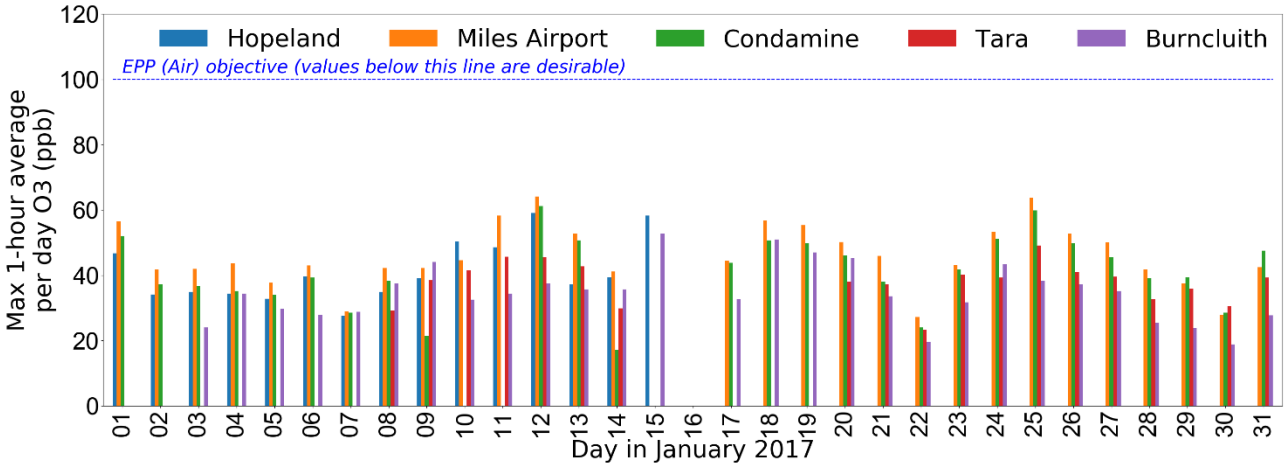
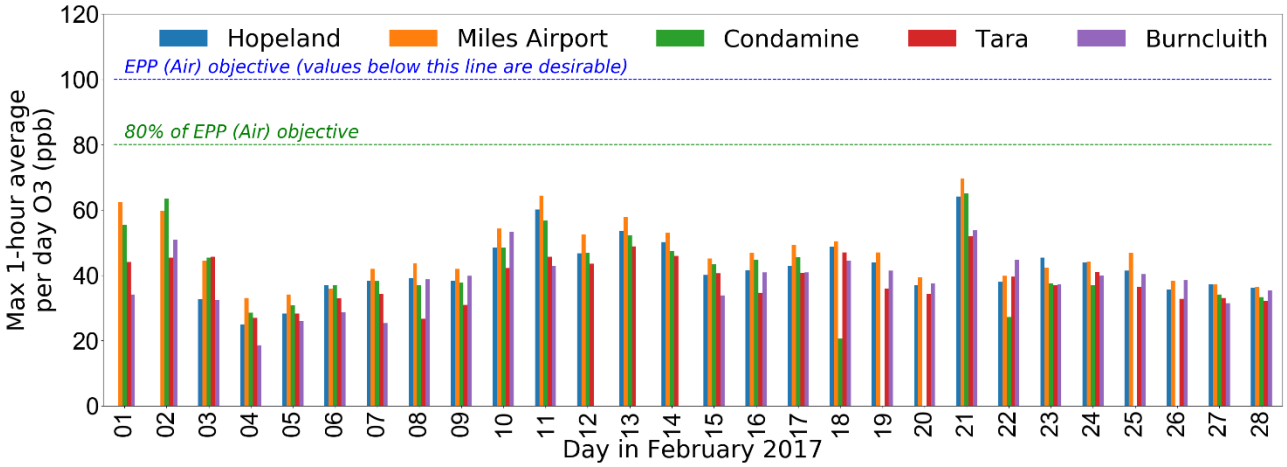
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 4-hour average per day O3 (ppb)
Day in December 2017

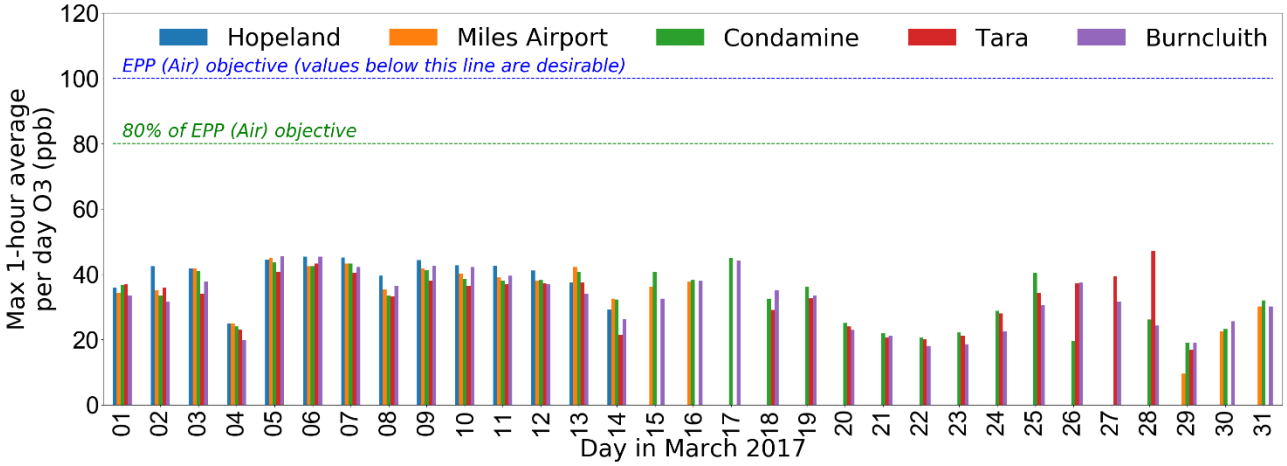

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 4-hour average per day O3 (ppb)
Day in January 2018

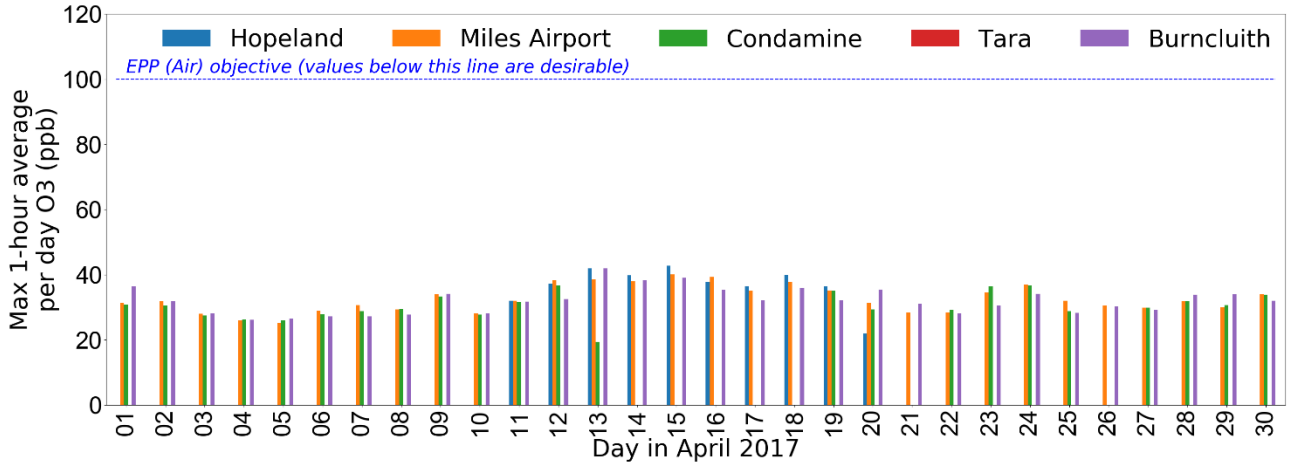

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 4-hour average per day O3 (ppb)
Day in February 2018

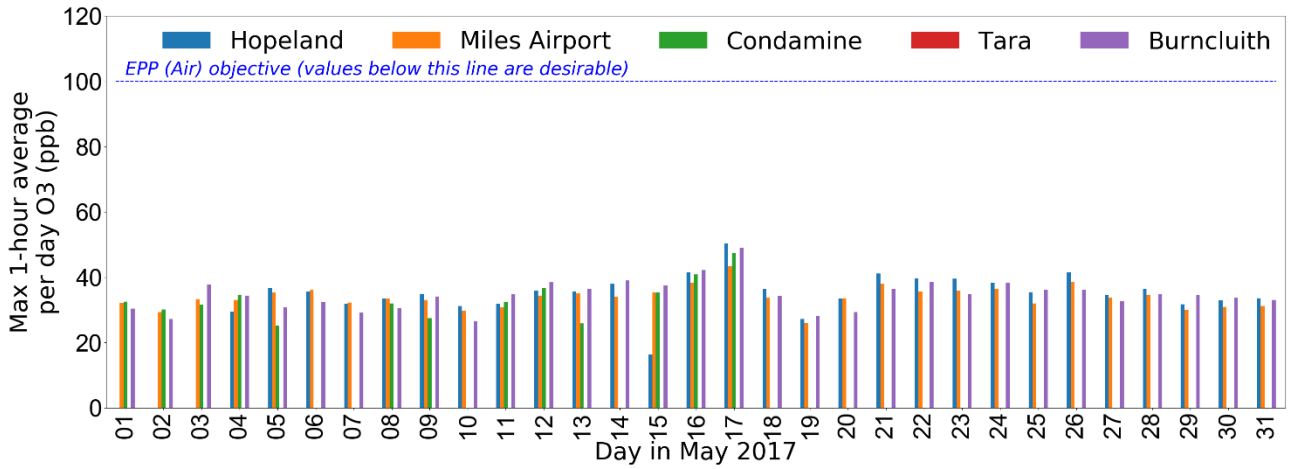
A.5.4 **Ozone – maximum 1 hour average for January 2017 – February 2018**

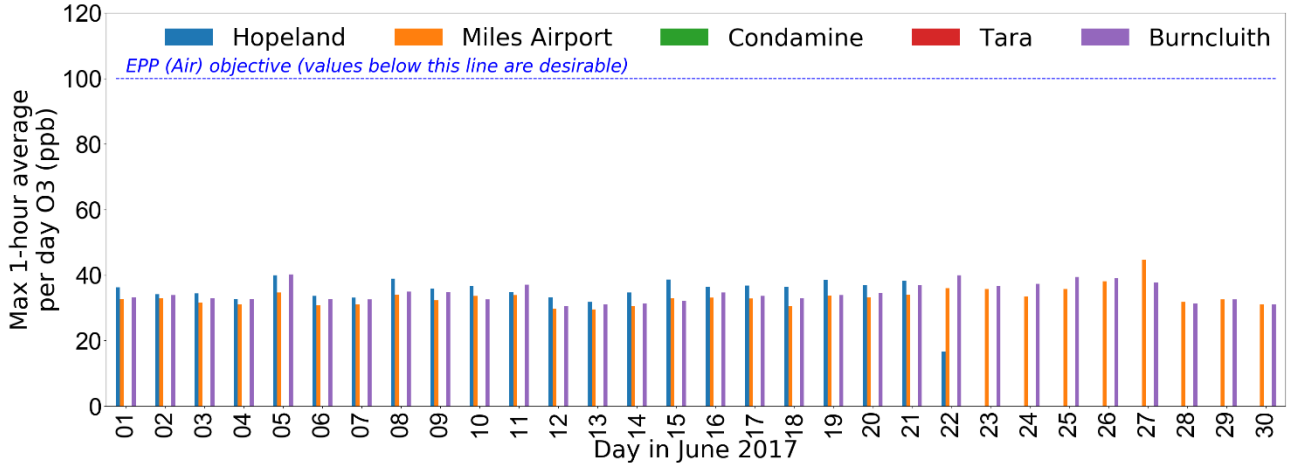


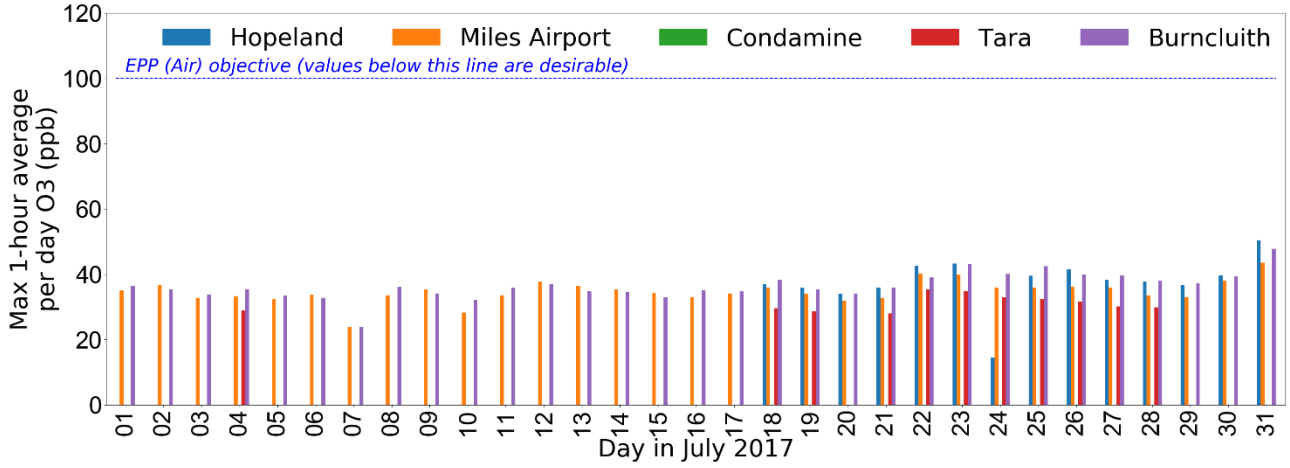


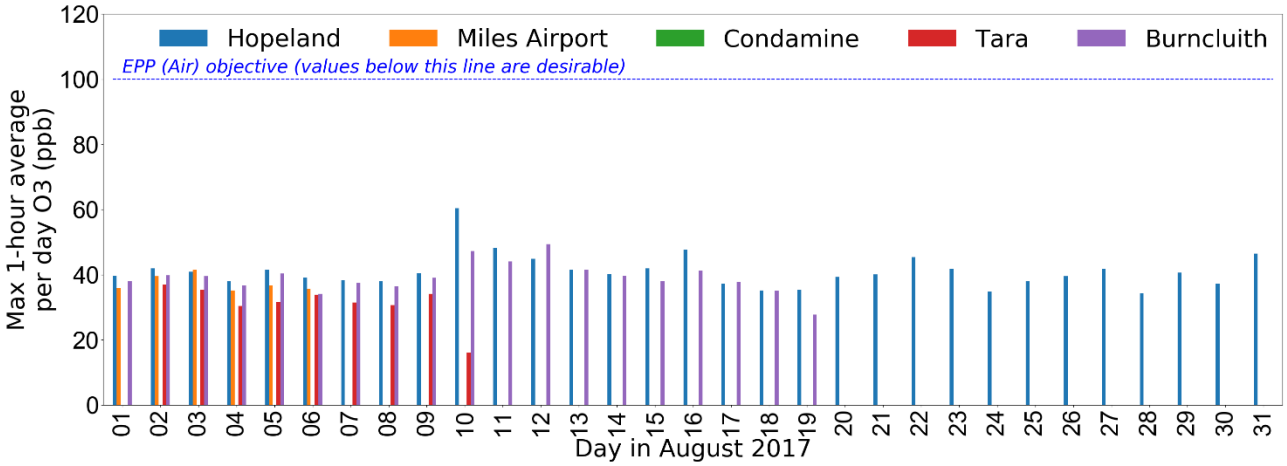


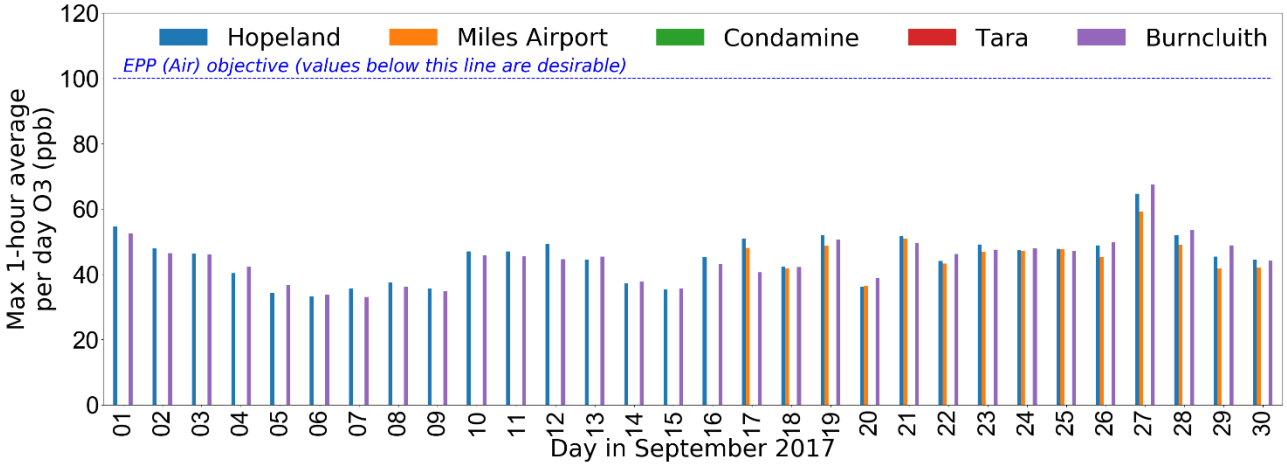

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in April 2017

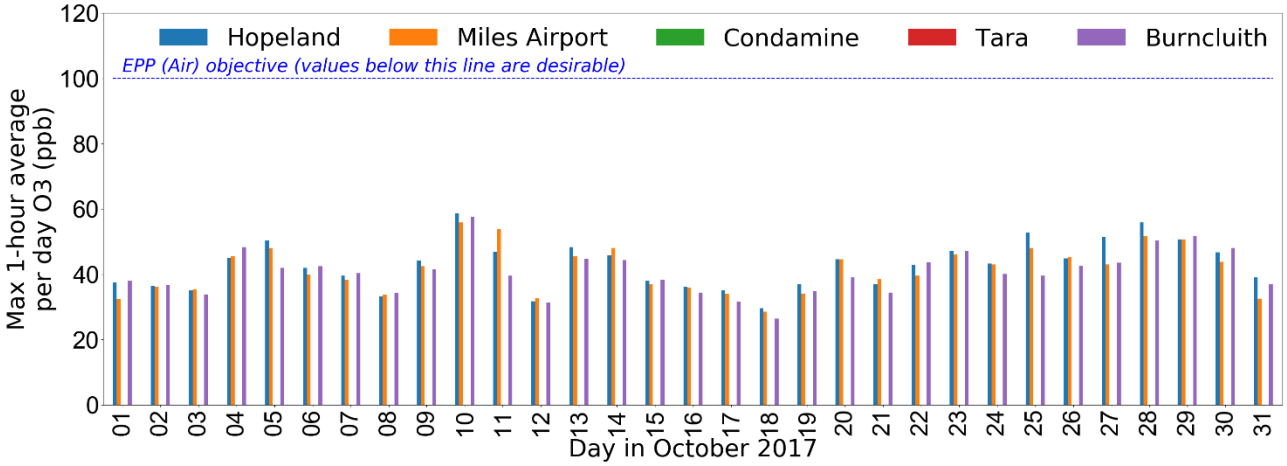

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in May 2017

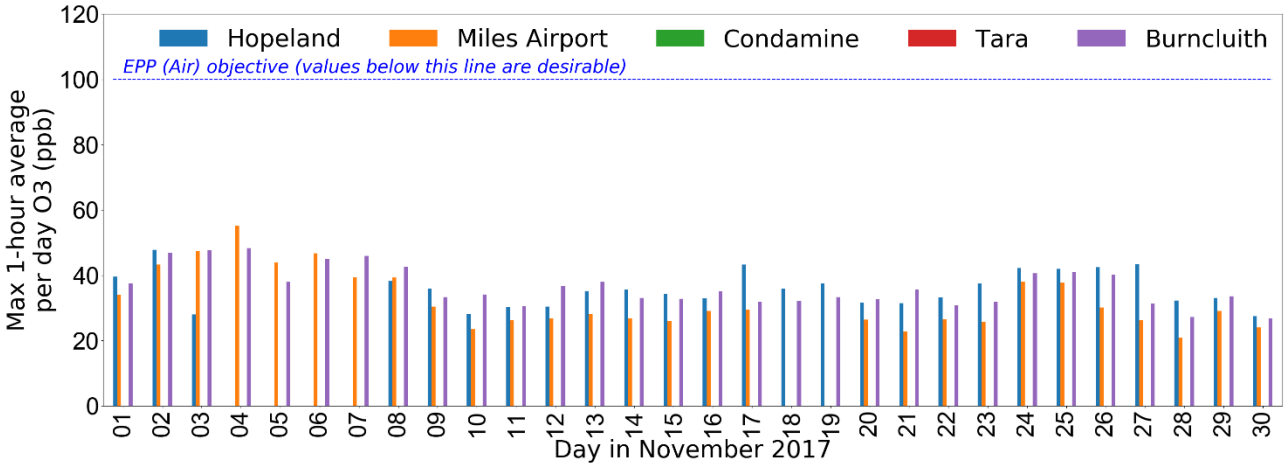

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in June 2017

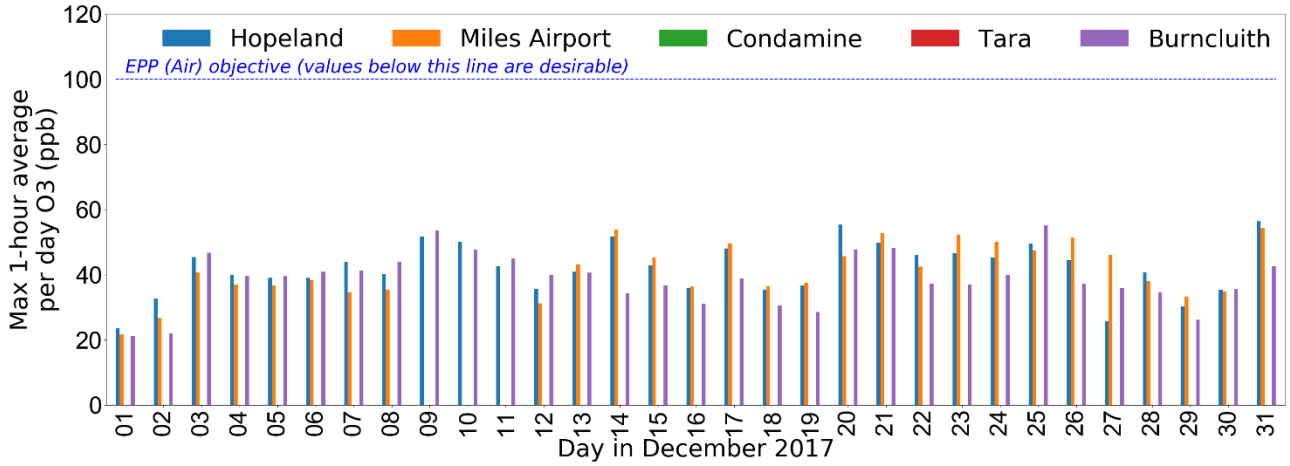

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in July 2017

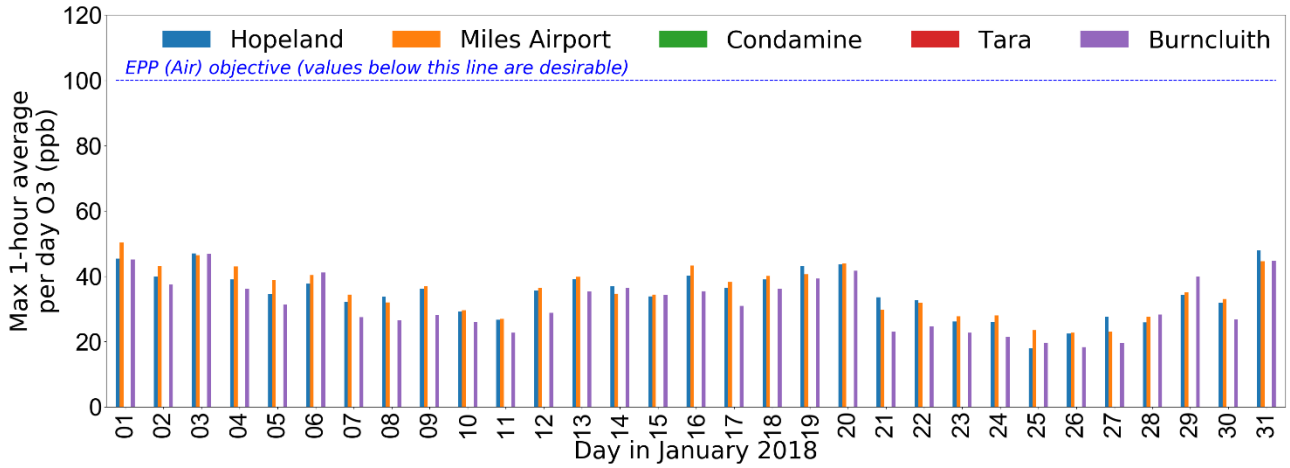

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in August 2017

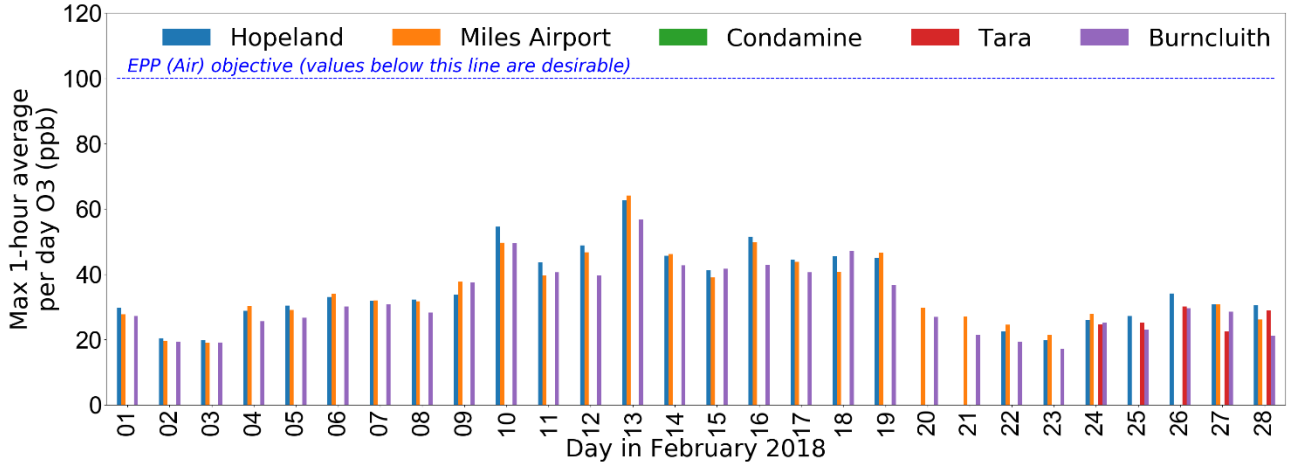

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in September 2017


Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in October 2017

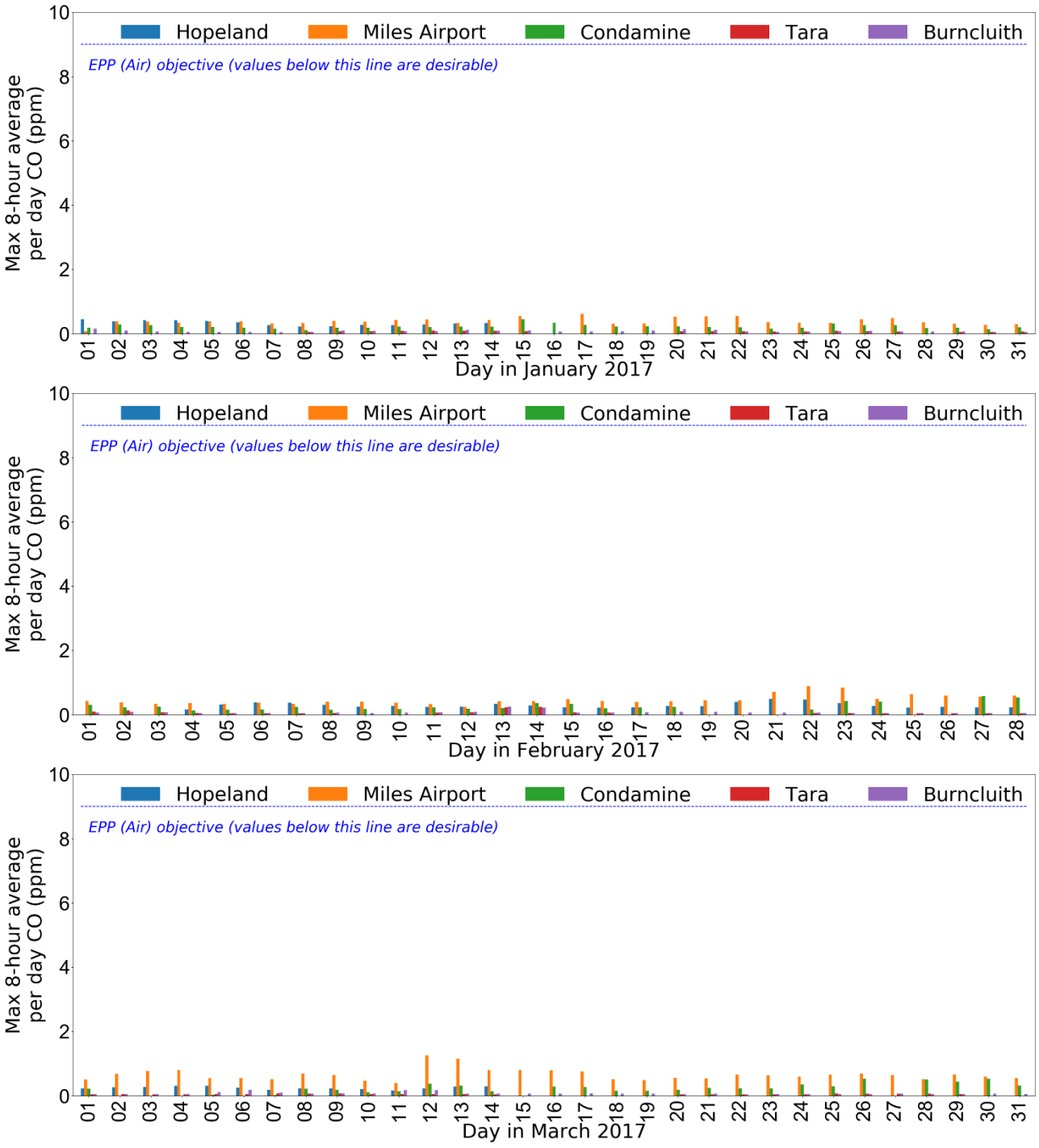

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in November 2017

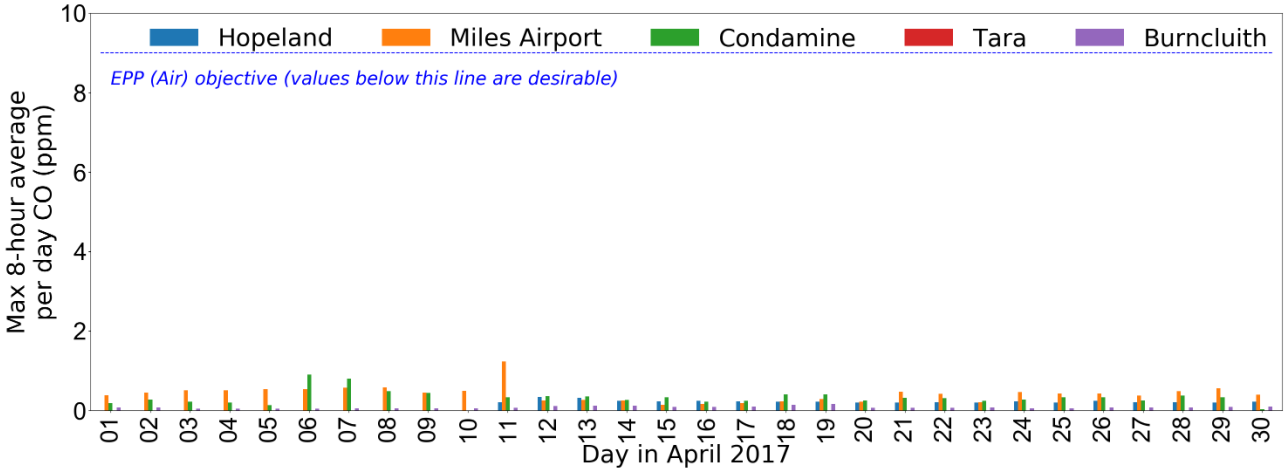

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in December 2017

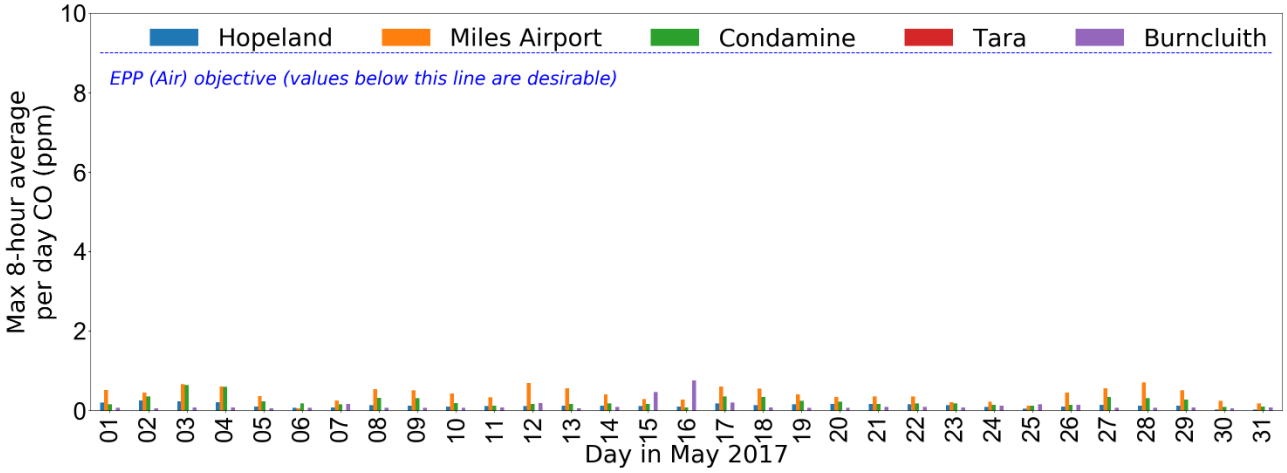

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in January 2018

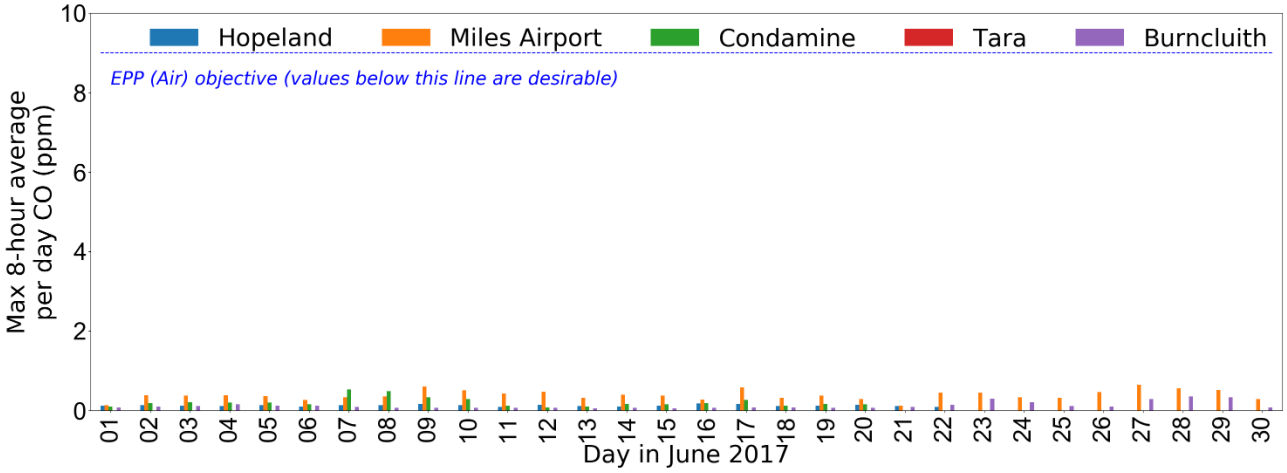

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 1-hour average per day O3 (ppb)
Day in February 2018

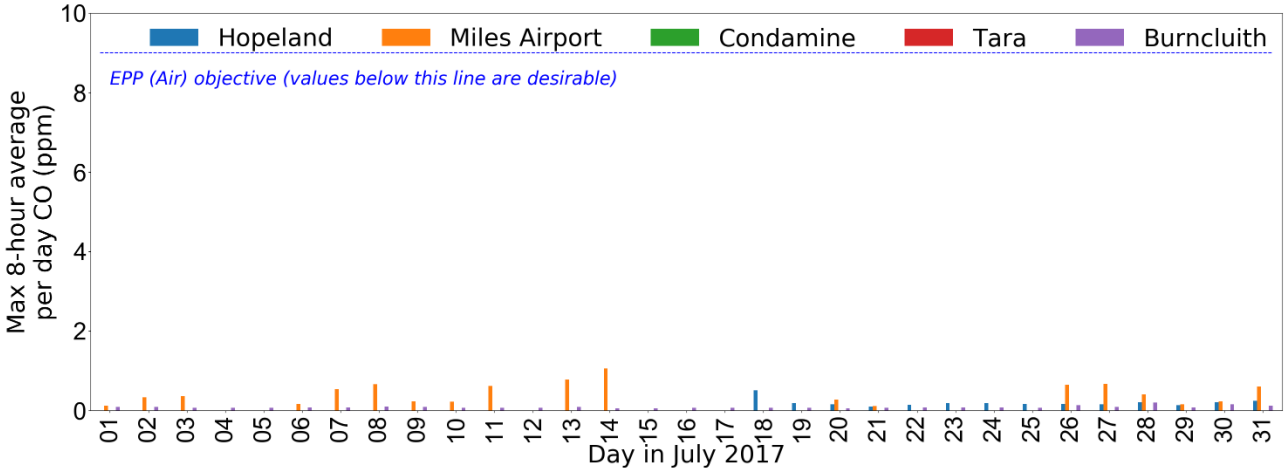
A.5.5 **Carbon monoxide - maximum 8-hour concentrations, January 2017 – February 2018**

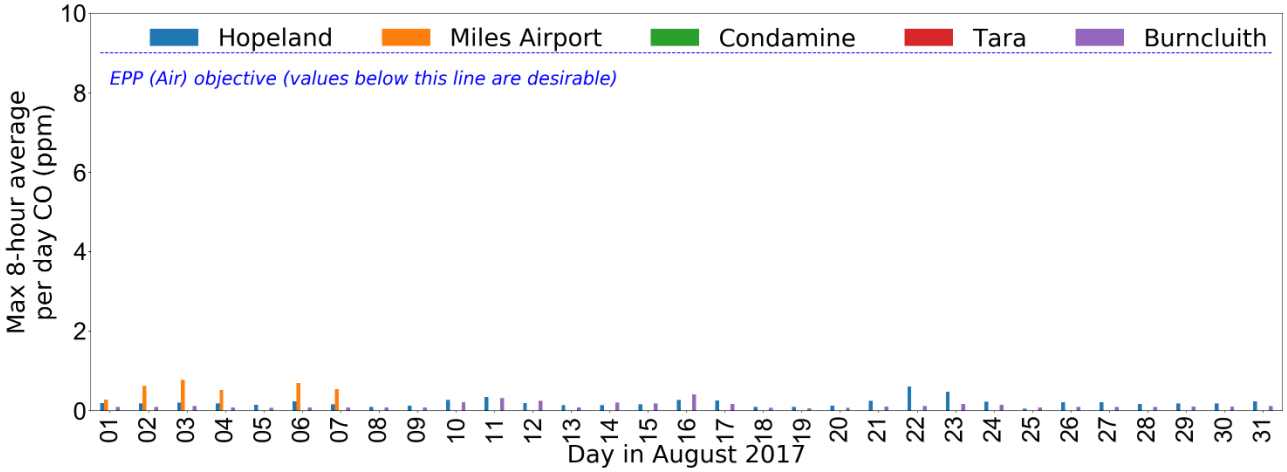


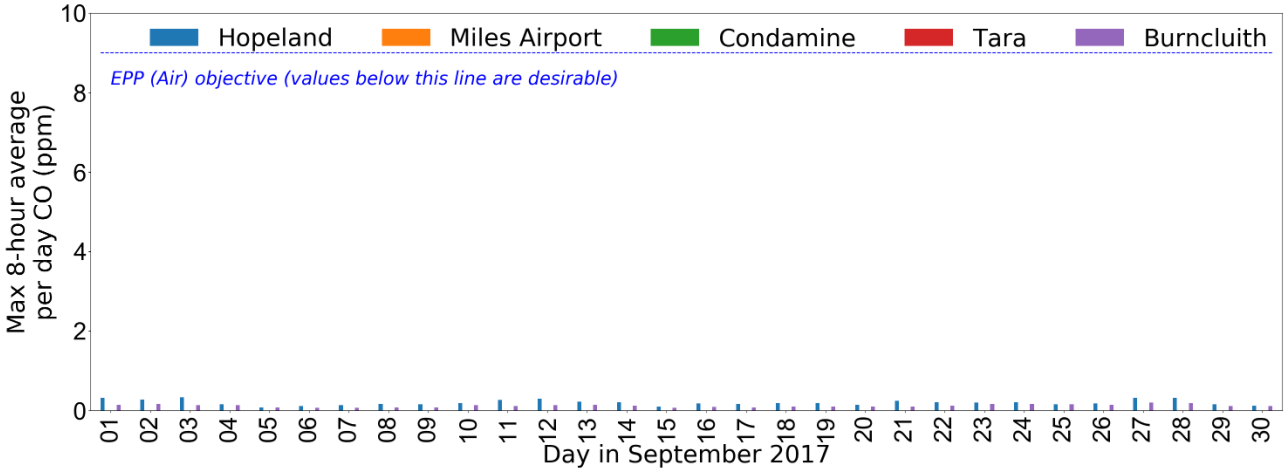

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in April 2017

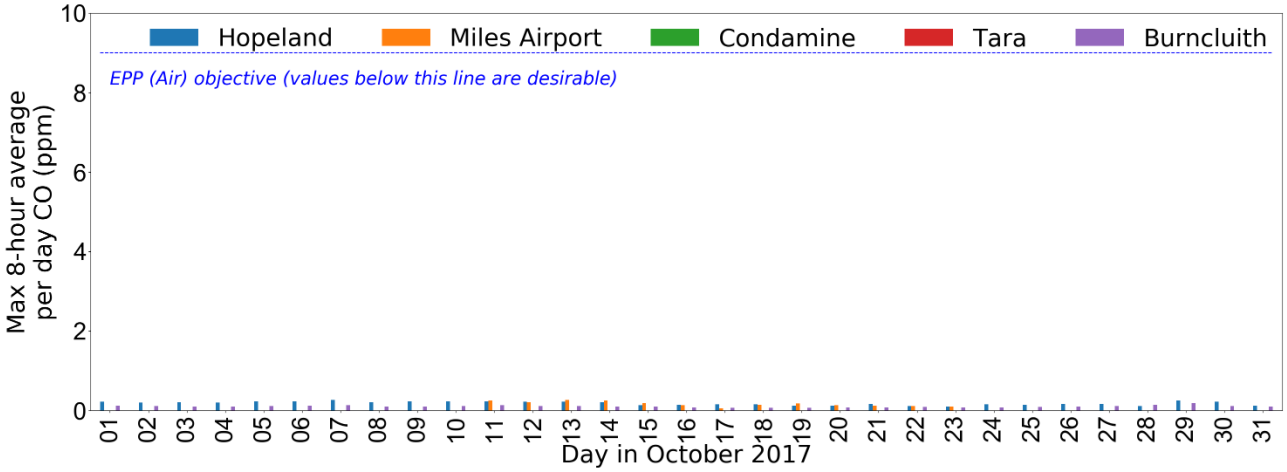

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in May 2017

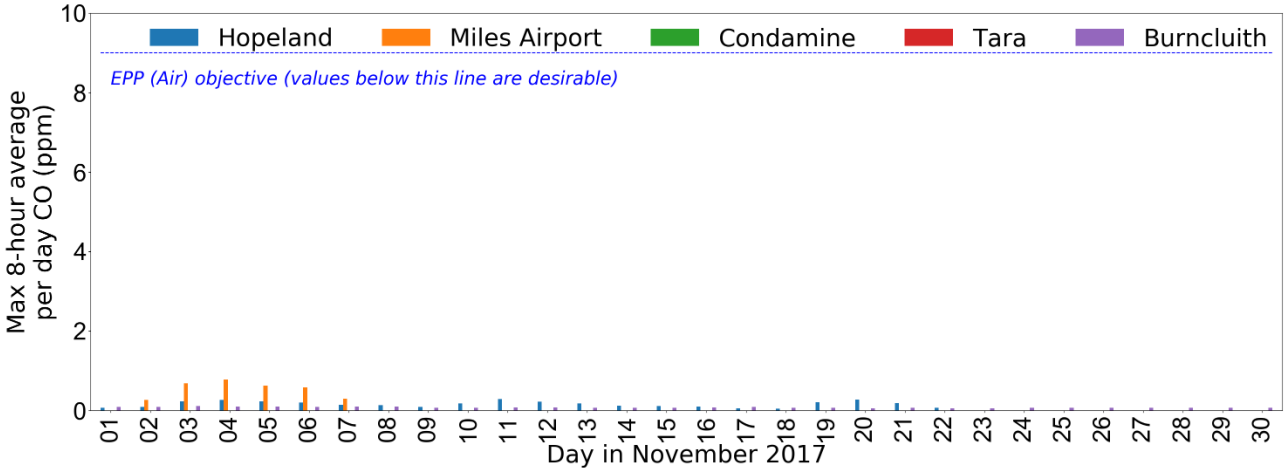

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in June 2017

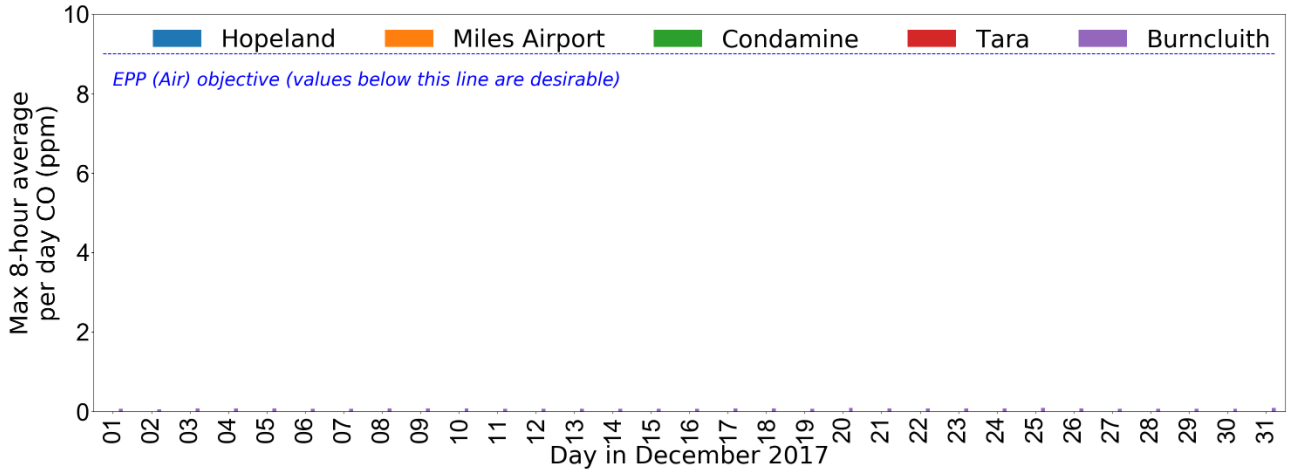

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in July 2017

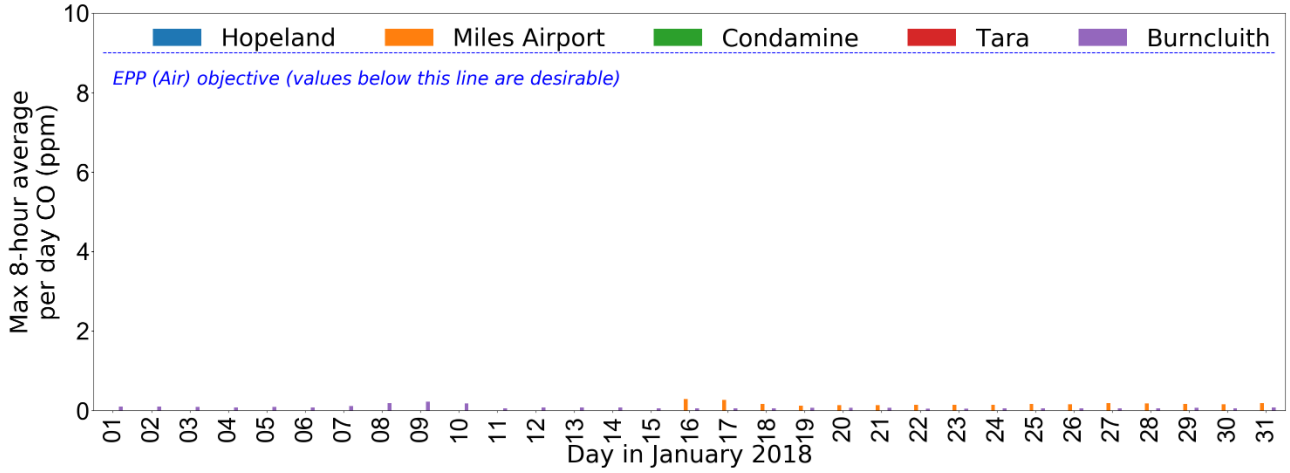

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in August 2017

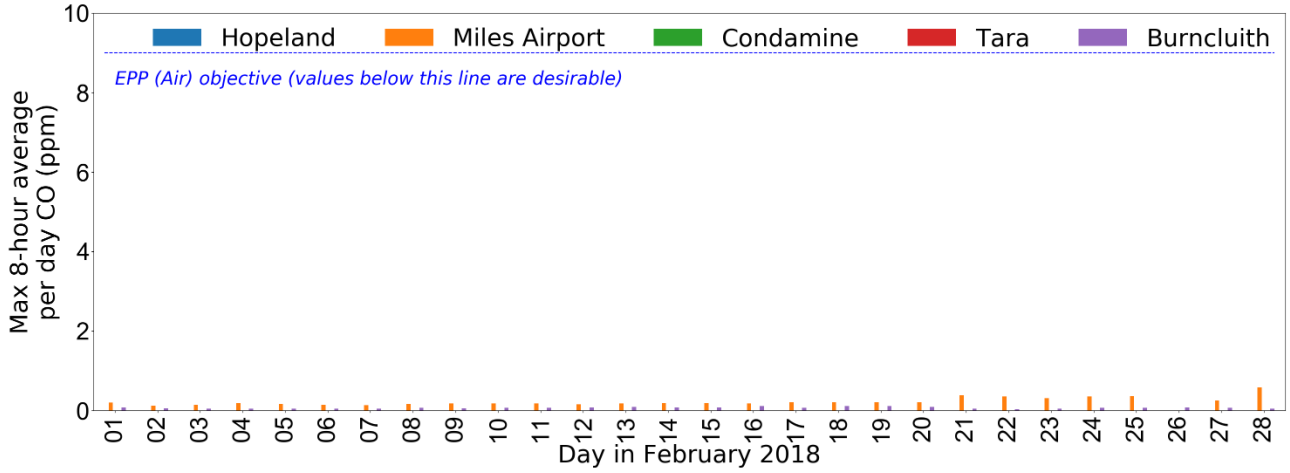

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in September 2017


Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in October 2017

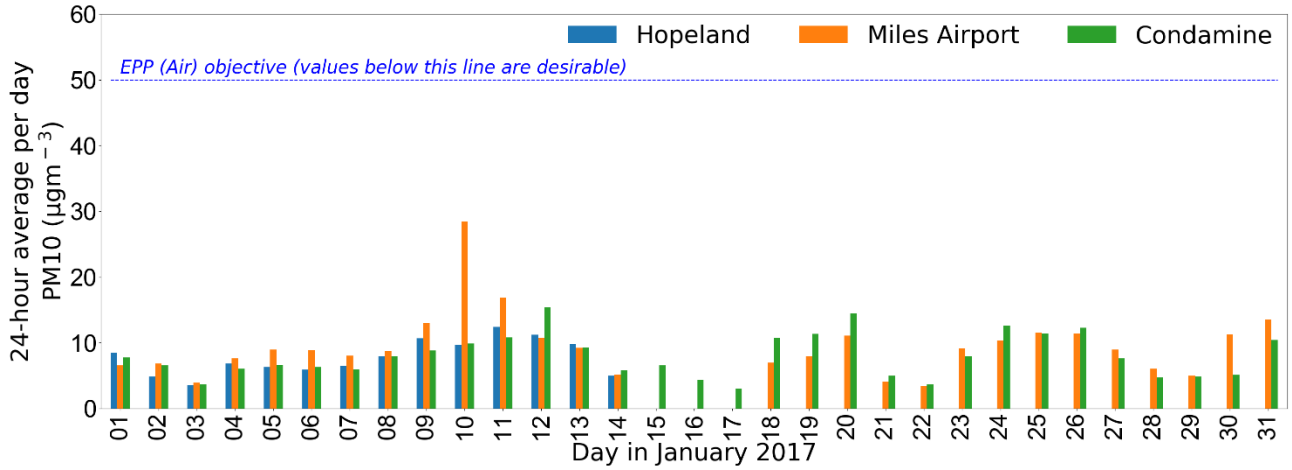

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in November 2017

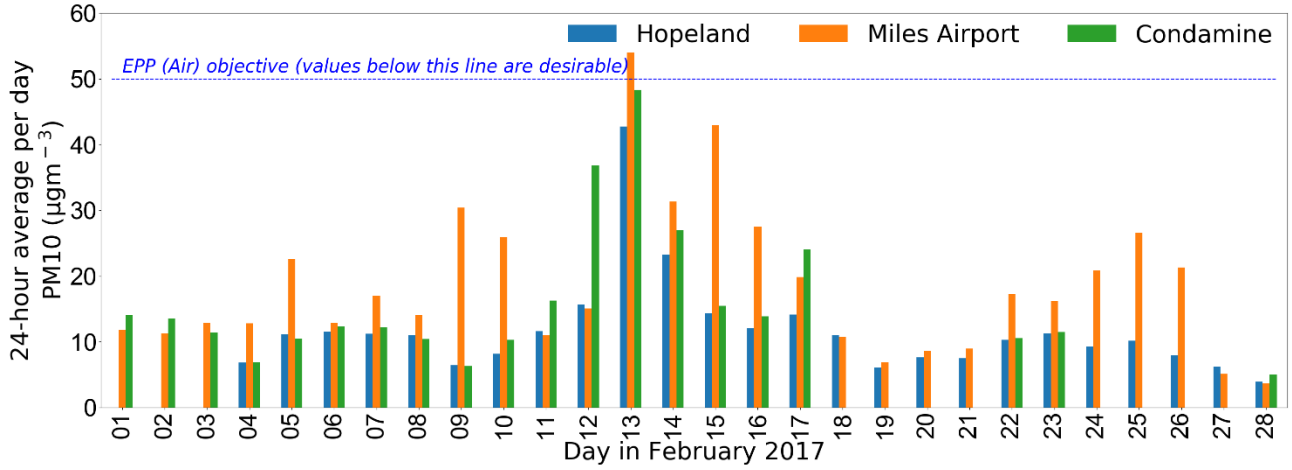

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in December 2017

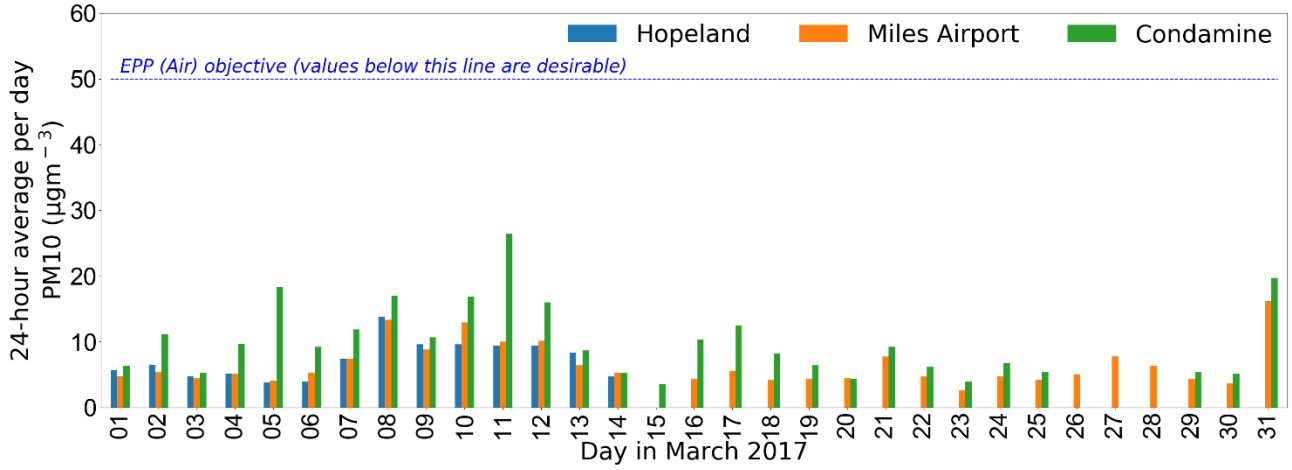

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in January 2018

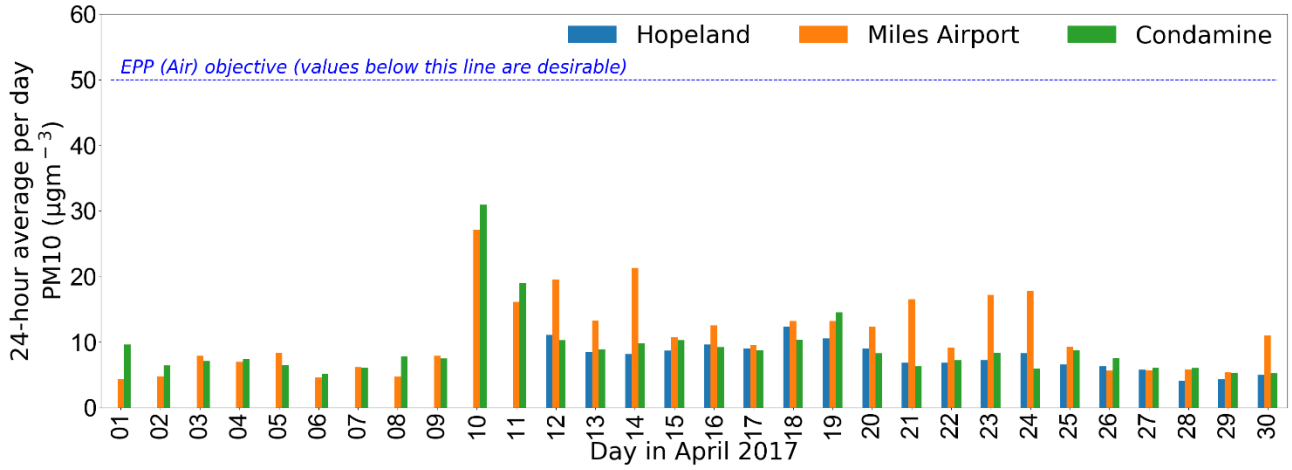

Hopeland
Miles Airport
Condamine
Tara
Burncluith
EPP (Air) objective (values below this line are desirable)
Max 8-hour average per day CO (ppm)
Day in February 2018

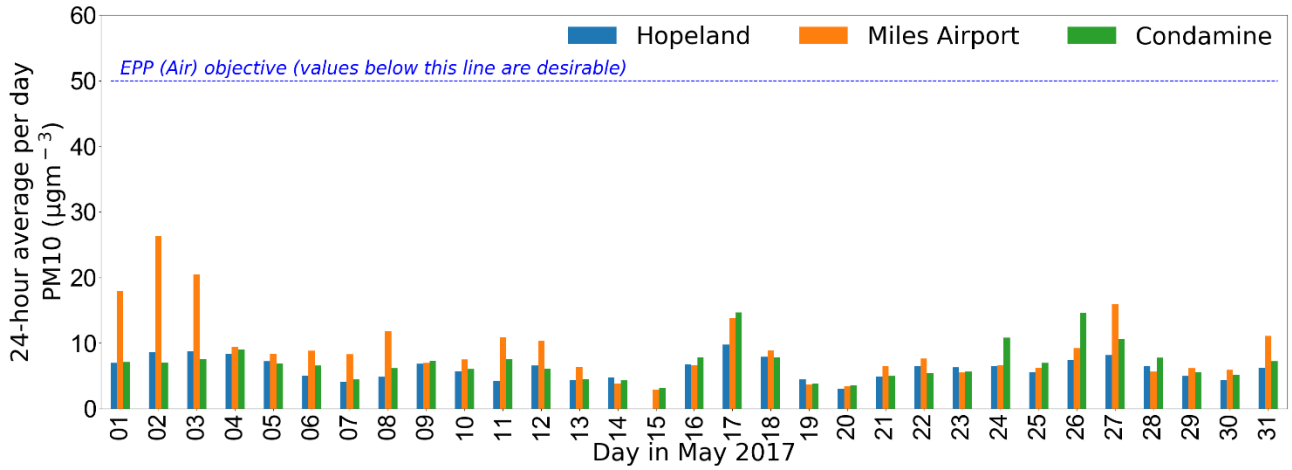
A.5.6 **PM10 – 24 hour averages from January 2017– February 2018**

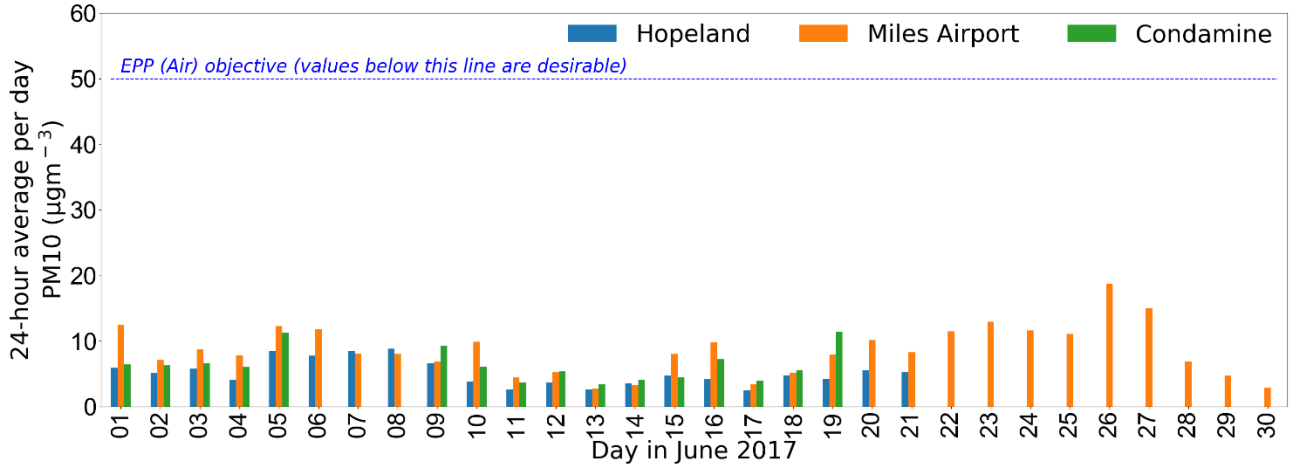


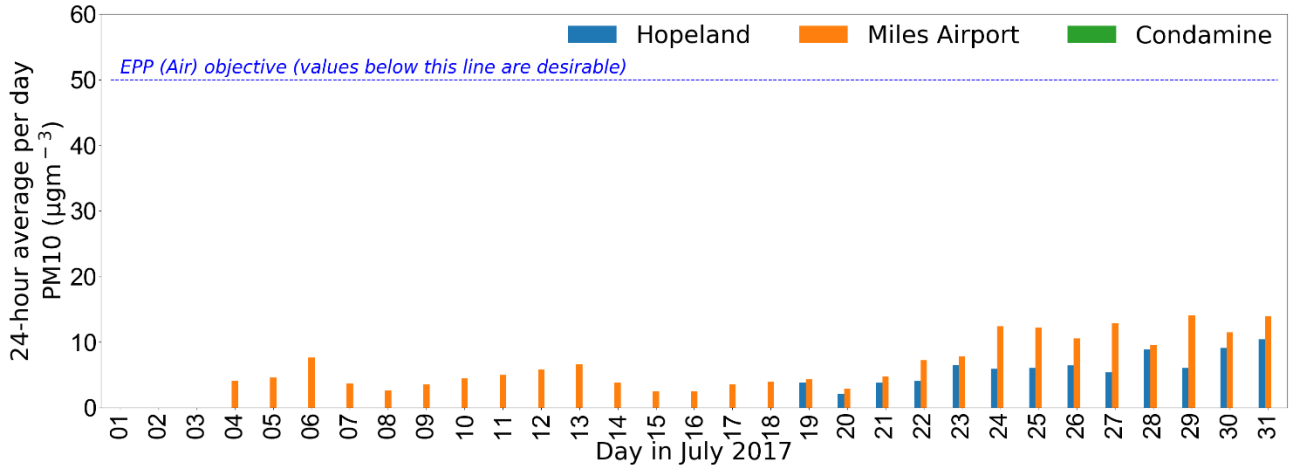


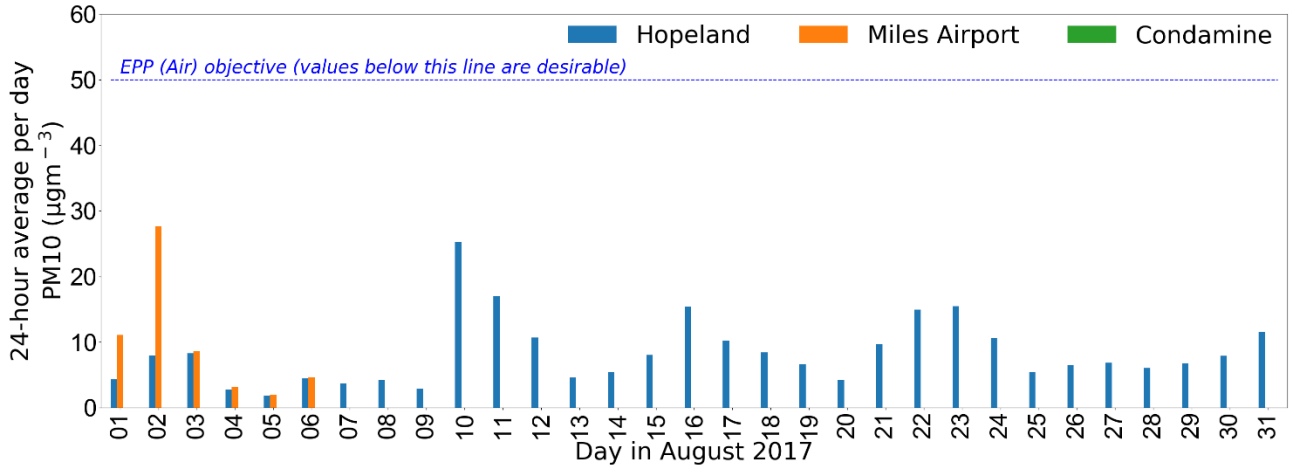


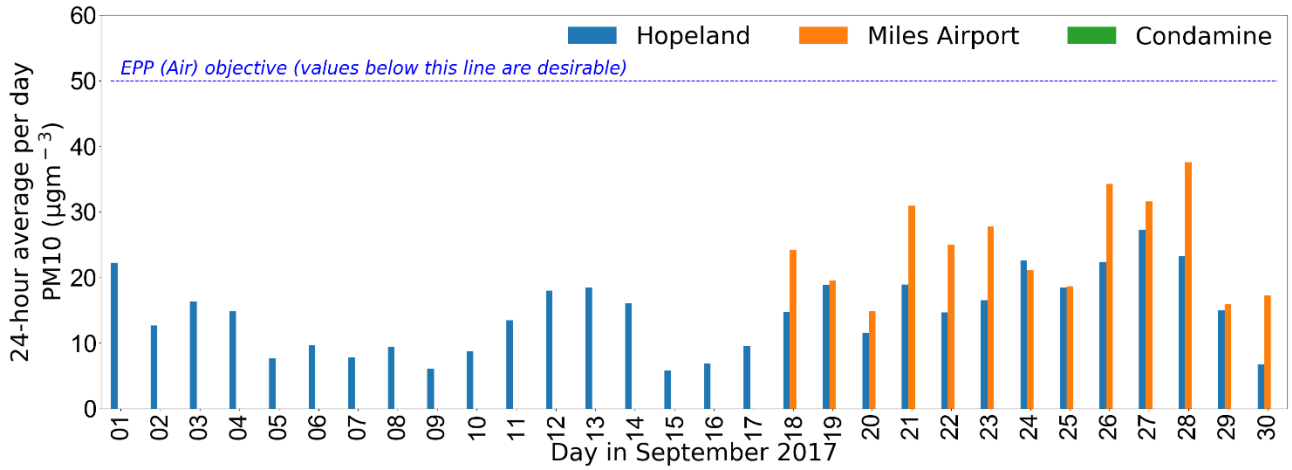

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in April 2017

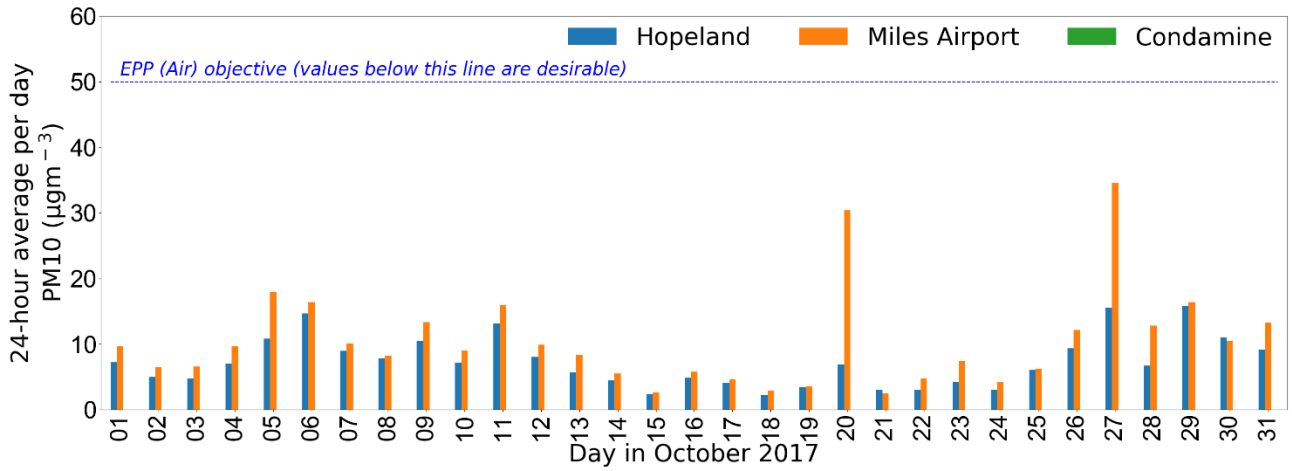

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in May 2017

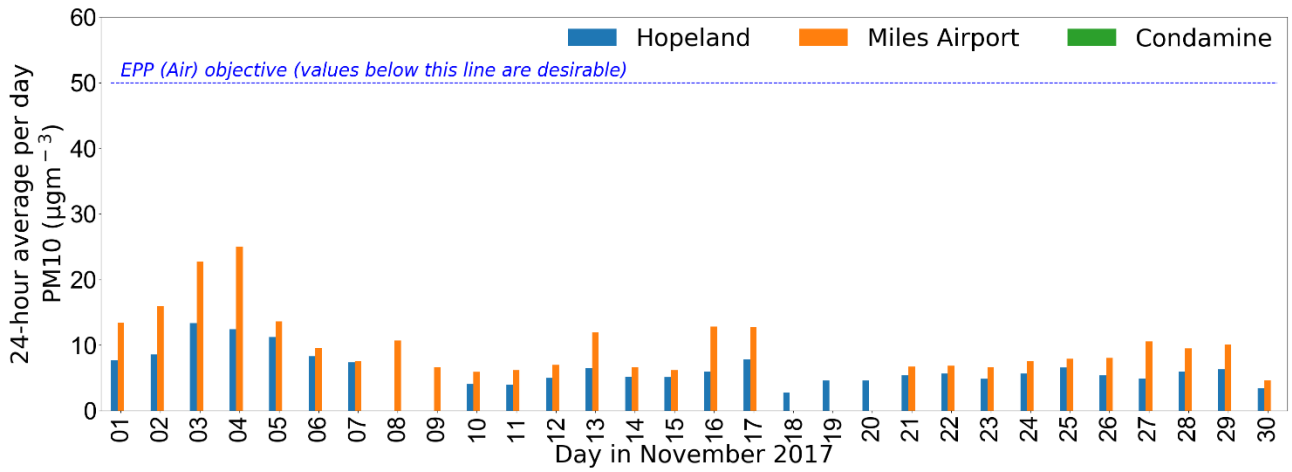

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in June 2017

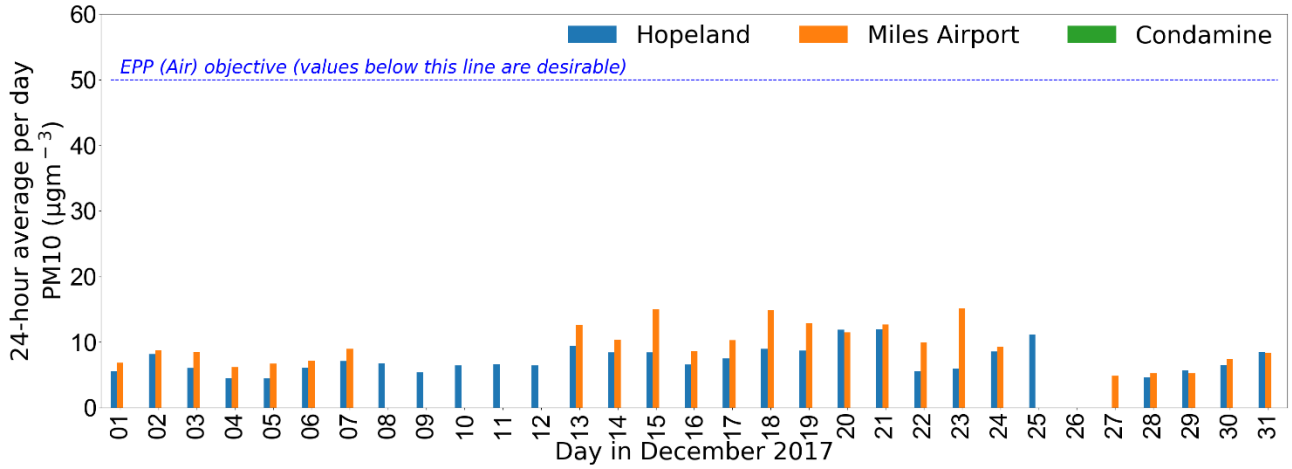

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in July 2017

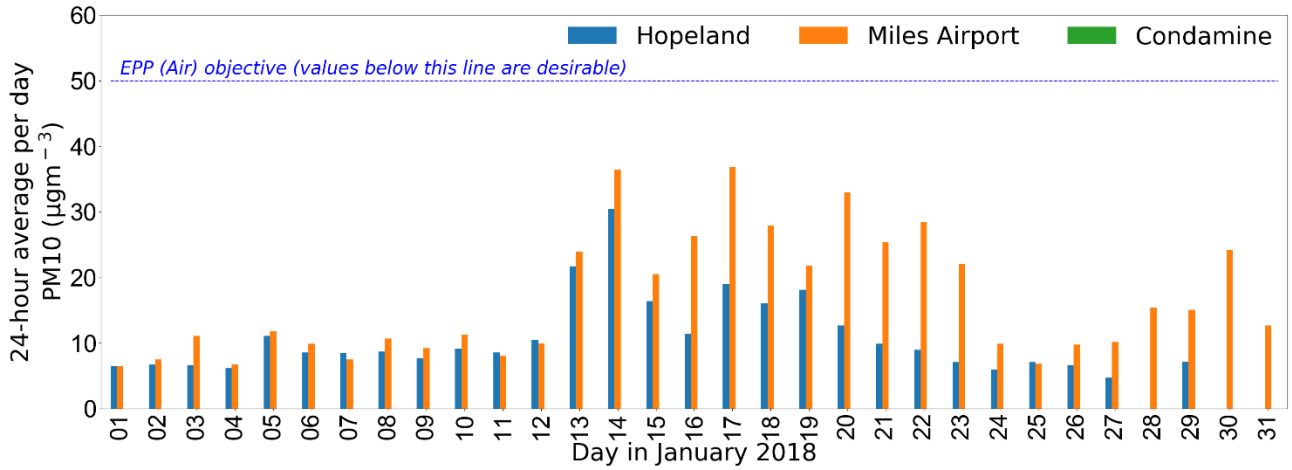

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in August 2017

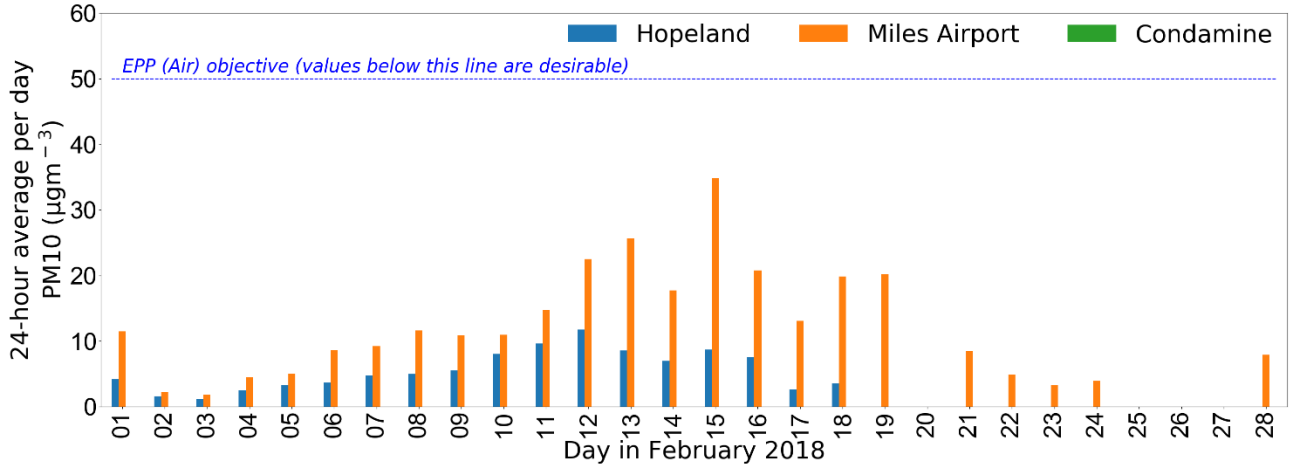

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in September 2017


Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in October 2017

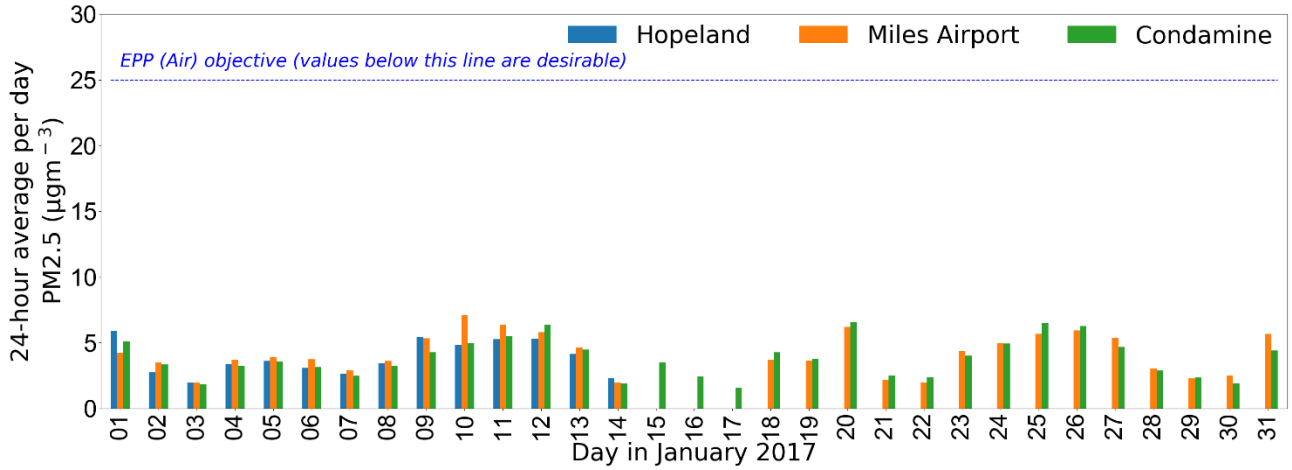

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in November 2017

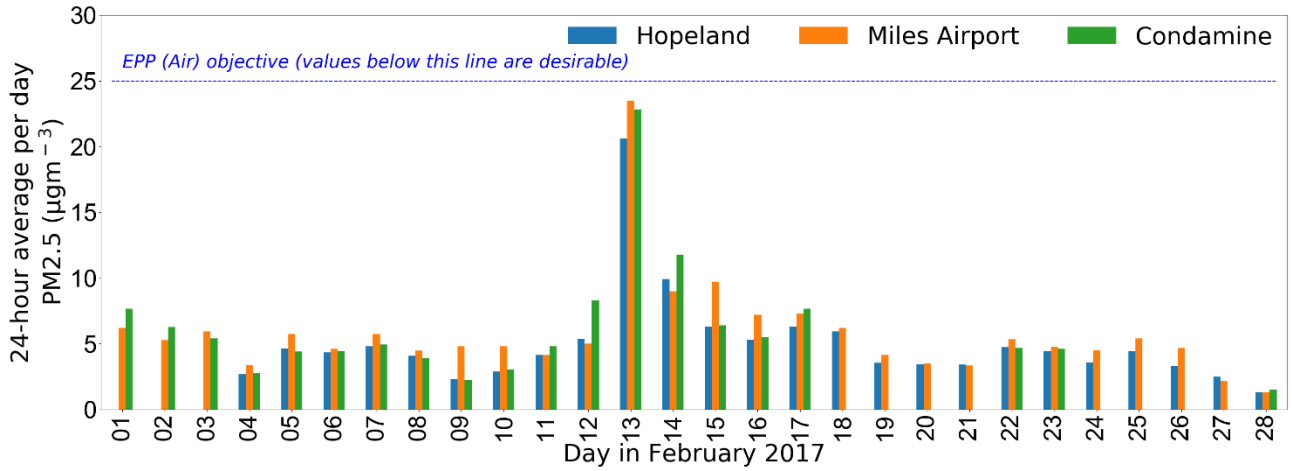

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in December 2017

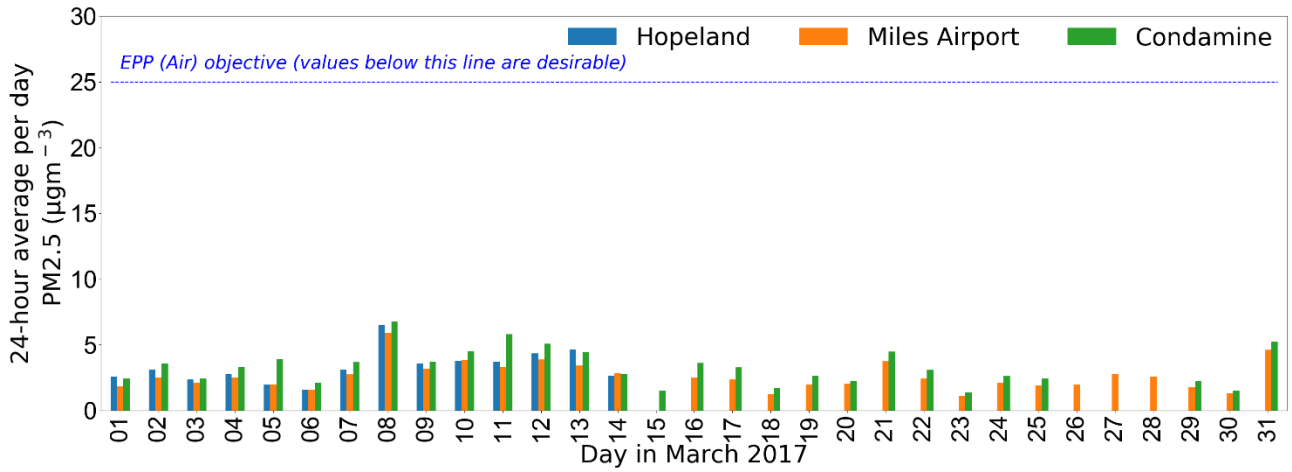

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in January 2018

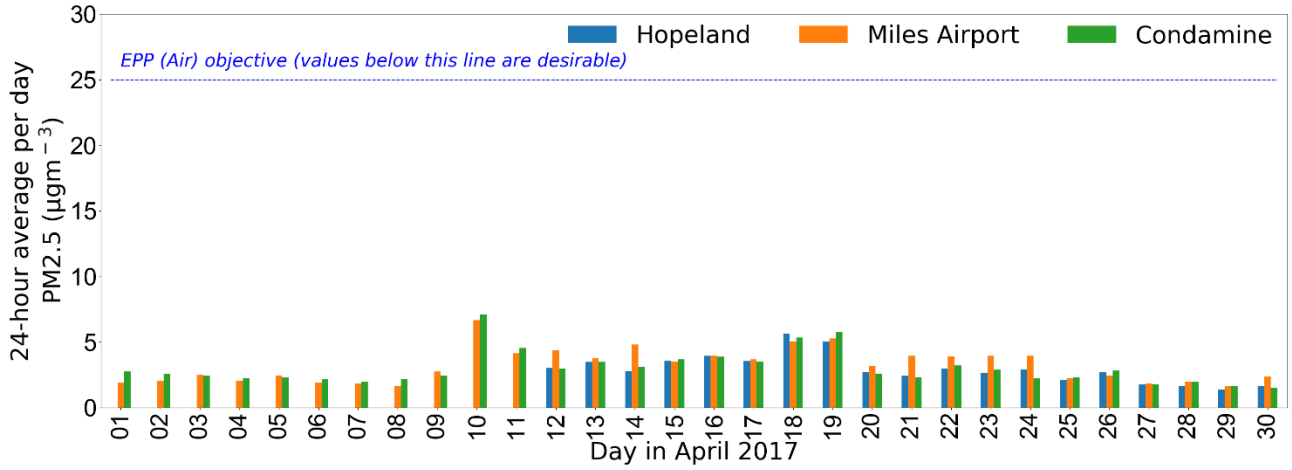

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM10 (µgm⁻³)
Day in February 2018

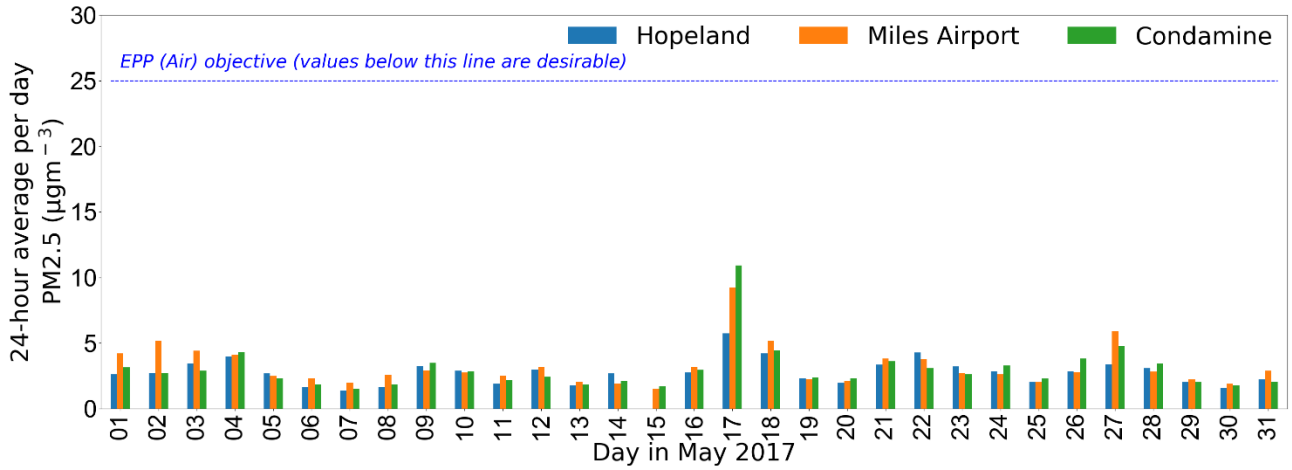
A.5.7 **PM2.5 – 24 hour averages, January 2017 – February 2018**

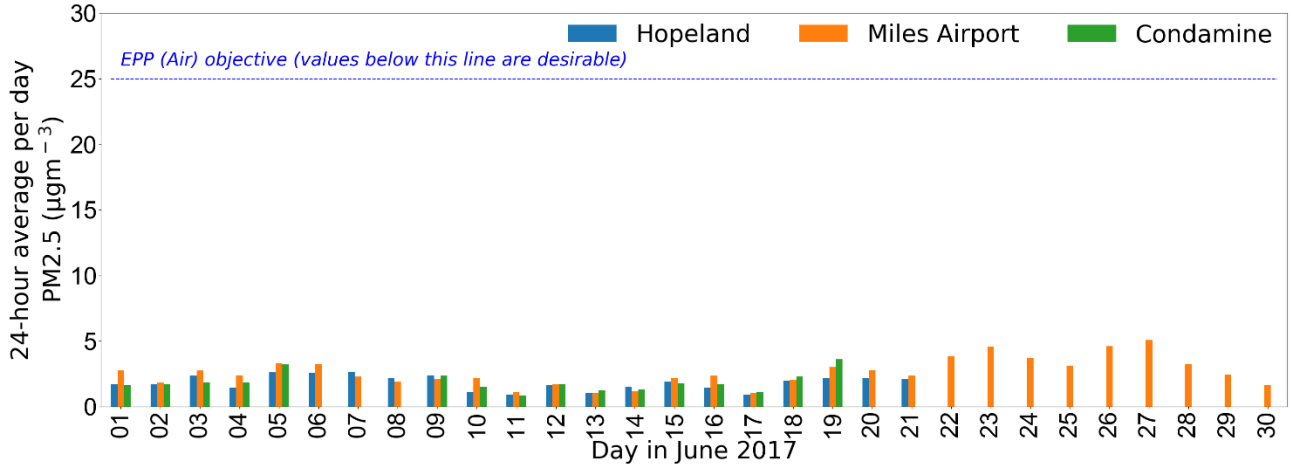


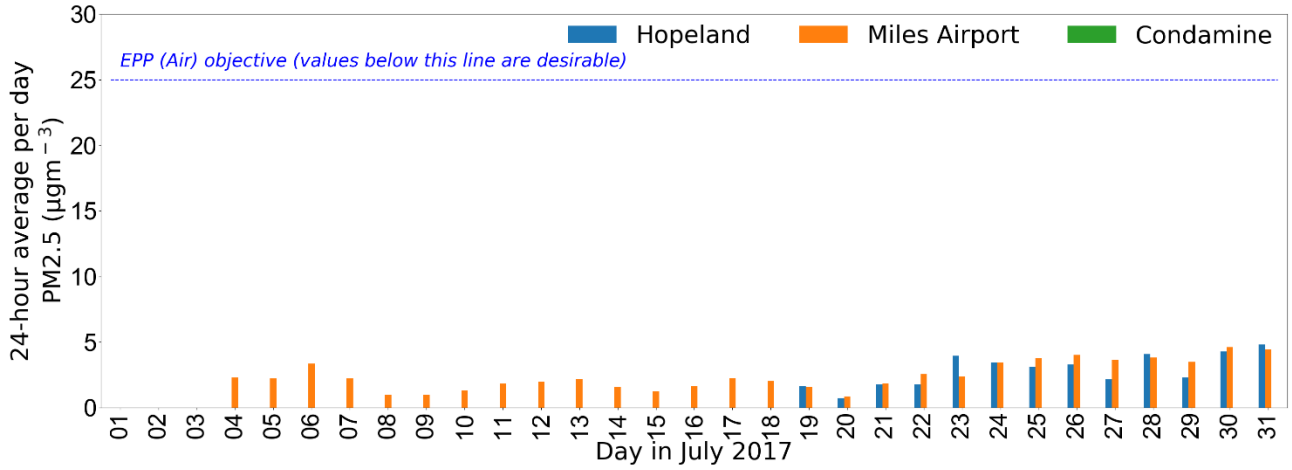


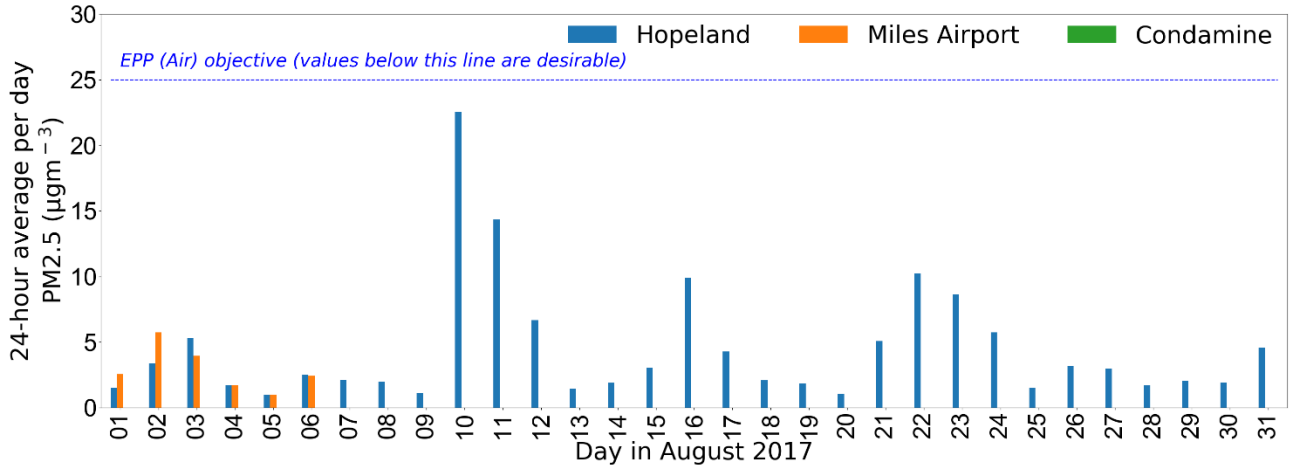


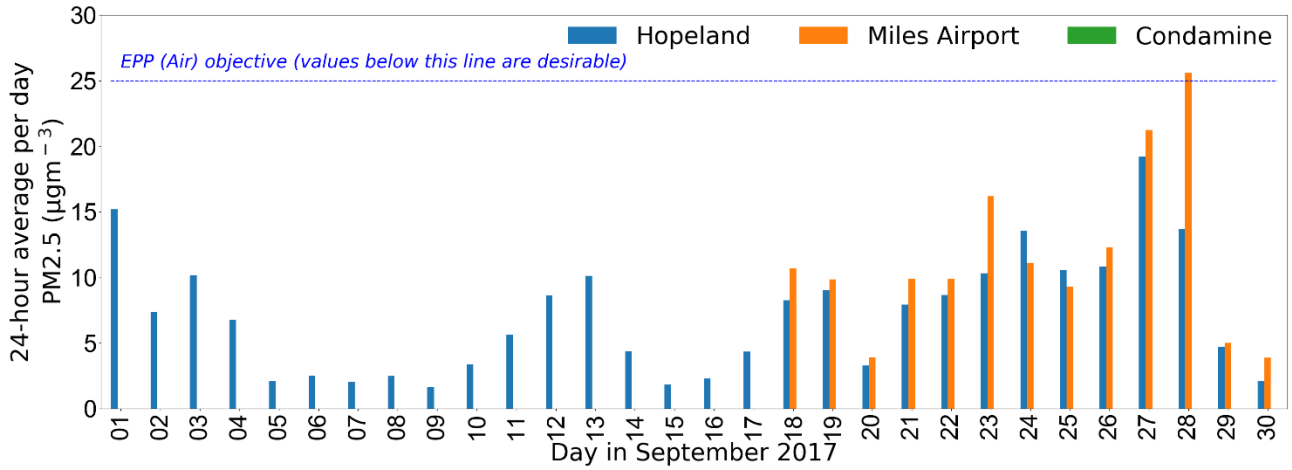

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in April 2017

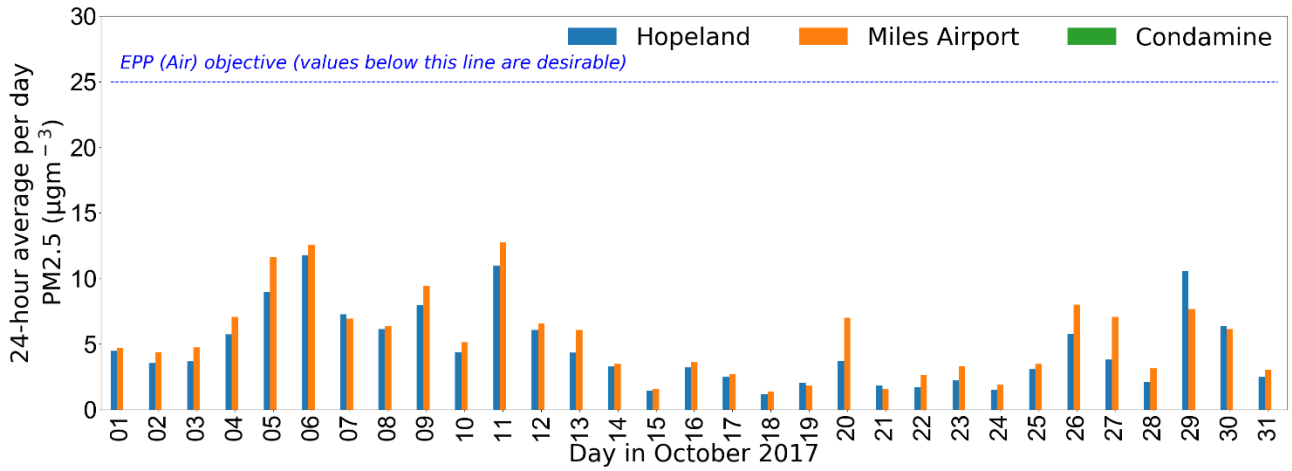

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in May 2017

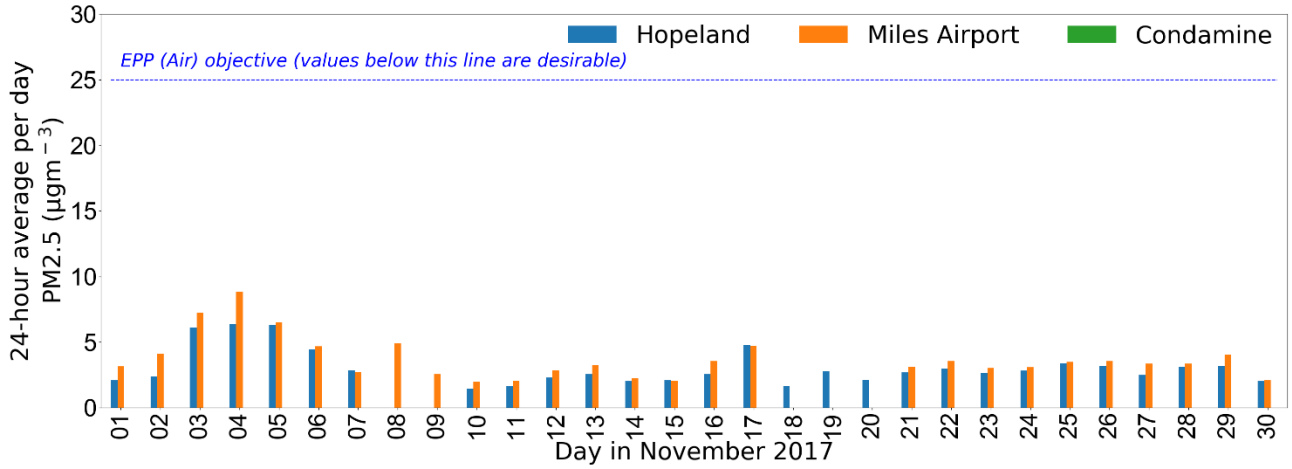

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in June 2017

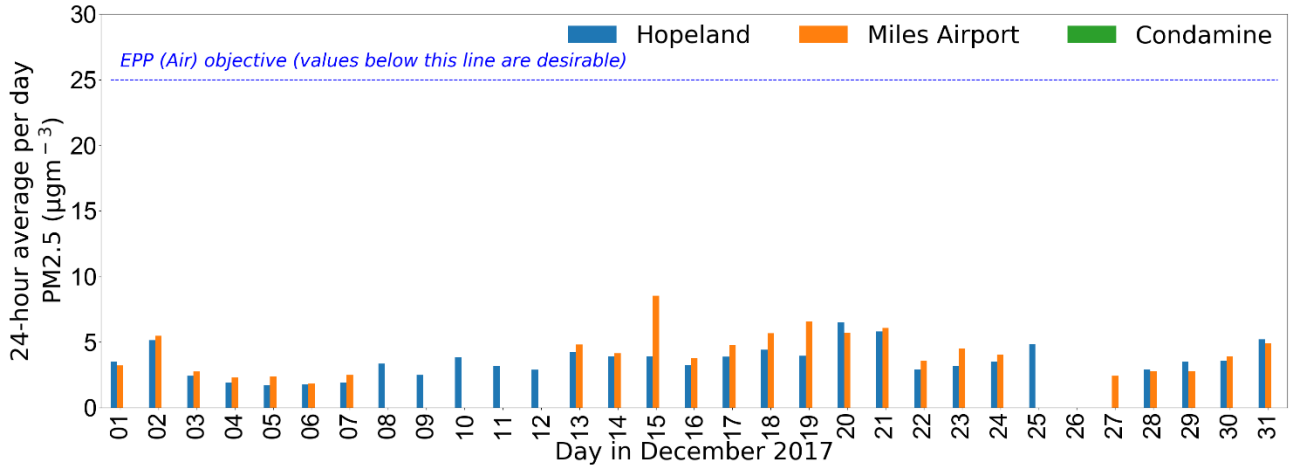

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in July 2017

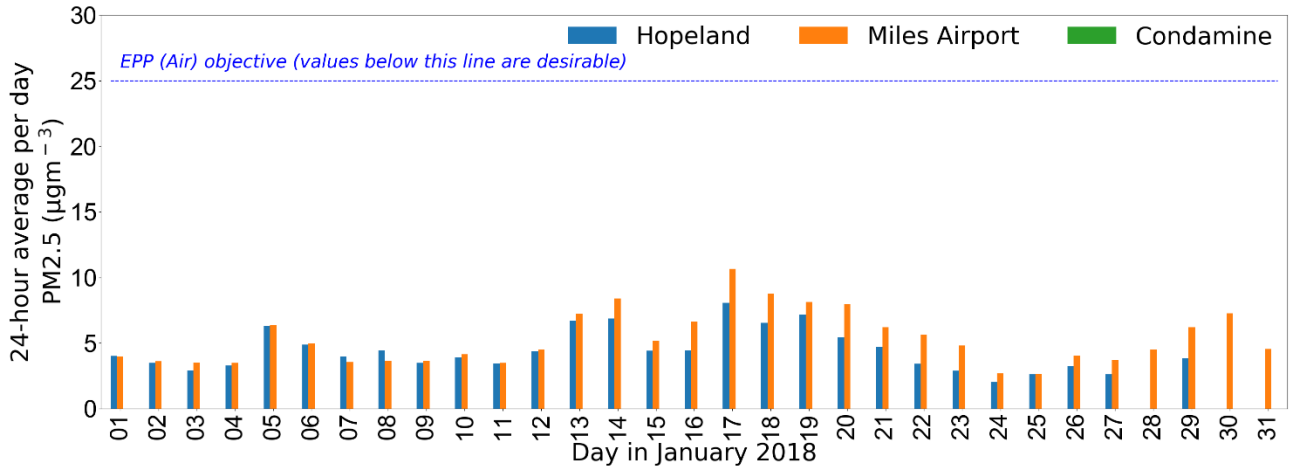

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in August 2017

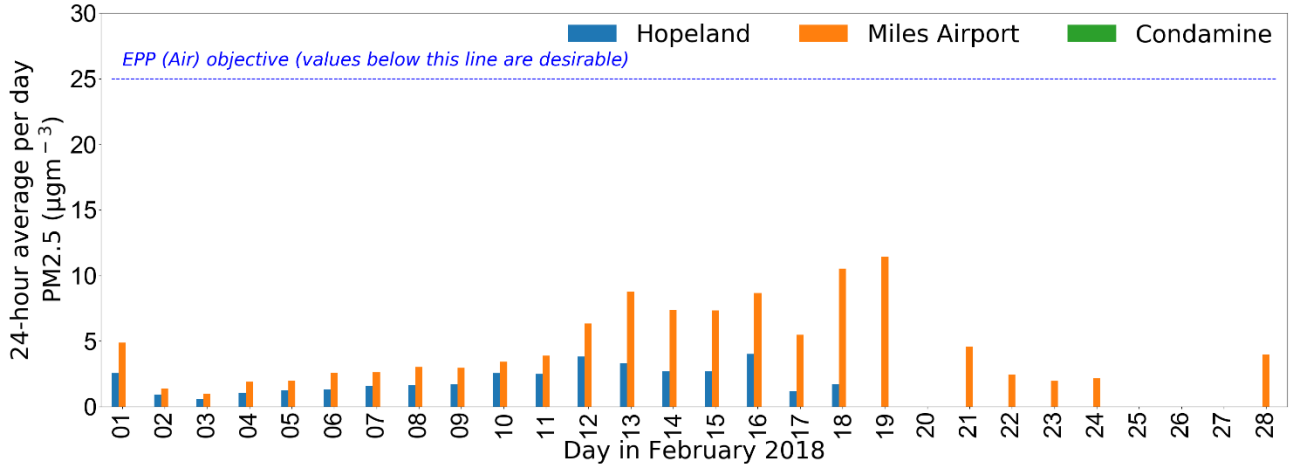

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in September 2017


Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in October 2017

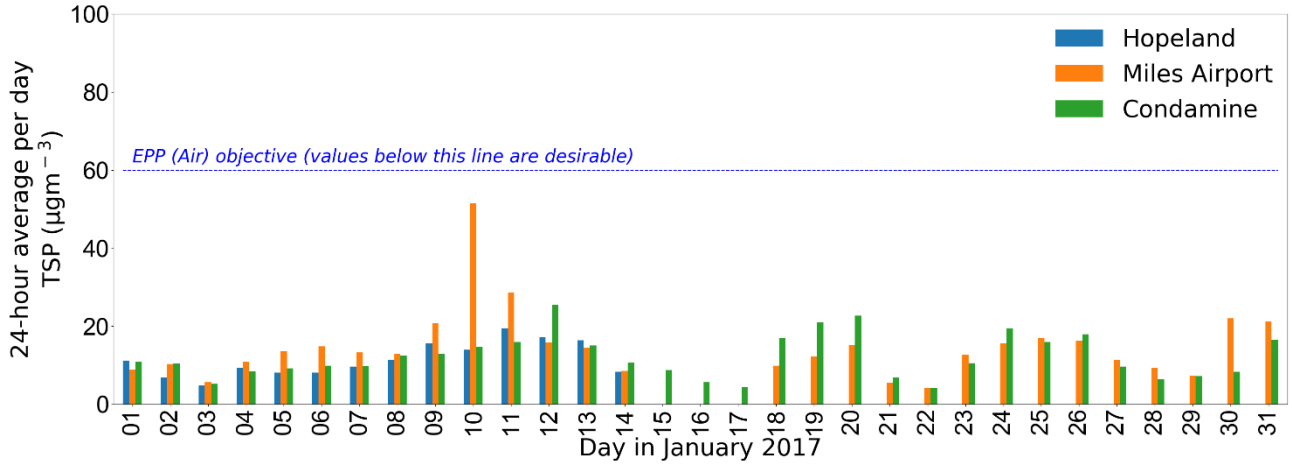

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in November 2017

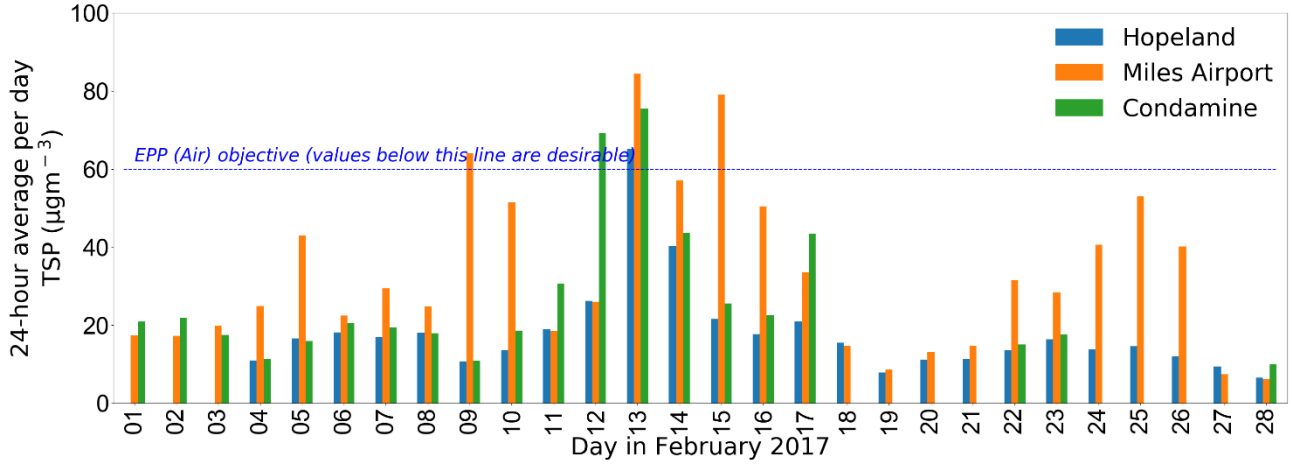

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in December 2017

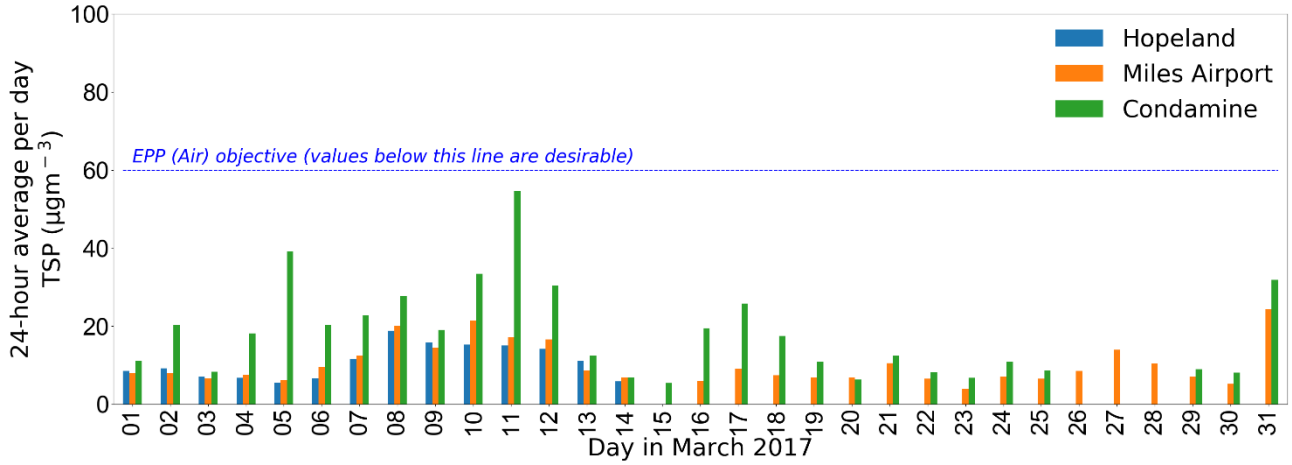

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in January 2018

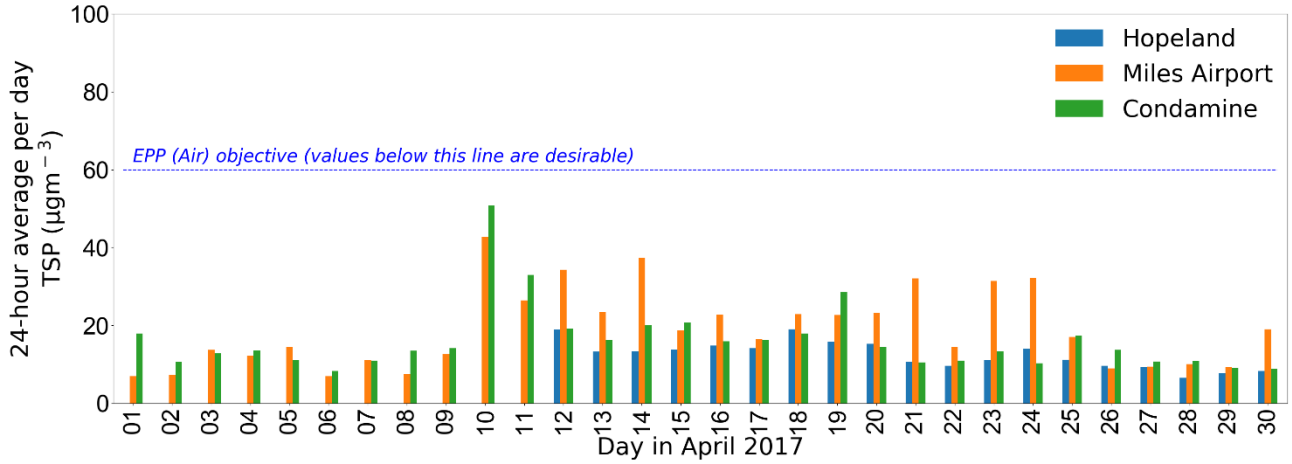

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
PM2.5 (µgm⁻³)
Day in February 2018

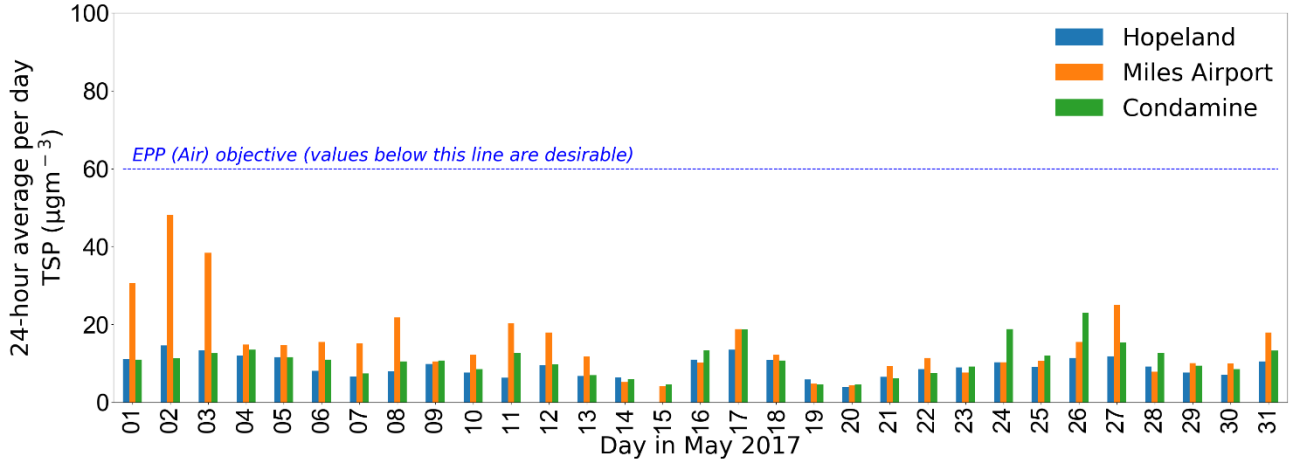
A.5.8 **TSP- 24 hour averages, January 2017 – February 2018**

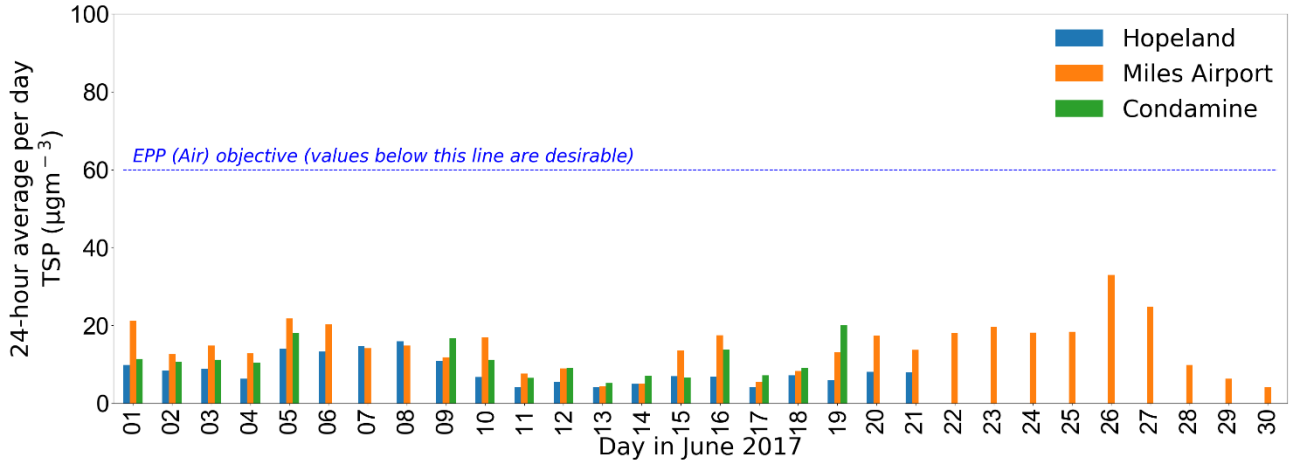


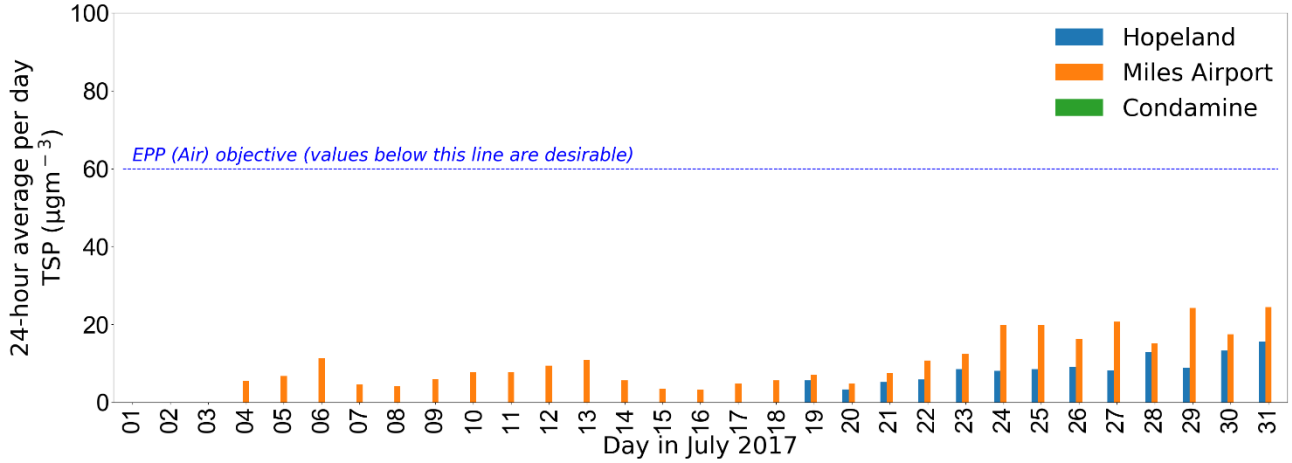


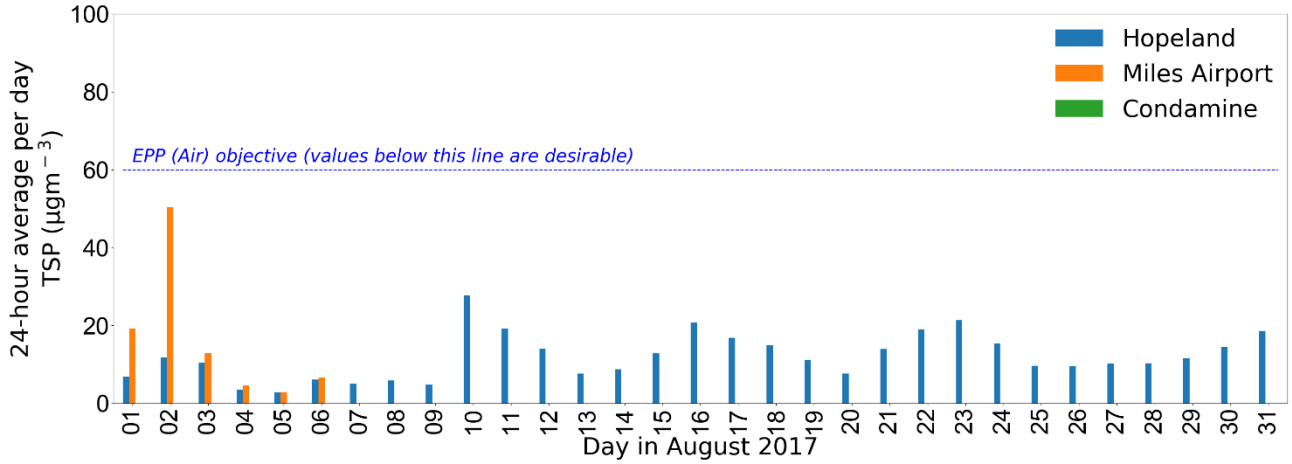


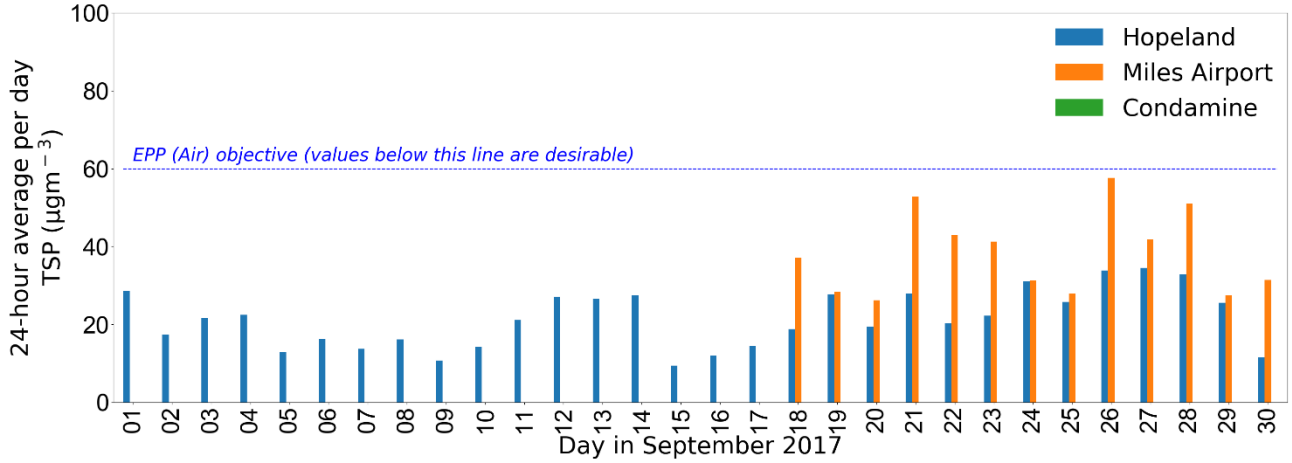

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in April 2017

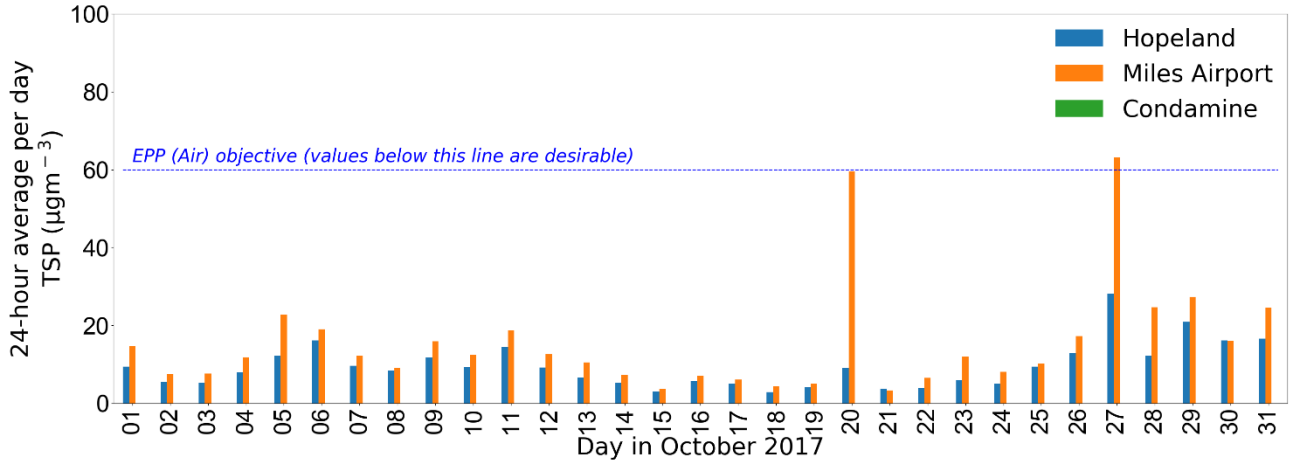

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in May 2017

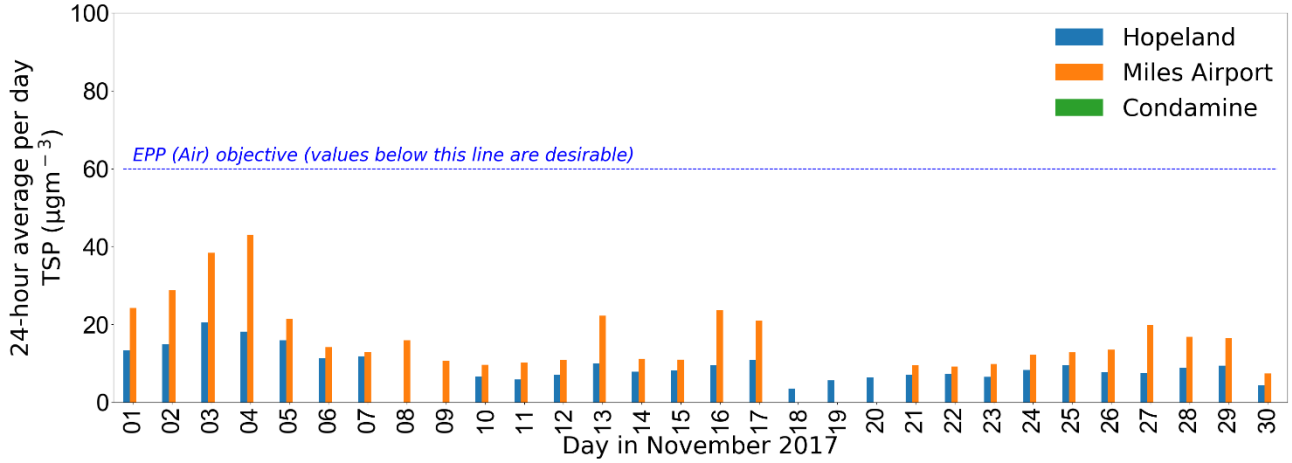

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in June 2017

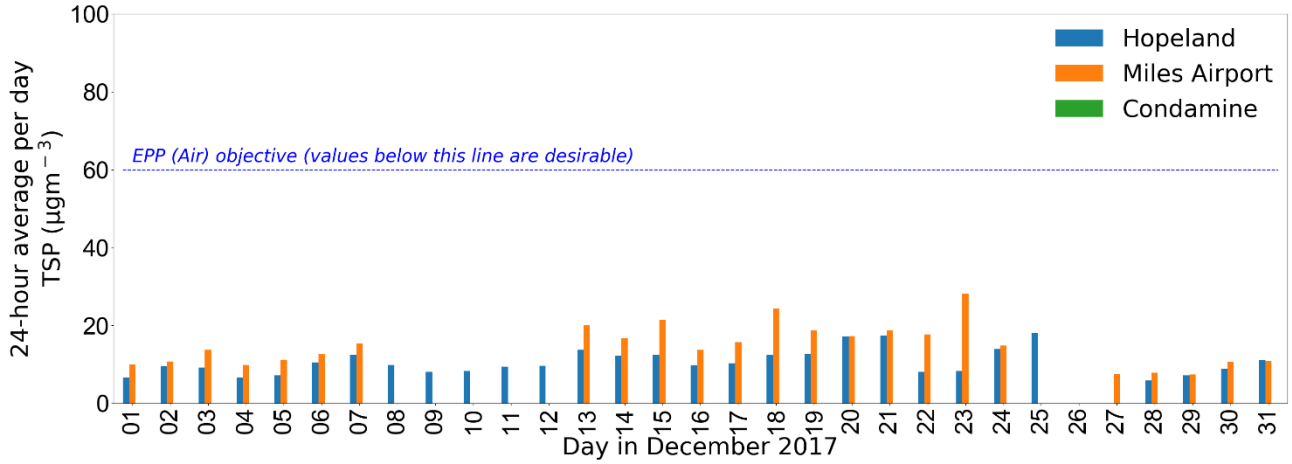

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in July 2017

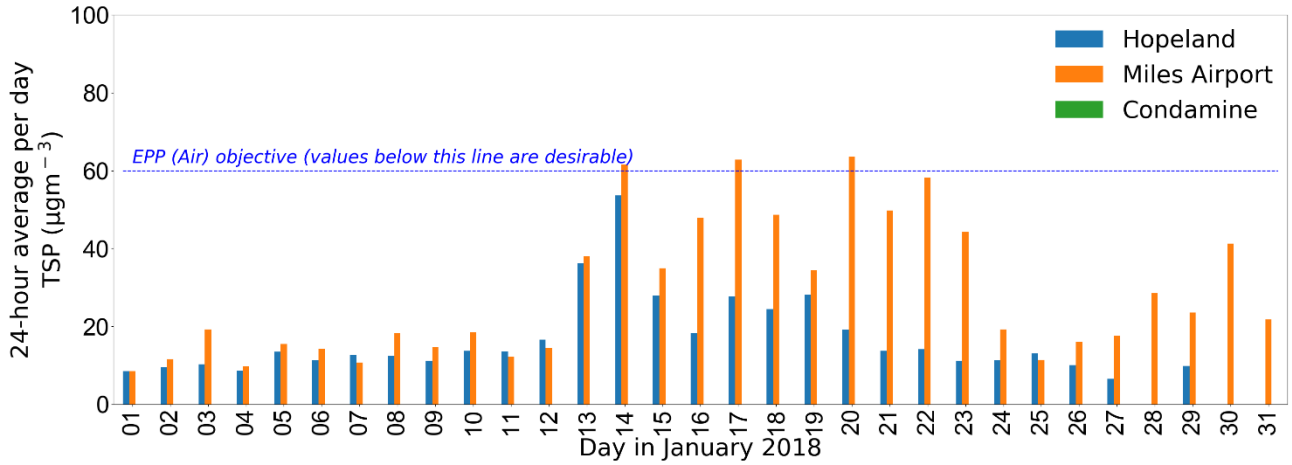

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in August 2017

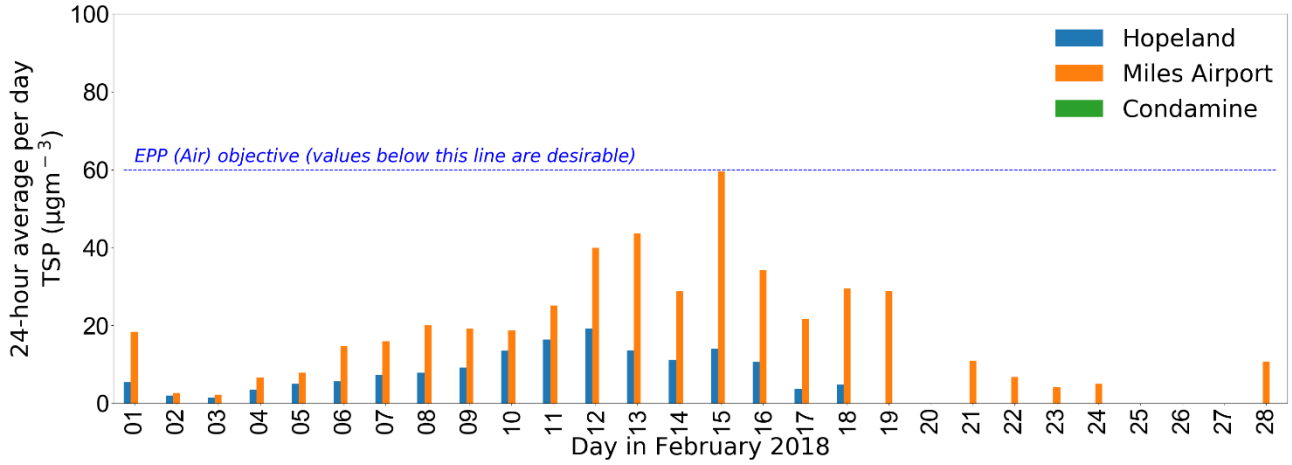

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in September 2017


Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in October 2017


Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in November 2017

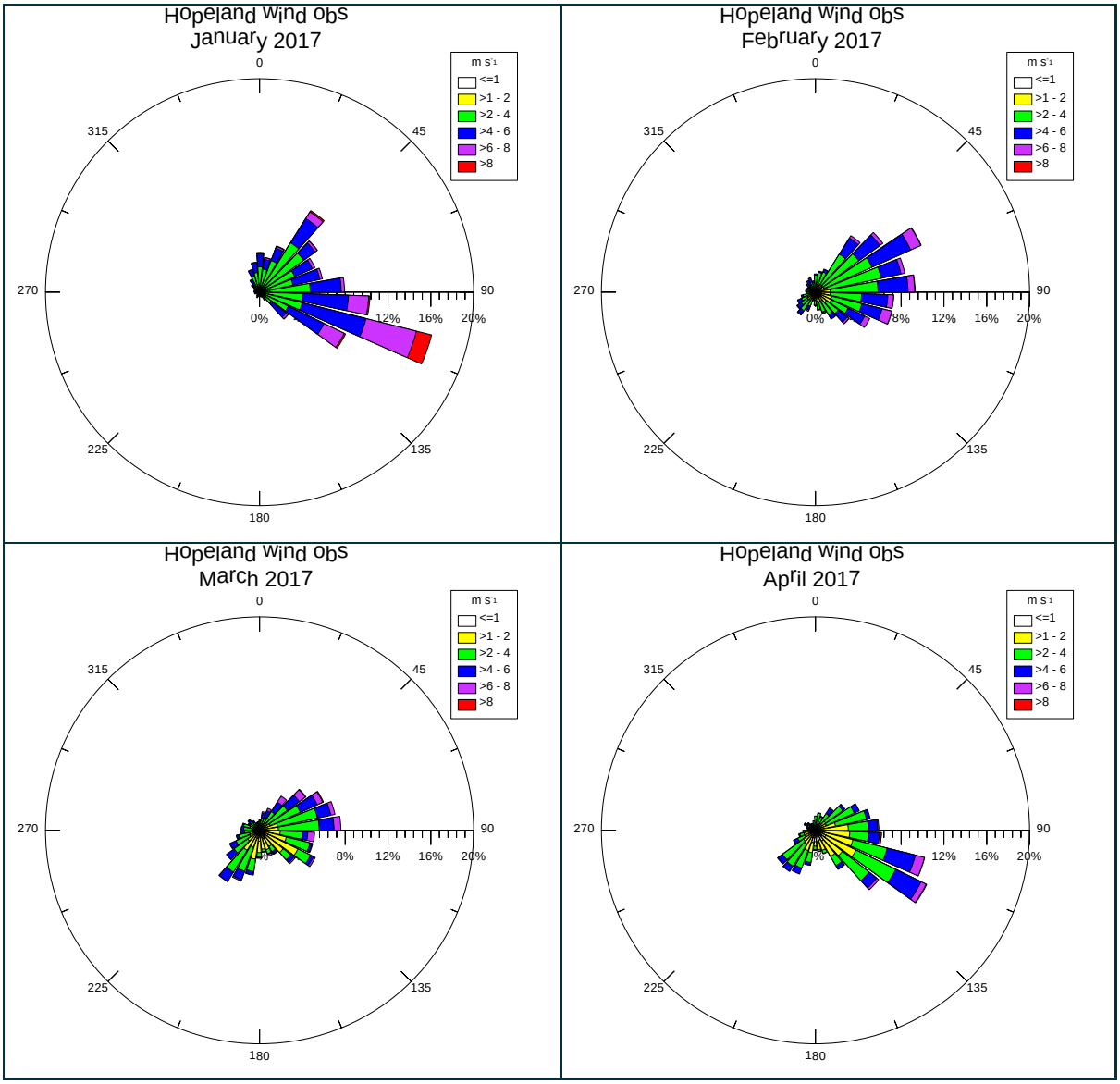

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in December 2017

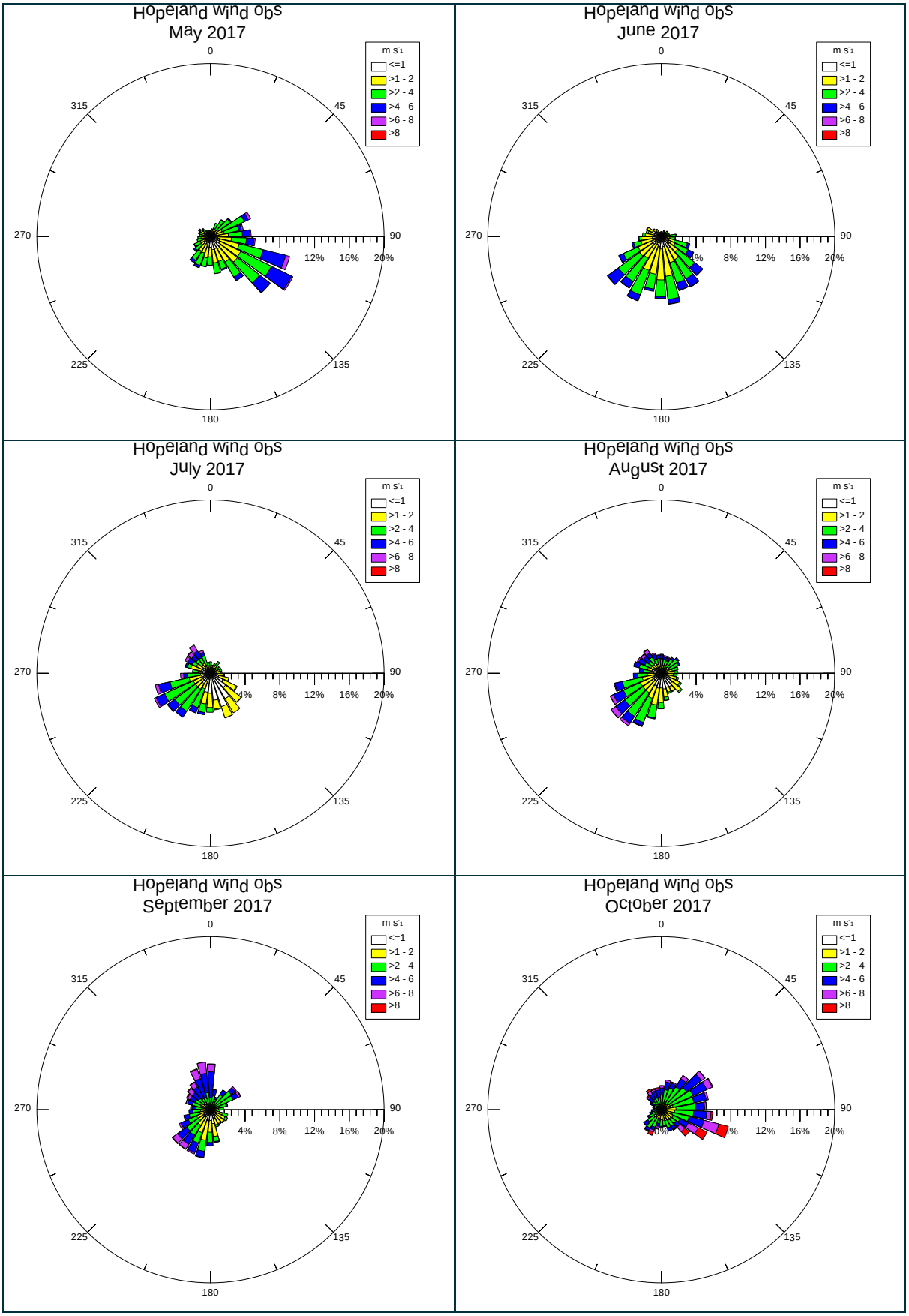

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in January 2018

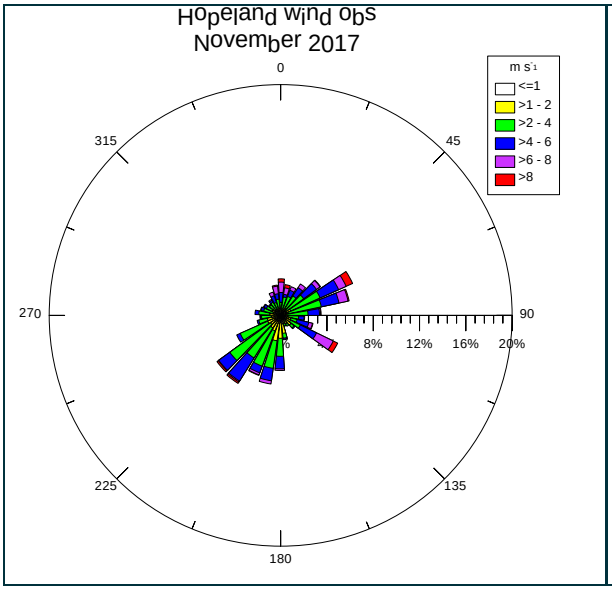

Hopeland
Miles Airport
Condamine
EPP (Air) objective (values below this line are desirable)
24-hour average per day
TSP (µgm⁻³)
Day in February 2018

A.6 Monthly wind roses from 2017 -2018

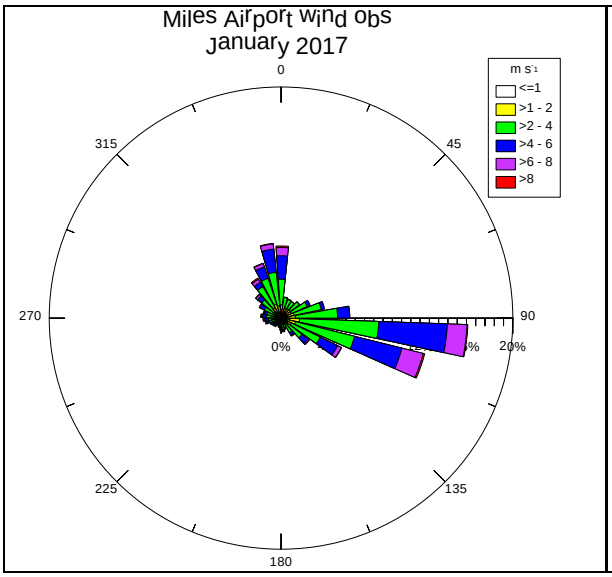
A.6.1 **Hopeland**

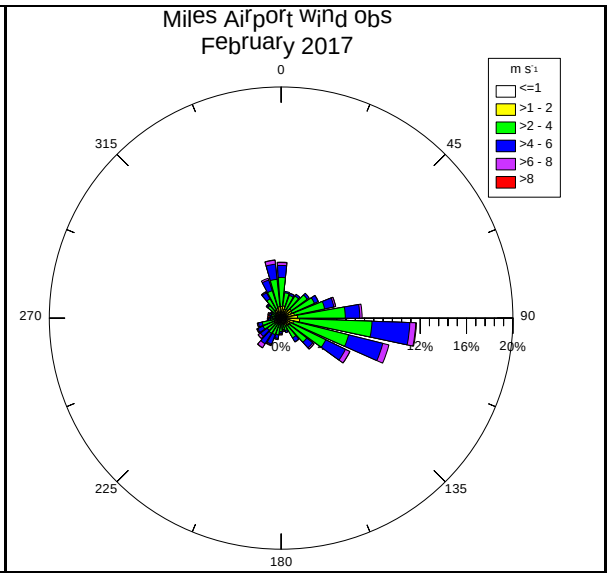


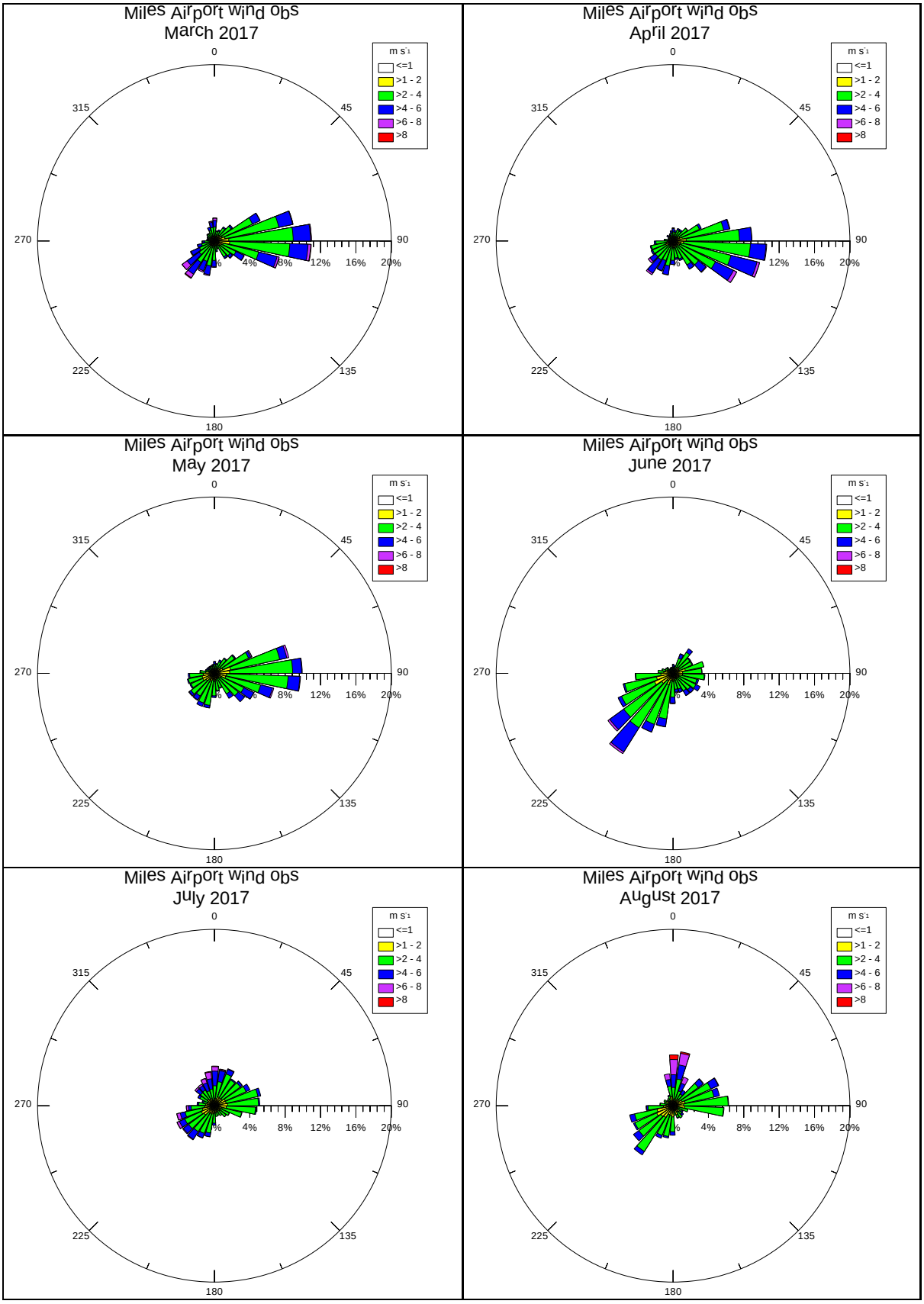

Hopeland wind obs
May 2017
Hopeland wind obs
June 2017
Hopeland wind obs
July 2017
Hopeland wind obs
August 2017
Hopeland wind obs
September 2017
Hopeland wind obs
October 2017
m s-1
<=1
>1 - 2
>2 - 4
>4 - 6
>6 - 8
>8
0
45
90
135
180
225
270
315
4%
8%
12%
16%
20%

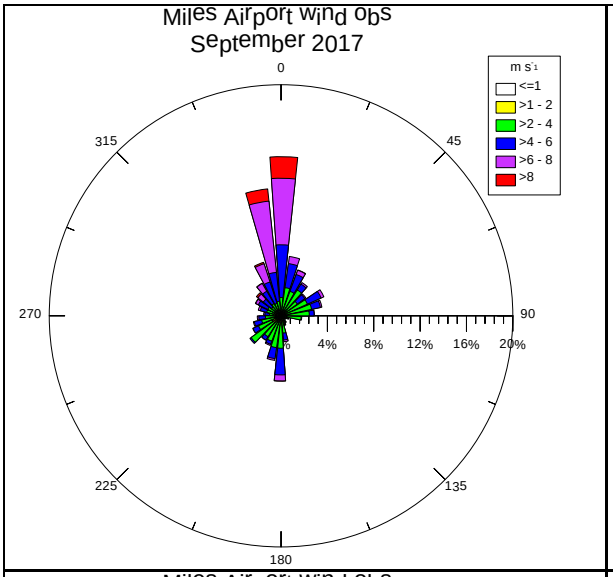


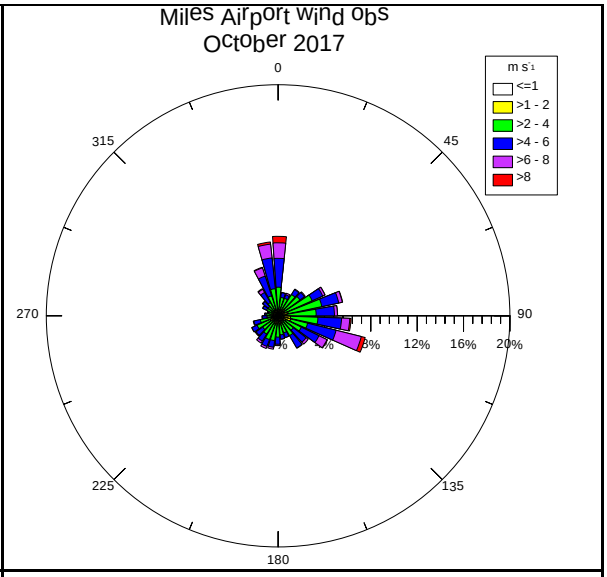
A.6.2 **Miles Airport**

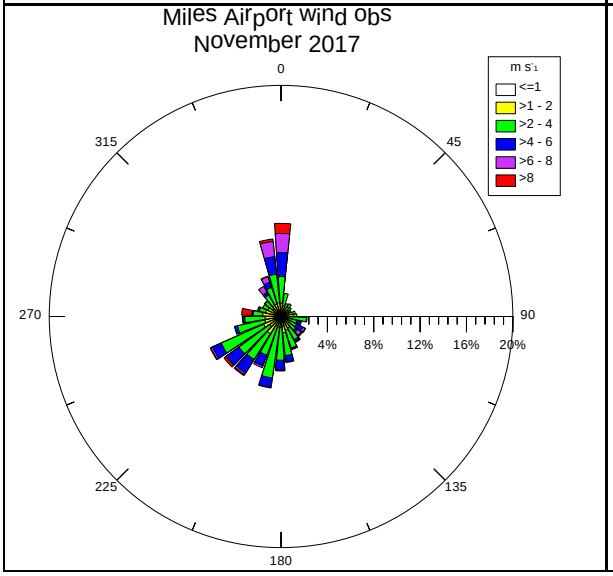





Miles Airport wind obs
March 2017
m s-1
<=1
>1 - 2
>2 - 4
>4 - 6
>6 - 8
>8
0
45
90
135
180
225
270
315
4%
8%
12%
16%
20%
Miles Airport wind obs
April 2017
Miles Airport wind obs
May 2017
Miles Airport wind obs
June 2017
Miles Airport wind obs
July 2017
Miles Airport wind obs
August 2017

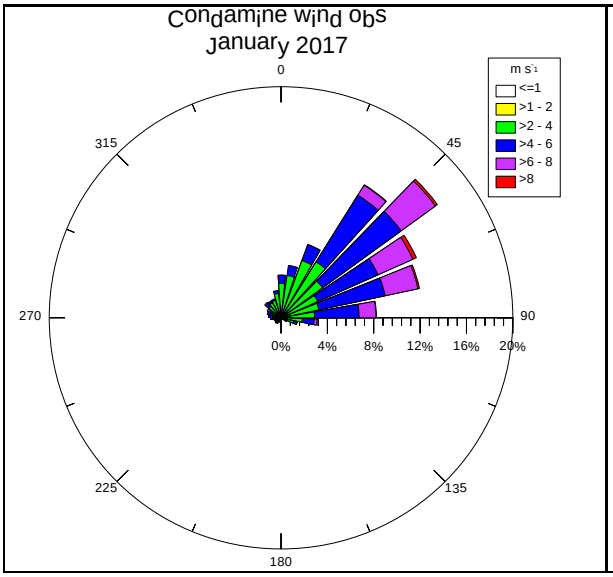


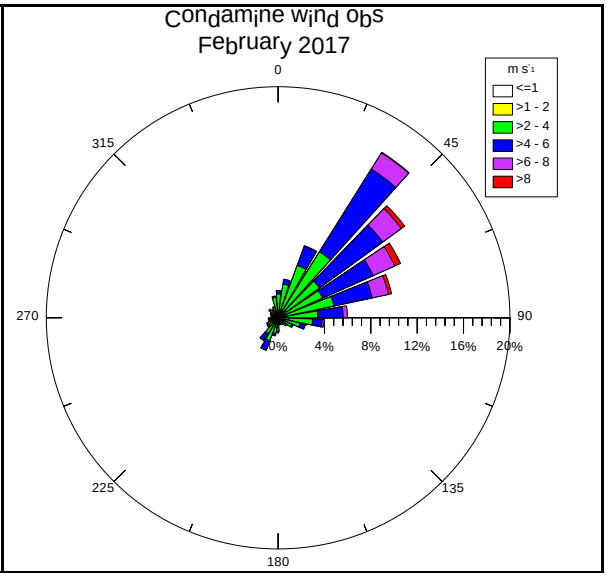


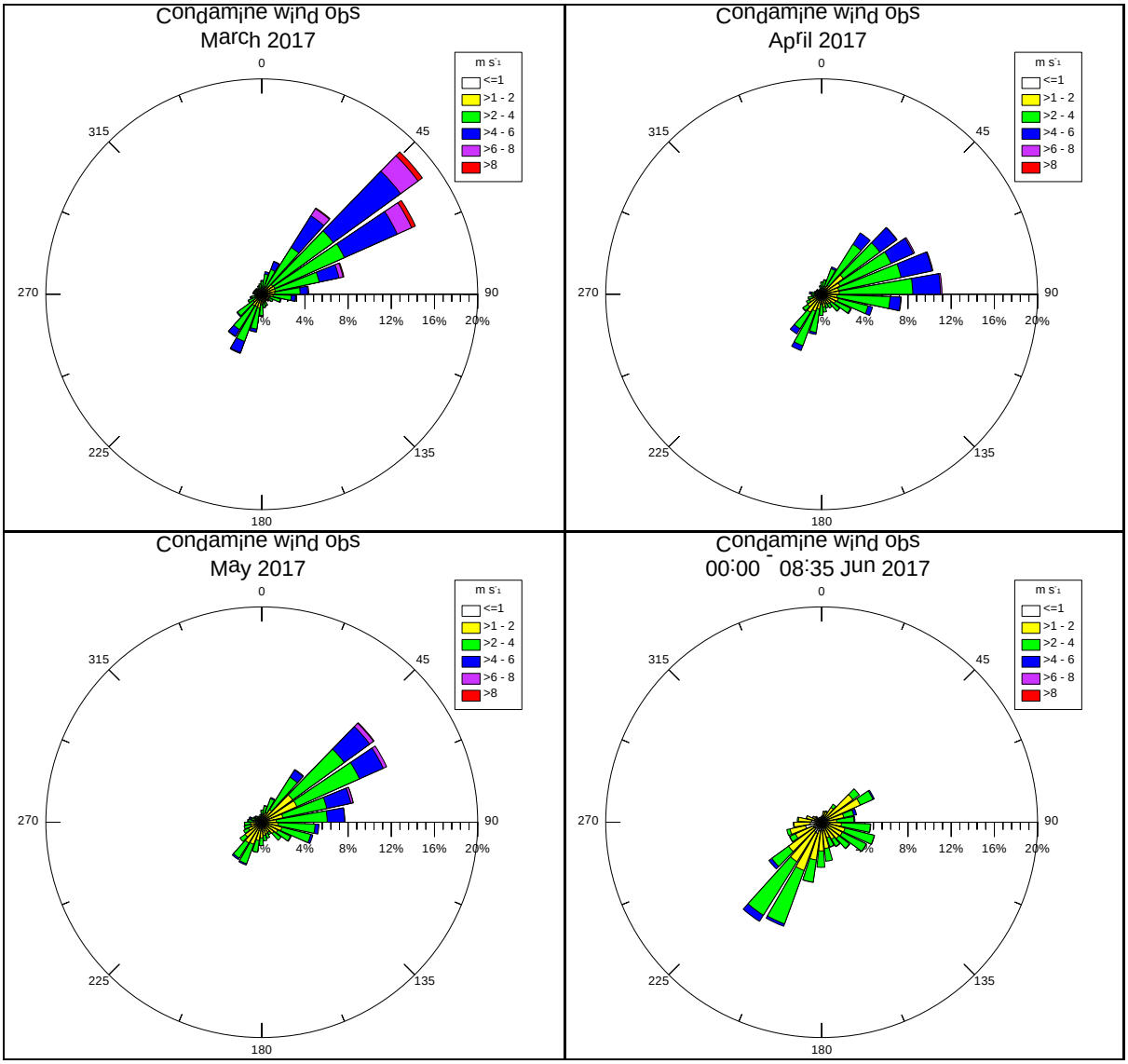


Obs available
Aug 1-6
Sep 18-30
Oct 1-31
Nov 1-6

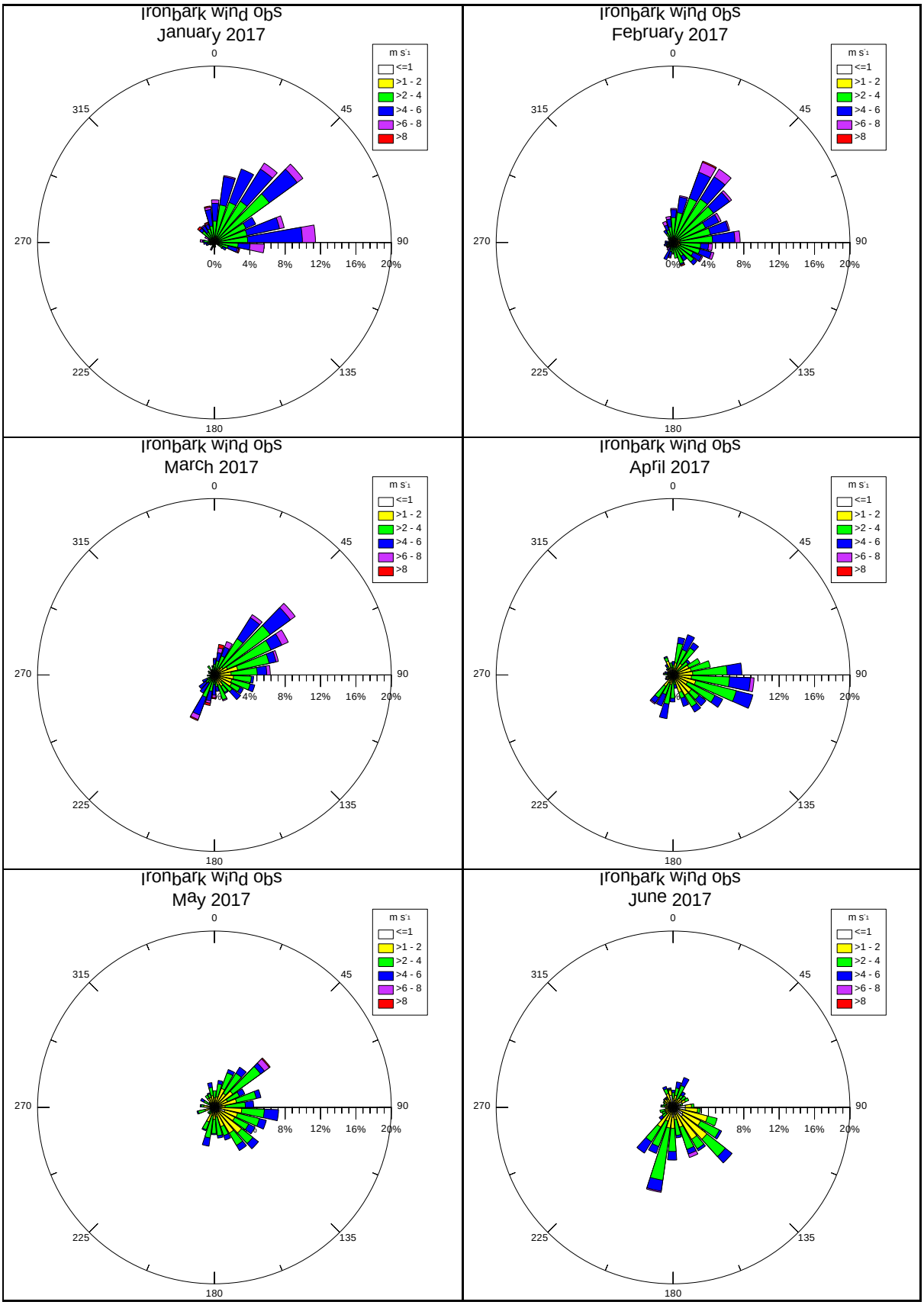
A.6.3 **Condamine**

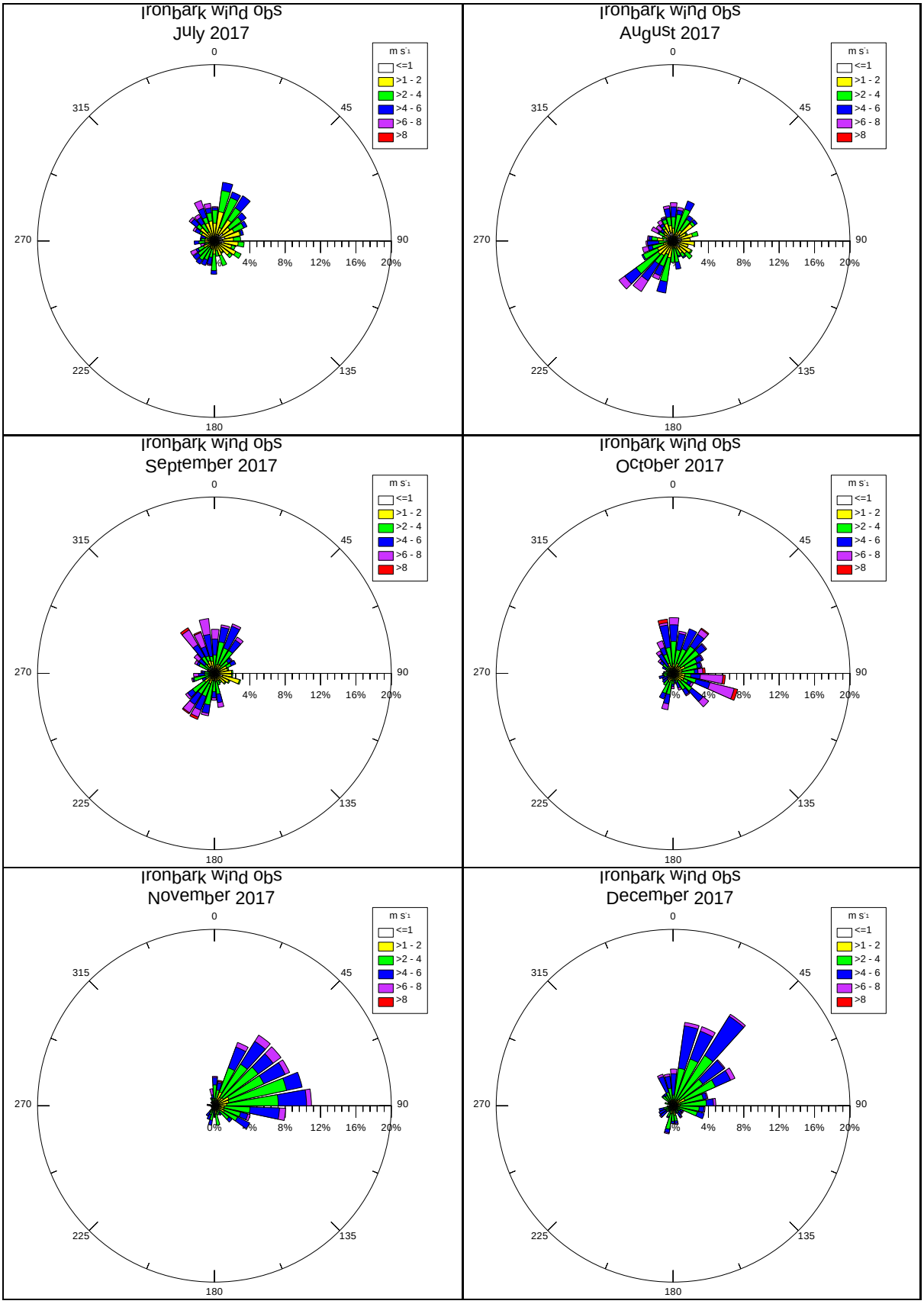


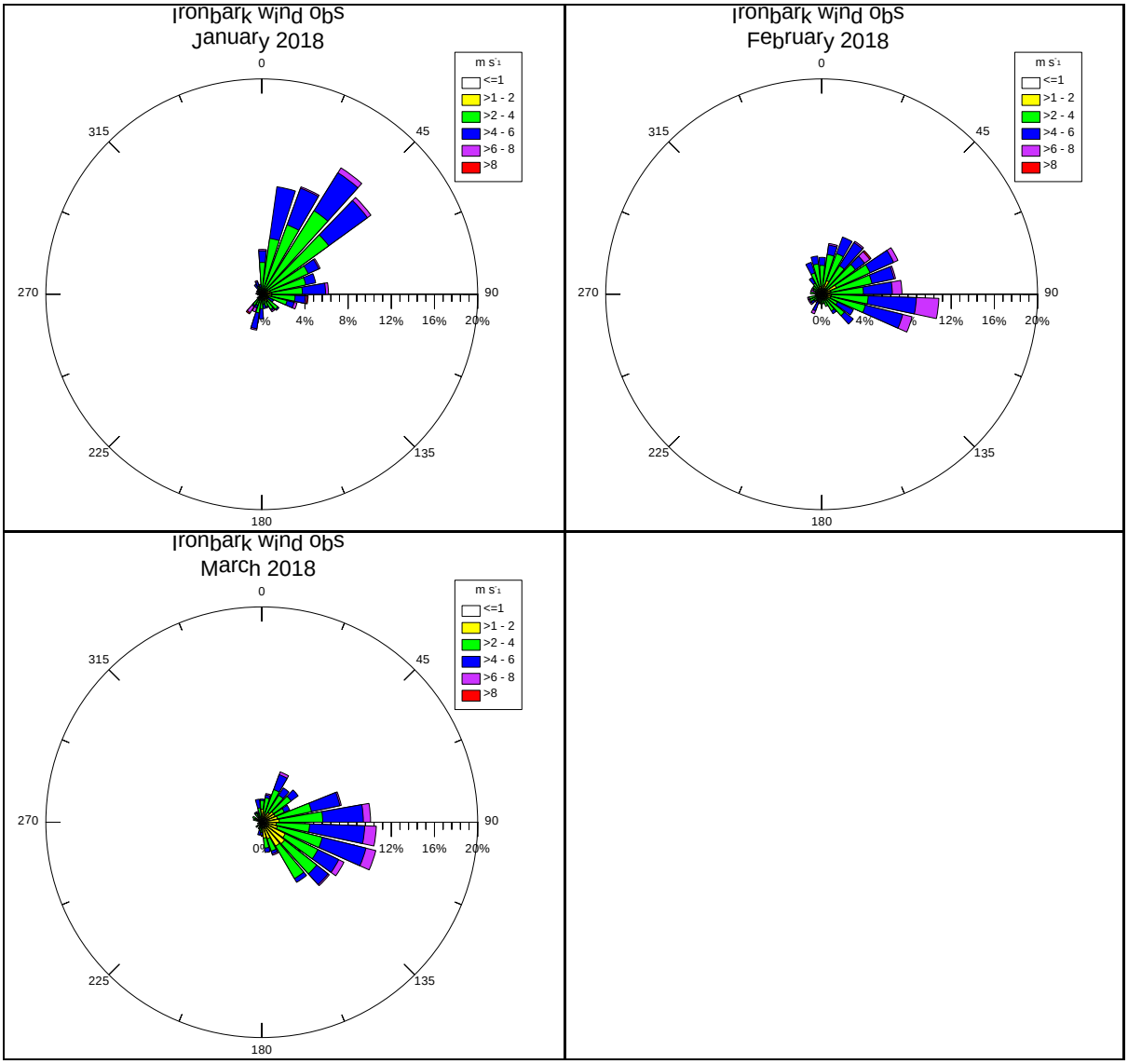



Condamine wind obs
March 2017
Condamine wind obs
April 2017
Condamine wind obs
May 2017
Condamine wind obs
00:00 - 08:35 Jun 2017
m s-1
<=1
>1 - 2
>2 - 4
>4 - 6
>6 - 8
>8
0
45
90
135
180
225
270
315
4%
8%
12%
16%
20%

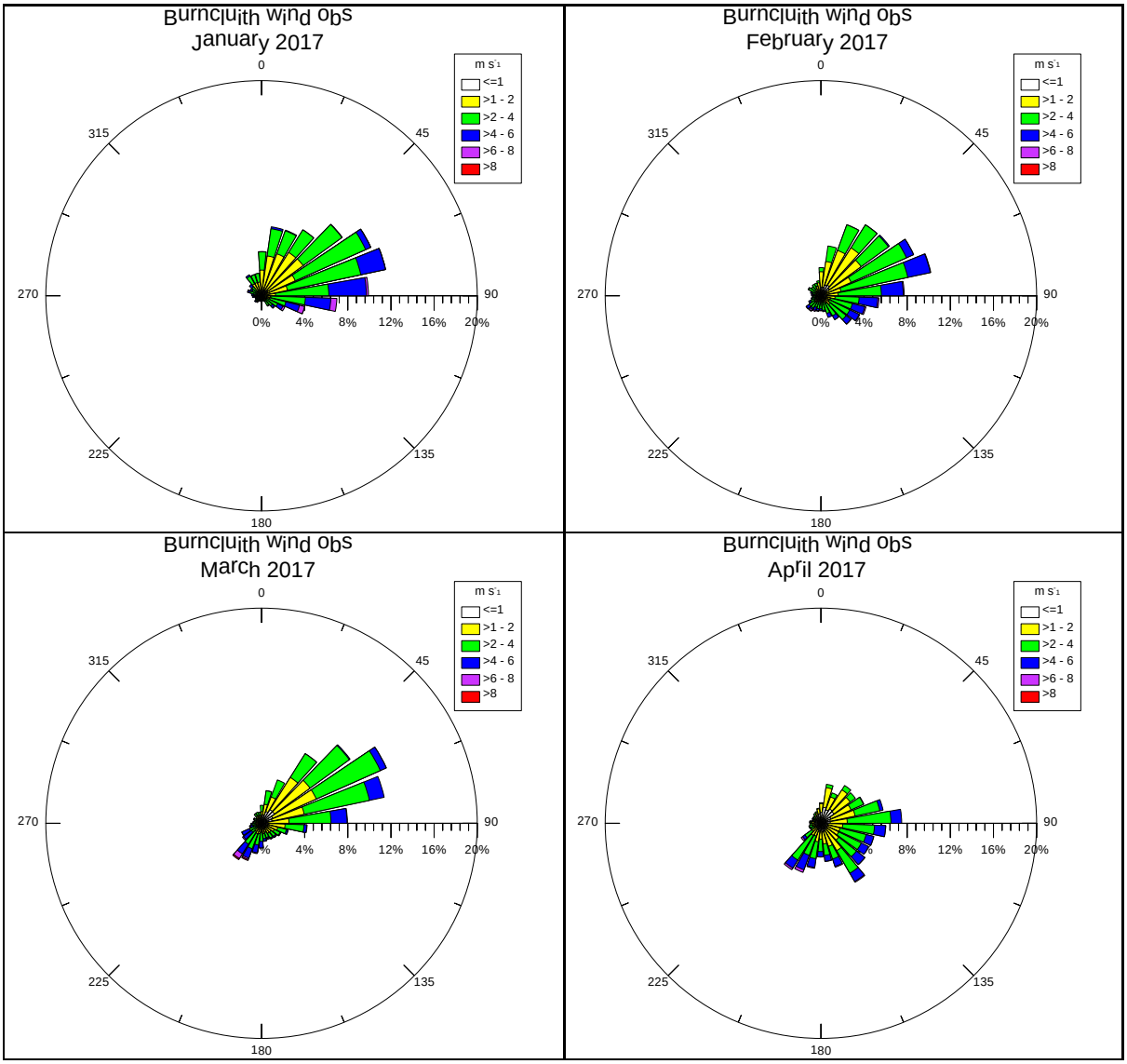
A.6.4 **Tara Region/Ironbark**

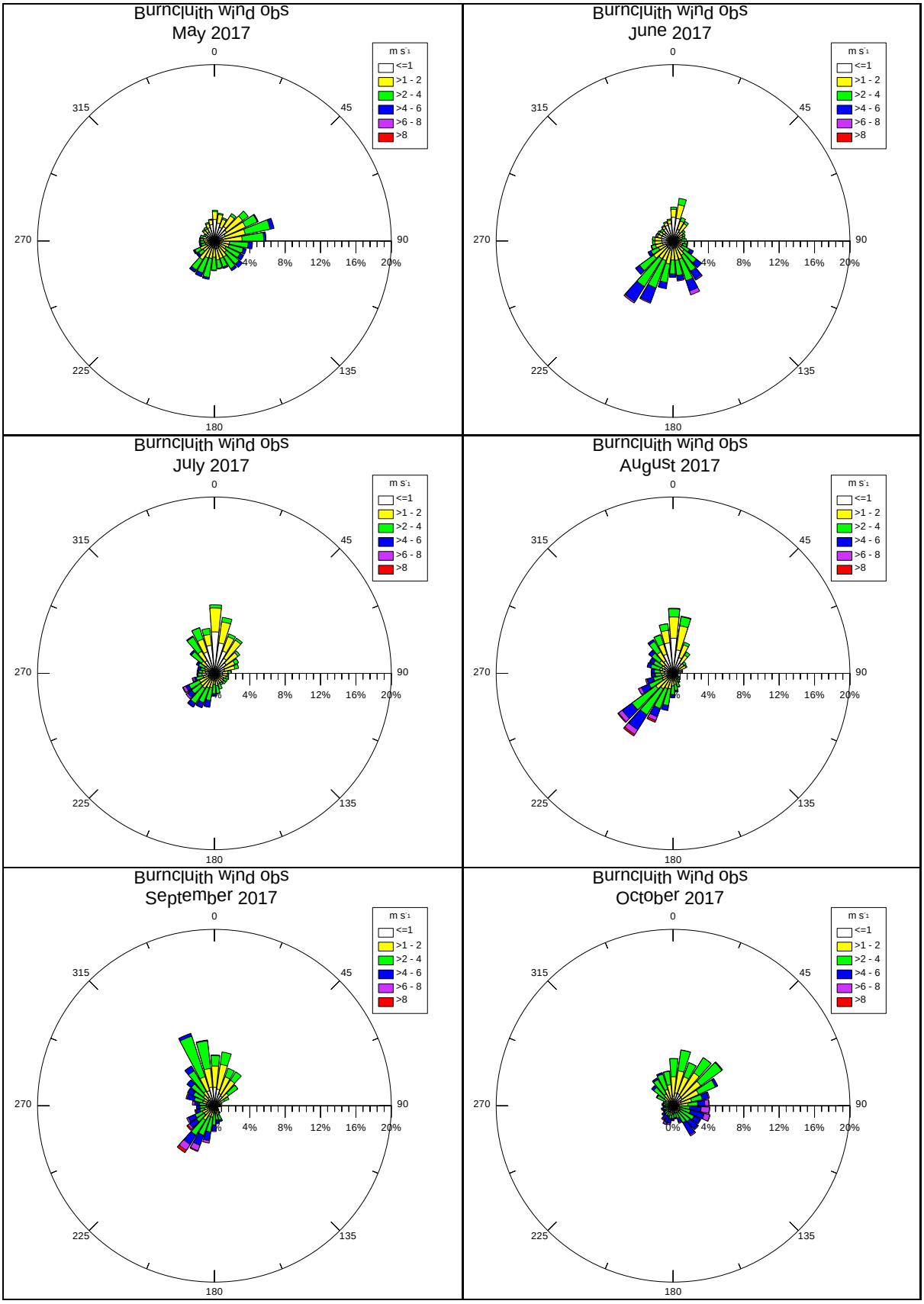


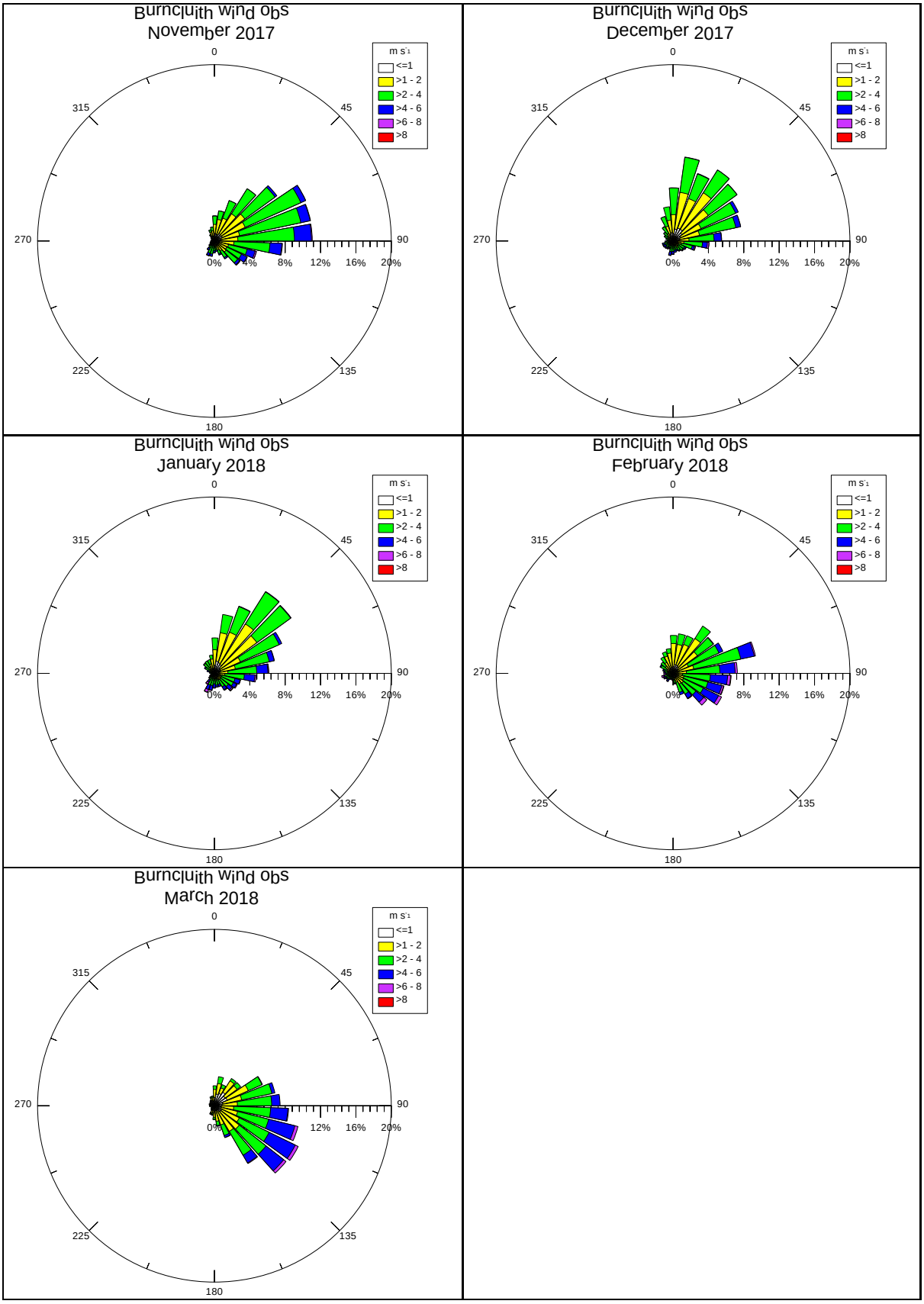

Ironbark wind obs
July 2017
Ironbark wind obs
August 2017
Ironbark wind obs
September 2017
Ironbark wind obs
October 2017
Ironbark wind obs
November 2017
Ironbark wind obs
December 2017
m s-1
<=1
>1 - 2
>2 - 4
>4 - 6
>6 - 8
>8
0
45
90
135
180
225
270
315
4%
8%
12%
16%
20%


Ironbark Wind Obs
January 2018
m s-1
<=1
>1 - 2
>2 - 4
>4 - 6
>6 - 8
>8
0
45
90
135
180
225
270
315
4%
8%
12%
16%
20%
Ironbark Wind Obs
February 2018
Ironbark Wind Obs
March 2018

A.6.5 **Burncluith**




Burncluith wind obs
May 2017
Burncluith wind obs
June 2017
Burncluith wind obs
July 2017
Burncluith wind obs
August 2017
Burncluith wind obs
September 2017
Burncluith wind obs
October 2017
m s-1
<=1
>1 - 2
>2 - 4
>4 - 6
>6 - 8
>8
0
45
90
135
180
225
270
315
4%
8%
12%
16%
20%


Burncluith wind obs
November 2017
m s-1
<=1
>1 - 2
>2 - 4
>4 - 6
>6 - 8
>8
0
45
90
135
180
225
270
315
0%
4%
8%
12%
16%
20%
Burncluith wind obs
December 2017
Burncluith wind obs
January 2018
Burncluith wind obs
February 2018
Burncluith wind obs
March 2018