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WESTERN SYDNEY AIRPORT EIS
REGIONAL AIR QUALITY ASSESSMENT

RAMBOLL ENVIRON

WESTERN SYDNEY AIRPORT EIS
REGIONAL AIR QUALITY ASSESSMENT

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EXECUTIVE SUMMARY

Introduction

Regional air quality considers the formation of secondary pollutants (such as ozone) through photochemical reactions from primary emissions of precursor gases. The primary emissions of precursor gases considered in this assessment include nitrogen oxides (NO_x), volatile organic compounds (VOCs) and carbon monoxide (CO), and the assessment focuses on the regional impacts from ozone formation. The regional assessment complements the local air quality assessment, prepared by Pacific Environment Limited, which is concerned with air quality impacts within a 5 km radius of the airport site (including impacts on the airport site) due to the Stage 1 construction phase, and the operation of the Stage 1 airport development and the long term development.

Study approach

Ozone air quality impacts from the airport were evaluated using the Comprehensive Air quality Model with extensions (CAMx) (ENVIRON, 2015). CAMx is a three-dimensional, gridded, atmospheric dispersion model with photochemistry that allows for assessments of gaseous and particulate air pollution over spatial scales ranging from sub-urban to continental. The assessment follows the modelling approach used for the New South Wales (NSW) Environment Protection Authority (EPA) tiered procedure for ozone assessment, developed for estimating ground level ozone impacts from stationary sources in NSW (ENVIRON, 2011).

Air quality standards

Schedule 1 of the *Airports (Environment Protection) Regulations 1997* outline the ambient air quality objectives applicable at an airport. The ozone objectives are numerically identical to standards outlined in the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) and equivalent to impact assessment criteria prescribed by the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (EPA, 2005). Modelling results for all sources are compared against the air quality objectives for maximum 1-hour and 4-hour ozone concentrations. The predicted maximum change in ozone concentration, from the operation of the proposed airport, is also compared against the maximum allowable increment of 1 part per billion (ppb), prescribed by the EPA in their tiered procedure for ozone assessment.

Existing environment

The relationship between ozone formation and emissions of precursor gases is not linear, for example NO_x emissions can lead to both formation and destruction of ozone, depending on the local quantities of NO_x, VOCs and sunlight (USEPA, 2014).

Peak ozone concentrations in Sydney tend to occur in the afternoon and during summer months. All areas of the Sydney region are currently classified as non-attainment, meaning they are not meeting an "acceptance limit" expressed as 82% of the NEPM standards (ENVIRON, 2011).

A review of the most recent 10 years of monitoring data reveals exceedances of the 1-hour and 4-hour ozone standard in 8 of the previous 10 years. Analysis of long term trends indicates that there is some evidence of decreasing monthly maximum ozone concentrations at Bringelly, near the airport site, and other areas of Sydney.

Emissions scenarios

The ozone modelling assessment considered emissions data for the following scenarios:

- 2008/2009 Base Case - for model evaluation.
- 2030 Future Base Case - for comparison with future airport operations.
- 2030 Airport Case – for Stage 1 airport emissions.
- 2063 Airport Case – for long term airport emissions.

Gridded emissions inventory data for 2008 were provided by EPA, as monthly weekday and weekend files (EPA, 2012). The 2008 emissions data are used for the 2008 / 2009 Base Case, which models an ozone season from November 2008 to February 2009.

The 2008/2009 period was selected for the Base Case because it has the greatest number of exceedances of the 1-hour and 4-hour ozone standard for the past 10 years. Periods of peak ozone are selected for modelling because these are the conditions relevant to compliance with the air quality objectives (which are expressed as maximum (peak) 1-hour and 4-hour averages). These peak ozone periods are what we want the model to be able to accurately predict, so that future compliance with the air quality objectives can be assessed. In other words, the modelling period represents the meteorological conditions that have historically led to peak ozone and therefore may also lead to peak ozone formation with future (airport) emissions added.

The 2008 monthly files are considered suitable for modelling January and February 2009, without the need for adjustment. The GMR air emissions inventory includes point source emissions from commercial and industrial sources and area source emissions for on-road mobile, commercial, industrial, domestic and off-road sources.

To assess the impact of airport operations for a future scenario, it was necessary to apply projections to the 2008 emissions. The EPA also provided annual future year emissions projections for 2031, which were used to scale baseline emissions for the 2030 Future Base Case, to allow direct comparison with the Stage 1 airport development year (2030).

Emissions data for airport operations scenarios (Stage 1 and long term development) were developed in the local air quality assessment, using the US Federal Aviation Administration Emissions and Dispersion Modeling System (EDMS), and have been provided for use in this assessment. A number of adjustments were made to the EDMS data for regional modelling, including chemical speciation of VOC and NOx emissions. Adjustments were also necessary for traffic emissions. The EDMS emissions data for roadways in the local air quality assessment includes all future traffic. For regional modelling, further processing of the traffic emissions was needed to disaggregate the change in traffic emissions attributed to the airport from all other roadway emissions for the links included in the EDMS modelling.

Model evaluation

TAPM was used to simulate meteorology within the study area using surface observation data from all suitable Bureau of Meteorology (BoM) and Office of Environment and Heritage (OEH) weather stations located in the modelling domain. The performance of the model for the Sydney region was evaluated. General wind patterns in the observation data were reflected reasonably well in the TAPM predictions. Statistical evaluation shows good correlation for wind speed and temperature with low bias and error.

The 2008/2009 Base Case emissions scenario was used to assess CAMx model performance by comparing predicted ozone concentrations against ambient monitoring data for the same period. Scatter plots presented for the evaluation demonstrate that modelled-observed data pairs are clustered around the 1:1 line showing that the model tends to correctly predict variability in ozone concentration. The model exhibits very little bias at the Bringelly and St Marys monitoring sites with normalised mean bias for 1-hour ozone less than 2% and for 4-hour ozone less than 7%.

Assessment of ozone impact – Stage 1 airport development (2030)

To assess the impact of Stage 1 airport development, modelling predictions are compared against a 2030 Future Base Case. A number of days were selected for detailed analysis, representing days when peak ozone impacts may be expected. Days with high observed ozone (1-hour ozone concentrations greater than 70 ppb and 4-hour ozone concentrations greater than 65 ppb) and good model performance (bias within ±15% in peak values) were selected for analysis. The selection of days for analysis follows guidance provided in the EPA's tiered procedure for ozone assessment.

The selection of historical dates in January and February 2009 may appear counter intuitive for the modelling future emissions in 2030 and 2063. However, the actual dates are arbitrary, and could be presented, for example as "Peak ozone day 1, Peak ozone day 2…etc.". They simply represent modelling periods when meteorological conditions are conducive to peak ozone formation and there is confidence in the model being able to accurately predict peak ozone formation with future emissions from the airport added.

For each day of analysis, peak predicted 1-hour ozone concentrations were unchanged between the 2030 Base Case and the 2030 Airport Case. This is because the predicted ozone concentrations from the proposed airport occur in different locations to where ozone peaks occur. Both the 2030 Base Case and the 2030 Airport Case peak ozone concentrations were above the NEPM criterion of 100 ppb for all but one day of analysis.

The largest difference in daily maximum 1-hour ozone concentration, from the addition of airport emissions, was 5.5 ppb. However, reliance on a single model result (e.g., the largest ozone change) could accentuate the influence of uncertainties in model input data or model formulation, therefore the average of the 2nd to 4th highest ozone change (1.2 ppb) is used to describe ozone impacts. This approach is similar to the use of a 99th percentile to describe maximum ozone impacts. When compared to the maximum allowable increment level of 1 ppb, a marginal impact is predicted for the 2030 Airport Case.

The peak predicted 4-hour ozone concentrations were unchanged between the 2030 Airport Case and the 2030 Base Case on eight days and increased on four days, by a maximum of 0.1 ppb. The highest change in daily maximum 4-hour ozone concentration, from the addition of airport emissions, was 2.4 ppb, while the second highest was 1.3 ppb. The average of the 2nd to 4th highest change in daily maximum 4-hour ozone was 0.9 ppb, which is below the maximum allowable increment of 1 ppb.

Locations of ozone differences due to 2030 airport emissions are shown in spatial plots. Decreases in daily maximum ozone occur in the vicinity of the airport for 2030 and are attributable to ozone suppression by NOx emissions. Increases in ozone occur downwind of the airport which, on most days, is to the south and southwest.

Assessment of ozone impact – Long term airport development (2063)

Future projected emissions for sources other than the proposed airport (commercial, industrial, on-road mobile, etc.) are not available for the 2063 Airport Case and there was no reasonable way of projecting out to 2063. Therefore the long term development scenario becomes a hypothetical scenario of the long term airport development occurring within the context of 2030 Base Case emissions.

The maximum predicted 1-hour ozone concentration was unchanged between the 2030 Base Case and the 2063 Airport Case for eight of the analysis days. On four days, the peak predicted 1-hour ozone concentration increased, by a maximum of 0.2 ppb. Both the 2030 Base Case and the 2063 Airport Case were above the NEPM criterion of 100 ppb for all but one day of analysis.

Larger ozone increases were predicted for the 2063 Airport Case than the 2030 Airport Case. The average of the 2nd to 4th highest increases in daily maximum 1-hour ozone rose from 1.1 ppb for the 2030 Airport Case to 4.6 ppb for the 2063 Airport Case. This is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

The peak predicted 4-hour ozone concentration was unchanged on seven days and increased on five days, by a maximum of 0.3 ppb. The highest change in daily maximum 4-hour ozone concentration, from the addition of 2063 Airport Case emissions, was 6.5 ppb, while the second highest was 5.9 ppb. The average of the 2nd to 4th highest increases in daily maximum 4-hour ozone is 3.8 ppb, which is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

Decreases in daily maximum ozone, due to ozone suppression by NOx emissions, occur in the vicinity of the proposed airport and on some days extend to the aircraft flight corridor and areas downwind of the airport for 2063. Areas of ozone decrease are more expansive for the 2063 Airport Case than for the 2030 Airport Case because NO_x emissions from the airport are higher in 2063. Increases in ozone occur downwind of the airport site and also are larger for 2063 than for 2030.

It is noted that emission data provided for airport operations assumes worst case operations, for example by including emissions from Auxiliary Power Units (APUs) rather than the use of mains powered APUs at the airport gates. Furthermore, for the long term airport development, we have not accounted for changes in emissions from all other sources (commercial, industrial, on-road mobile, etc.), some of which may increase and some of which may decrease. The modelling predictions for the long term development should therefore be viewed in this context.

Mitigation

Mitigation for ozone impacts should be considered for both the Stage 1 and long term development and should focus primarily on measures which result in reductions in NO_x emissions, which would achieve the greatest benefit in reducing peak ozone concentrations.

The NSW tiered procedure for ozone assessment requires that the best management practice (BMP) determination for facilities located within ozone non-attainment areas should consider best available techniques (BAT) and/or emission offsets. As recommended in the local air quality assessment, the proposed airport operator would implement BAT where it can, for example through the use of mains powered APUs at the airport gates. When assessing the effectiveness of any proposed mitigation measures, it is recommended that an evaluation is done of the sensitivity of ozone concentrations to reduction in NO_x and VOCs (i.e., ppb ozone per tonne of emissions) for future years.

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1. INTRODUCTION

Ramboll Environ Australia Pty Ltd (Ramboll Environ) has been engaged by GHD, on behalf of the Australian Government (Department of Infrastructure and Regional Development), to assess regional air quality impacts associated with the proposed Western Sydney Airport (the airport). The regional air quality assessment forms part of the environmental impact statement (EIS) being prepared by GHD.

The regional air quality assessment considers impacts from emissions associated with the airport forming secondary pollutants (principally ozone) through atmospheric reactions on a regional scale.

The regional assessment complements the local air quality assessment (LAQA), prepared by Pacific Environment Limited (PEL), which is concerned with impacts on a local scale, for primary pollutants that are emitted directly from the airport.

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946, with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the Joint Study on Aviation Capacity in the Sydney Region (Department of Infrastructure and Transport, 2012) and A Study of Wilton and RAAF Base Richmond for civil aviation operations (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,780 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Airport operations are expected to commence in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport (referred to as the Stage 1 development) would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of approximately 10 million passengers per year as well as freight operations. To maximise the potential of the site, the airport is proposed to operate on a 24-hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site subject to relevant approvals.

While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A joint scoping study is being undertaken with the NSW Government to determine rail needs for Western Sydney and the airport. A potential final rail alignment will be determined through the joint scoping study with the New South Wales Government, with any significant enabling work required during Stage 1 expected to be subject to a separate approval and environmental assessment process.

As demand increases, additional aviation infrastructure and aviation support precincts are expected to be developed until the first runway reaches capacity at around 37 million passenger movements. At this time, expected to be around 2050, a second parallel runway is expected to be required. In the longer term, approximately 40 years after operations commence, the airport development is expected to fully occupy the airport site, with additional passenger and transport facilities for around 82 million passenger movements per year.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015.

Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996 (Cth)* (Airports Act). The Airports Act provides for the preparation of an Airport Plan, which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. A draft Airport Plan was exhibited for public comment with the draft EIS late in 2015.

Following receipt of public comments, a revised draft Airport Plan has been developed. The revised draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The revised draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, as well as a long-term vision of the airport's development over a number of stages. This enables preliminary consideration of the implications of longer term airport operations. Any airport development beyond Stage 1, including the construction of additional terminal areas or supporting infrastructure to expand the capacity of the airport using the first runway or construction of a second runway, would be managed in accordance with the existing process in the Airports Act. This includes a requirement that, for major airport developments (defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Purpose of this report

The 1997-99 EIS considered the potential impacts on local and regional air quality, however since this report was published, there are more extensive air quality monitoring data available to describe background conditions and ambient air quality goals have changed.

This report has been prepared in accordance with the EIS guidelines. In particular, the EIS Guidelines for the project (Reference: EPBC 2014/7391) indicate the following is required to be included in the EIS:

> (section 5c)
>
> *"The EIS should address the potential for facilitated impacts upon MNES at the local, regional, state, national and international scale"*
>
> (section 5g)
>
> *"…changes to air quality during construction and operation (including consideration of seasonal and meteorological variations that influence local air quality)"*

The primary objective of the regional air quality assessment is to therefore update the previous assessment, consistent with best science and contemporary modelling and assessment techniques. It should be noted that a separate report considering the impact on local air quality and greenhouse gases has also been prepared and included in the EIS. The regional air quality report has used consistent assumptions on aircraft and ground fleet use, including airport vehicles on external roadways and meteorology to ensure consistency of the results.

1.3 Structure of this report

The remainder of this report is structured as follows:

- Section 2 – provides an introduction to regional air quality effects.
- Section 3 – considers and documents the relevant legislation and guidelines in relation to ozone impact assessment.
- Section 4 – presents the methodology used to undertake the regional modelling assessment.
- Section 5 – outlines the existing environment.
- Section 6 – evaluates the meteorology used for modelling.
- Section 7 – presents the results of the Base Case model evaluation.
- Section 8 – presents the impact assessment of both the Stage 1 and long term airport development.
- Section 9 – outlines recommended mitigation measures.
- Section 10 – provides the summary and conclusions of the report.
- Section 11 – provides a glossary of terms and acronyms.
- Section 12 – presents a list of references drawn on by this report.

2. INTRODUCTION TO REGIONAL AIR QUALITY EFFECTS

2.1 Introduction to regional air quality

Regional air quality considers the formation of secondary pollutants (such as ozone (O_3)) through photochemical reactions from primary emissions of precursor gases. The primary emissions of precursor gases considered in this assessment include nitrogen oxides (NO_x), volatile organic compounds (VOCs) and carbon monoxide (CO). The direct impacts from these precursor gases is considered in the local air quality assessment within 5 km of the airport site boundary.

International studies have shown that emissions from airport operations are small when compared in the context of regional emission inventories (Ratliff et al., 2009). This is supported by data presented in the Air emissions inventory for the Greater Metropolitan Region (GMR) in New South Wales (EPA, 2012a) which shows that emissions from existing airport operations in Sydney are less than 3% of total emissions for the Sydney Region (refer **Table 2-1)**.

Notwithstanding the relatively small contribution to regional emissions, impacts on a local and regional scale need to be assessed.

Table 2-1: Proportion of emissions from existing airports as a percentage of total emissions for the Sydney Region

Activity	NO_x	VOCs	CO
Flight operations	2.37%	0.19%	0.32%
Ground Operations	0.34%	0.1%	0.2%

Note: Does not include emissions associated with airport traffic

Regional ozone is affected both by local formation and the transport of ozone and its precursors from upwind areas. As a secondary pollutant, ozone concentrations are generally more regionally homogeneous than concentrations of primary pollutants emitted directly from stationary and mobile sources (USEPA, 2013).

The relationship between ozone formation and emissions of precursor gases is not linear. NO_x emissions can lead to both formation and destruction of ozone, depending on the local quantities of NO_x, VOCs and sunlight (USEPA, 2014). For example, a study in the US found that near some urban centres, aircraft emissions reduced ozone, whereas in suburban and rural areas, aircraft emissions increased ambient ozone levels (Ratliff et al., 2009).

Scavenging of ozone by reaction with NO ("titration") can result in localised reduction in ozone concentrations. However, the resulting NO_2 can then contribute to subsequent ozone formation further downwind. Ozone titration is most pronounced in urban areas that have high NO_x emissions from vehicles and other sources. In areas with relatively low NO_x concentrations ozone formation typically increases monotonically with increasing NO_x emissions (USEPA, 2014).

Meteorology and seasonality also play an important role in ozone formation. Elevated ground level concentrations of ozone in Sydney occur during the warmer seasons because of the greater availability of sunlight and higher temperatures. Also, the largest source of VOC precursor emissions in the Sydney GMR is from vegetation and the highest emissions occur from the tree canopy during the warmer months (November to February) (EPA, 2012a; EPA, 2012b).

Elevated ground-level ozone concentrations are also associated with slow moving high pressure systems during the warmer seasons, associated with generally cloudless skies, light winds and the development of stable conditions near the surface that inhibit or reduce the vertical mixing of ozone precursors. The combination of inhibited vertical mixing and light winds minimises the dispersal of pollutants, allowing their concentrations to build up (USEPA, 2014).

Exceedances of the ambient ozone standards in Sydney are therefore generally limited to the summer months (December to February). In some years exceedances occur in the months of October, November and March, however outside the core summer periods, exceedances often coincide with bushfires events (for example October 2013 and November 2009). Further discussion on ambient ozone concentrations for Sydney is provided in **Section 4**.

2.2 Effects of ground level concentrations of ozone

In 2012, the Council of Australian Governments (COAG) identified air quality as an issue of national priority (COAG, 2012), and agreed that its Standing Council on Environment and Water would implement a strategic approach to air quality management in the form of a National Plan for Clean Air. One of the first deliverables identified for the first stage of the National Plan for Clean Air was a health risk assessment (HRA) of air pollution (including ozone) and a summary report for policy makers that outlined the key findings of the HRA (Morgan et al, 2013).

A range of health effects associated with exposure to ozone pollution were outlined in Morgan et al (2013) and are summarised in **Table 2-2**. Morgan et al (2013) also reported that current short-term ozone exposure above background is estimated be responsible for 3.7% of annual deaths and 3.4% of annual childhood hospital emergency department attendances for the Sydney region.

Table 2-2: Human health effects of ambient ozone pollution

Exposure period	Health effects
Short-term Exposure	Adverse effects on lung function
	Lung inflammatory reactions
	Adverse effects on the respiratory system
	Increased medication use
	Increased hospitalisations
	Increased mortality
Long-term Exposure	Reduced lung function development

Source: Morgan et al (2013)

The USEPA's Integrated Science Assessment for Ozone and Related Photochemical Oxidants (ISA) assessed a large body of peer reviewed literature to draw conclusions on the causal relationships between pollution and health and welfare effects (USEPA, 2013). A summary of the human health effects associated with ozone exposure are summarised in **Table 2-3**, based on the USEPA ISA review of exposures studies, toxicology and epidemiology evidence. The strongest evidence for health effects is from studies on respiratory effects, however there is also a significant body of evidence to suggest that short term exposure to ozone, directly or indirectly, contributes to cardiopulmonary-related mortality (USEPA, 2013).

Table 2-3: Summary of causal determination of human health outcomes for ozone

Exposure period	Health outcome	Conclusion from ISA[1]
Short-term Exposure	Respiratory effects	Causal Relationship
	Cardiovascular effects	Likely to be a Causal Relationship
	Central nervous system effects	Suggestive of a Causal Relationship
	Total mortality	Likely to be a Causal Relationship
Long-term Exposure	Respiratory effects	Likely to be a Causal Relationship
	Cardiovascular effects	Suggestive of a Causal Relationship
	Reproductive and developmental effects	Suggestive of a Causal Relationship
	Central nervous system effects	Suggestive of a Causal Relationship
	Cancer	Inadequate to Infer a Causal Relationship
	Total mortality	Suggestive of a Causal Relationship

Source: USEPA (2013)

2.3 Effects of ground level concentrations of ozone on vegetation

Effects related to impacts on vegetation and ecosystems are also outlined in the USEPA ISA review. Based on over 40 years of research in the US, a clear causal link has been established between ambient ozone concentrations and visible foliar injury, decreased photosynthesis, changes in plant reproduction, and decreased growth.

A summary of vegetation and ecosystem effects from the ISA are presented in **Table 2-4**.

[1] The health effects are characterised by the strength of evidence for causality. The classification of a causal relationship means the evidence is sufficient to show that a pollutant causes health effects. For the "likely to be causal" group, the evidence is also sufficient, however important uncertainties remain (for example chance or bias). Where evidence is "suggestive", evidence is limited.

Table 2-4: Summary of vegetation and ecosystem effects for ozone

Vegetation and ecosystem effects	Conclusions from 2006 NAAQS review	Conclusion from ISA
Visible Foliar Injury Effects on Vegetation	Data published since the 1996 O_3 review strengthen previous conclusions that there is strong evidence that current ambient O_3 concentrations cause impaired aesthetic quality of many native plants and trees by increasing foliar injury.	Causal Relationship
Reduced Vegetation Growth	Data published since the 1996 O_3 review strengthen previous conclusions that there is strong evidence that current ambient O_3 concentrations cause decreased growth and biomass accumulation in annual, perennial and woody plants, including agronomic crops, annuals, shrubs, grasses, and trees.	Causal Relationship
Reduced Productivity in Terrestrial Ecosystems	There is evidence that O_3 is an important stressor of ecosystems and that the effects of O_3 on individual plants and processes are scaled up through the ecosystem, affecting net primary productivity.	Causal Relationship
Reduced Carbon (C) Sequestration in Terrestrial Ecosystems	Limited studies from the 2006 O_3 review.	Likely to be a Causal Relationship
Reduced Yield and Quality of Agricultural Crops	Data published since the 1996 O_3 review strengthen previous conclusions that there is strong evidence that current ambient O_3 concentrations cause decreased yield and/or nutritive quality in a large number of agronomic and forage crops.	Causal Relationship
Alteration of Terrestrial Ecosystem Water Cycling	Ecosystem water quantity may be affected by O_3 exposure at the landscape level.	Likely to be a Causal Relationship
Alteration of Belowground Biogeochemical Cycles	Ozone-sensitive species have well known responses to O_3 exposure, including altered carbon (C) allocation to below-ground tissues, and also altered rates of leaf and root production, turnover, and decomposition. These shifts can affect overall C and nitrogen (N) loss from the ecosystem in terms of respired C, and leached aqueous dissolved organic and inorganic C and N.	Causal Relationship
Alteration of Terrestrial Community Composition	Ozone may be affecting above- and below –ground community composition through impacts on both growth and reproduction. Significant changes in plant community composition resulting directly from O_3 exposure have been demonstrated.	Likely to be a Causal Relationship

Source: USEPA (2013)

3. LEGISLATIVE SETTING AND AMBIENT OZONE STANDARDS

3.1 Introduction

The *Airports (Environment Protection) Regulations 1997*, made under the Airports Act, describe the requirements for preventing or minimising air pollution. Schedule 1 of the *Airports (Environment Protection) Regulations 1997* outline the accepted limits for emissions from stationary sources, which are defined as plant and equipment that "*is not a vehicle*" and is "*fixed to a particular location*". Stationary sources at an airport that would be subject to the limits in Schedule 1 include, for example, boilers and gas fired stationary engines.

Schedule 1 of the *Airports (Environment Protection) Regulations 1997* also outline the ambient air quality objectives applicable at an airport. The objectives are numerically equivalent to national standards outlined in the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) (NEPC, 1998; NEPC, 2003; NEPC, 2015). The ambient air quality objectives and standards for ozone are outlined in **Section 3.2**.

A future airport operator will be under an obligation to monitor air quality under the *Airports (Environment Protection) Regulations 1997* and to include details of the proposed monitoring arrangements in its environment strategy as part of the master planning process under the *Airports Act 1996*.

Guidance for air quality impact assessment in NSW is outlined in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (the Approved Methods) (EPA, 2005). The guidance typically relates to local air quality assessment and when detailed regional modelling of ozone is required, the Approved Methods recommends that advice is sought from the Air Technical Advisory Services Unit of the EPA. The EPA also outlined a tiered procedure for ozone assessment, developed for estimating ground level ozone impacts from stationary sources in NSW (ENVIRON, 2011). Aspects of the guidance that are relevant to this assessment are discussed in **Section 3.4**.

3.2 Ambient air quality standards

The *Airports (Environment Protection) Regulations 1997* ambient objectives for ozone are outlined in **Table 3-1**. The objectives are numerically identical to the AAQ NEPM air quality standards (refer **Table 3-2**) expressed as ppm (parts per million), by volume. It is noted that the form of the NEPM standard also allows for 1 day a year for the goal to be exceeded.

The impact assessment criteria for ozone, prescribed by the EPA in their Approved Methods (refer **Table 3-3**) are also the same, although expressed as pphm (parts per hundred million) and converted to micrograms per cubic metre of air (μg/m³) using different reference conditions.

Table 3-1: Airports (Environment Protection) Regulations Ambient Objective for ozone

Averaging period	Maximum averaged concentration	
	ppm	μg/m³ [a]
1 hour	0.10	210
4 hours	0.08	170

Note: [a] referenced to a temperature of 0 degrees Celsius and an absolute pressure of 101.3 kilopascals

Table 3-2: National (NEPM) standards for ozone

Averaging period	Maximum concentration	Maximum allowable exceedances
1 hour	0.10 ppm	1 day a year
4 hours	0.08 ppm	1 day a year

Table 3-3: EPA Impact Assessment criteria for ozone

Averaging period	Concentration	
	pphm	µg/m³ [a]
1 hour	10	214
4 hours	8	171

Note: [a] reference conditions not specified

The ambient ozone monitoring data and ozone modelling results presented in this report use ppb (parts per billion) as the preferred reporting unit. The NEPM standard of 0.10 ppm for 1-hour ozone is equivalent to the EPA criteria of 10 pphm and the criterion of 100 ppb used in this report. Similarly, the NEPM standard of 0.08 ppm for 4-hour ozone is equivalent to the EPA criterion of 8 pphm, which is likewise equivalent to 80 ppb, which is used in this report.

3.3 Ozone standards for the protection of vegetation and ecosystems

Ozone standards for vegetation are not prescribed by the EPA, however under the Queensland Environment Protection (Air) Policy (EPP (Air)) 2008, air quality objectives are listed for both human health and ecosystems damage. The EPP (Air) adopts the NEPM health based standards (). The EPP (Air) ecosystem goals are presented in **Table 3-4**.

Table 3-4: EPP (Air) ozone goals for vegetation

Indicator	Environmental value	Air Quality Objective	Period
Ozone (measured as accumulated exposure over a threshold of 40 ppb during daylight hours)	Protecting agriculture	0.2 ppm-hr	5 days
	Health and biodiversity of ecosystems (for semi-natural vegetation)	3 ppm-hr	3 months
	Health and biodiversity of ecosystems (for natural or uncultivated area)	10 ppm-hr	3 months

3.4 NSW tiered procedure for ozone assessment

The EPA's tiered procedure for ozone assessment was developed for estimating ground level ozone impacts from stationary sources in NSW (ENVIRON, 2011). Stationary sources are defined as scheduled activities listed in Schedule 1 of the Protection of the Environment Operations (POEO) Act (1997) (NSW).

The most significant sources at the proposed airport (e.g. aircraft in flight) would not be designated as scheduled activity under the POEO Act and, as such, the tiered procedure for ozone assessment is only applicable to minor emissions sources such as boilers.

Notwithstanding, the tiered procedure provides guidance on how ozone assessment should be conducted in NSW and there are aspects of the guidance that are relevant and applicable to this assessment, described as follows:

- The assessment approach described in **Section 4** follows the modelling approach used to derive the tiered procedure and screening tool (ENVIRON, 2011).
- The tiered procedure describes a process to define areas as "attainment" or "non-attainment" for ozone. This process is useful to provide context for the existing environment and the analysis is presented in **Section 5.1**.
- The tiered procedure provides criteria for selecting days for detailed analysis, for a Level 2 assessment. These criteria are used in this assessment as discussed in **Section 8.1**.
- The tiered procedure provides a maximum allowable increment level of 1 ppb for ozone assessment. This is a useful metric to compare the modelled change in ozone concentrations attributable to emissions from the airport.

An overview of the tiered procedure framework is provided in **Appendix 1**.

4. OVERVIEW OF ASSESSMENT APPROACH

Ozone air quality impacts from the proposed airport were evaluated using the Comprehensive Air Quality Model with extensions (ENVIRON, 2015). CAMx is a three-dimensional, gridded, atmospheric dispersion model with photochemistry that allows for assessments of gaseous and PM air pollution (e.g. ozone, $PM_{2.5}$, PM_{10} and air toxics) over spatial scales ranging from sub-urban to continental. CAMx was used to assess ozone impacts in the Sydney GMR in a study for EPA to develop the tiered assessment procedure for ozone (ENVIRON, 2011). CAMx is used around the world and is one of two models used by the USEPA to develop air quality regulations for ozone and PM (USEPA, 2011).

CAMx requires numerous input data including the following:

- An emissions inventory that specifies emissions of all ozone precursors from all sources contained within the CAMx modelling domain.
- Meteorological input data that determine how pollutants are transported within the CAMx modelling domain and the atmospheric conditions under which ozone is formed.
- Boundary conditions define pollutant concentrations that enter the CAMx modelling domain with prevailing winds that cross into domain boundaries.

This section describes how the CAMx input data were prepared.

4.1 Meteorological model

CAMx requires meteorological input data for the parameters shown in **Table 4-1**.

Table 4-1: CAMx meteorological input data requirements

Input Parameter	Description
Winds (m/s)	3-D gridded wind vectors (u,v) for the start and end of each hour
Temperature (K)	3-D gridded temperature and 2-D gridded surface temperature for the start and end of each hour
Pressure (mb)	3-D gridded pressure for the start and end of each hour
Vertical Diffusivity (m^2/s)	3-D gridded vertical exchange coefficients for each hour
Water Vapor (ppm)	3-D gridded water vapor mixing ratio for each hour
Clouds and Rainfall (g/m^3)	3-D gridded cloud and rain liquid water content for each hour
Layer interface height (m)	3-D gridded time-varying layer heights for the start and end of each hour

TAPM has been used to simulate meteorology within the study area. TAPM is a three-dimensional meteorological and air pollution model developed by the CSIRO Division of Atmospheric Research. A detailed description of TAPM and its performance can be found in Hurley (2008) and Hurley et al. (2009). TAPM has been extensively used as a meteorological modelling tool, both in Australia and internationally (Wang et al., 2008; Soriano et al.; 2003; Mahmud, 2009; Mocioaca et al., 2009).

TAPM uses fundamental fluid dynamics and scalar transport equations to predict meteorology and (optionally) pollutant concentrations. The model predicts airflows that are important to local-scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

The modelling approach in this study reflects the modelling approach used in previous ozone modelling assessment for the GMR, consistent with ENVIRON (2011). TAPM is used to generate gridded three-dimensional meteorological data for each hour of the model run period, for input into the chemical transport model.

Surface observation data from all suitable Bureau of Meteorology (BoM) and Office of Environment and Heritage (OEH) meteorological stations located in the modelling domain are included in the meteorological modelling. The inclusion of these data (referred to as "data assimilation") provides real-world observations to improve the accuracy of the wind field, provided that the measurement is located so as to represent the surrounding area (e.g., clear of wind obstructions).

The observation sites included in the modelling are listed in **Table 4-2** and the locations are shown in **Figure 4-1**. The radius of influence (ROI) for each station is selected on the basis of the surrounding terrain and land use. For example, a small ROI is applied where a monitoring site is influenced by local terrain or obstructions.

Table 4-2: Data assimilation sites included in the meteorological model

BoM Site	Radius of influence (km)	NSW OEH Site	Radius of influence (km)
Albion Park (Wollongong Airport)	5	Albion Park South	2.5
Badgerys Creek	10	Bargo	2.5
Bankstown Airport	7	Bringelly	10
Bellambi AWS	2.5	Chullora	0.5
Camden Airport AWS	7	Earlwood	2.5
Canterbury Racecourse AWS	2.5	Londfield	2.5
Cessnock Airport AWS	10	MacArthur	5
Gosford (Narara) AWS	2.5	Newcastle	2.5
Holsworthy Control Range	2.5	Oakdale	2.5
Horsley Park Equestrian Centre AWS	5	Prospect	5
Kiama (Bomb Headland)	2.5	Randwick	5
Moss Vale AWS	10	Rozelle	0.5
Mount Boyce AWS	10	St Marys	5
Nora Head AWS	2.5	Vineyard	7
Nullo Mountain	10	Wollongong	2.5
Patterson (Tocal AWS)	5		
Penrith Lakes AWS	2.5		
Richmond RAFF AWS	7		
Sydney Airport AWS	5		
Sydney Olympic Park	5		
Terry Hills AWS	5		
AWS	2.5		
Williamtowm RAFF	7		

4.1.1 Modelling domain

TAPM was run in three nested grids with grid spacing of 10km x 10km, 4km x 4km and 3km x 3km with 25 vertical levels (up to 8,000m). The number of grid points (70 x 90) was selected to ensure that the inner most grid (3km x 3km) covers an area of 210km x 270km; that is, the Greater Metropolitan Region (GMR) of NSW.

The outer grid spacing is limited to a 10km spacing, to remain within the maximum domain size recommended for TAPM. As outlined in Hurley (2008), domains larger than 1500km x 1500km should be avoided as the model does not account for curvature of the earth.

Hurley (2008) also recommends that the ratio of grid spacing from one nest to another be in the range 2 to 4, as this has been found to optimise both model run time and numerical noise generated in the nesting regions. The ratio of grid spacing selected between the outer grid and grid 2 was 2.5 and between grid 2 and the inner grid was 1.3. Although the grid 2 to inner grid ratio is lower than the recommended range, this is not expected to significantly influence the wind field for the areas of interest in this study, which are located at a distance from the edge of this nesting region. It is also noted that the meteorological modelling conducted by the EPA, for the tiered ozone assessment procedure, used similar small grid spacing ratios for the innermost grid.

The inner grid modelling domain, grid spacing and observation sites are shown in **Figure 4-1**.

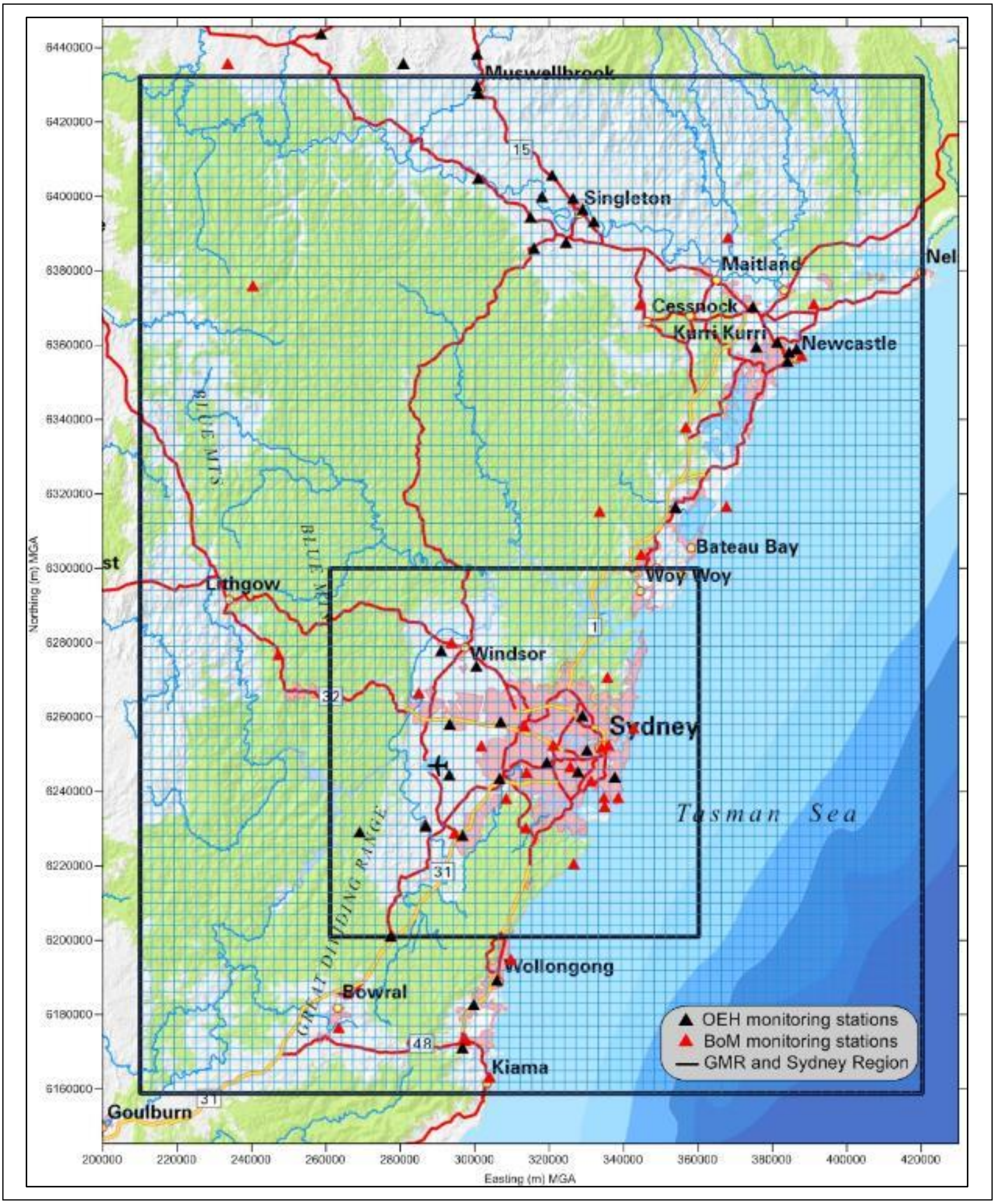


Figure 4-1: TAPM inner grid domain (GMR), grid spacing and monitoring sites

4.1.2 Modelling period

To provide confidence in the ozone modelling for a new emission source (in this case the proposed airport), it was necessary to select a suitable baseline period for modelling, which is used to evaluate model performance and make model refinements if they are needed.

The most suitable periods for evaluation are when peak ozone impacts occur (when exceedances of the 1-hour and 4-hour ozone standards occur frequently on consecutive days). Periods of peak ozone are selected for modelling because these are the conditions relevant to compliance with the air quality objectives (which are expressed as maximum (peak) 1-hour and 4-hour averages).

A review of ozone concentration data for the most recent 10 years indicates that the greatest number of exceedances of the 1-hour and 4-hour ozone standard occurred during summer 2008/2009. Peak ozone events also occurred during the summer 2006/2007, 2005/2006, 2007, 2011 and 2013, however analysis of the Geoscience Australia Sentinel Hotspots database for these periods indicates that significant bushfire activity may have contributed to some of these ozone episodes.

For example, during the summer of 2006/2007 there was significant bushfires to the northwest of Sydney and on the Central coast, in November 2009 there were bushfires on the northern outskirts of Sydney and in October 2013 there was a significant bushfire event in the Blue Mountains. During the summer of 2008/2009 some isolated fires were recorded on the Sentinel Hotspots database, however no significant bushfire events were recorded. Considering the high number of exceedances of both the 1-hour and 4-hour ozone concentrations in the summer of 2008-2009, this period was selected for model evaluation.

The extended 2008/2009 summer period was modelled, from November 2008 to February 2009.

4.2 Overview of the chemical transport model

The model selected for this assessment is consistent with the EPA's tiered procedure for ozone assessment in NSW (ENVIRON, 2011). The Comprehensive Air quality Model with extensions (CAMx), developed by Ramboll Environ (ENVIRON, 2015), is an Eulerian photochemical dispersion model that allows for integrated "one-atmosphere" assessments of gaseous and particulate air pollution (e.g. ozone, $PM_{2.5}$, PM_{10} and air toxics) over a wide range of spatial scales ranging from sub-urban to continental. CAMx is one of two photochemical grid models that accounts for virtually all of the ozone assessment modelling currently performed in the US.

CAMx is a publicly available, open-source computer modelling system that can be downloaded from the CAMx home page at http://www.camx.com/. This site also provides a comprehensive User's Guide and other technical documentation (including journal publications), as well as pre- and post-processing utilities. The model is actively maintained and updated by Ramboll Environ, and the latest version of the model was used for this assessment (Version 6.2), released in March 2015.

4.2.1 Chemical mechanism

Photochemical models incorporate atmospheric chemistry modules to describe the conversion of emitted pollutants to secondary pollutants such as ozone. The 2005 version of the Carbon Bond chemical mechanism (CB05) was selected for this study (Yarwood et al., 2005).

CB05 supersedes the CB4 mechanism and should be used rather than CB4. CB05 has been evaluated against smog chamber data and has been used in multiple photochemical models (e.g. CAMx and CMAQ).

The Air Emission Inventory for the GMR has been compiled for the CB4 mechanism. However, CB4 emission inventories can be used with CB05 without causing any problems because CB05 is backwards compatible with CB4.

4.3 Emissions scenarios

Emissions data for modelling are required for the following scenarios:

- 2008/2009 Base Case – for model evaluation.
- 2030 Future Base Case – for comparison with airport operations.
- 2030 Airport Case – for the Stage 1 airport development emissions.
- 2063 Airport Case – for the long term airport development emissions.

4.3.1 Baseline model evaluation

The 2008/2009 Base Case model evaluation assesses model performance by modelling existing emissions sources for 2008/2009 and comparing results against monitoring data for the same period. The 2008/2009 Base Case was used to evaluate and calibrate the model and provides confidence in the model's ability to predict the future air quality impact from the addition of the airport.

As previously discussed, the 2008/2009 period was selected because it has the greatest number of exceedances of the 1-hour and 4-hour ozone standard for the past 10 years. These peak ozone periods are what we want the model to be able to accurately predict, so that future compliance with the air quality objectives can be assessed. In other words, the modelling period represents the meteorological conditions that have historically led to peak ozone and therefore may also lead to peak ozone formation with future (airport) emissions added.

Gridded emissions inventory data were provided by EPA for 2008 (EPA, 2012). The GMR air emissions inventory data includes point source emissions from commercial and industrial sources, area source emissions for on-road mobile, commercial, industrial, domestic and off-road sources for the entire GMR.

The following emissions files were provided by the EPA:

- Areas source files (aems), including fugitive area source emissions from commercial, domestic, industrial and off-road sources. In extracting the data, the control factor for biogenic sources (bushfires, prescribed burning, soil and vegetation) is set to zero, to exclude these sources (refer **Section 4.4** for details on how biogenic emissions were modelled).
- Vehicle emission files (mvems), including area source emissions for on-road mobile sources.
- Point source files (pems), including elevated point source emission files for commercial and industrial premises.

Gridded emissions inventory data were received as weekday and weekend files by month, at a grid resolution of 1km x 1km and speciated for the CB4 chemical mechanism.

From these data, time-varying emissions are generated for the modelling period (November 2008 to February 2009) for input into CAMx by aggregating emissions into a 3km x 3km grid. The resulting emission files were ready for use with CAMx but required merging with emissions from biogenic sources and the airport.

Annual emission totals for the NSW GMR and the Sydney Region are presented in **Table 4-3** and **Table 4-4**, for ozone precursor emissions considered in the modelling. For some sources the majority of emissions occur within the Sydney region. For example, 74% of NO_x emissions for on-road mobile sources occur in Sydney. For others source groups, such as industrial, the majority of emissions occur outside of the Sydney region.

As described in **Section 2.1**, emissions from existing airport operations in Sydney are less than 3% of total emissions for the Sydney Region (EPA, 2012a). A summary of the annual emissions for existing airports in the Sydney Region (e.g. Sydney Airport, Bankstown Airport, Camden Airport and Richmond RAAF) is presented in **Table 4-5**, to provide context with emissions estimates presented for the proposed airport. It is noted that airport related traffic is not included in the emission totals.

Table 4-3: Summary of annual emissions for NSW GMR in 2008

Source	Tonnes per year		
	Carbon Monoxide	Oxides of Nitrogen	Total VOCs
Commercial	389	501	9,176
Domestic-Commercial	109,377	3,290	68,809
Industrial	613,365	191,411	11,519
Off-Road Mobile	53,817	53,210	17,950
On-Road Mobile	153,812	60,932	29,504
Total	**930,759**	**309,344**	**136,957**

Table 4-4: Summary of annual emissions for Sydney Region in 2008

Source	Tonnes per year		
	Carbon Monoxide	Oxides of Nitrogen	Total VOCs
Commercial	335	344	6,652
Domestic-Commercial	82,186	2,531	53,178
Industrial	14,173	8,921	8,205
Off-Road Mobile	20,801	16,238	7,341
On-Road Mobile	123,712	45,392	23,512
Total	**241,208**	**73,427**	**98,889**

Table 4-5: Summary of annual emissions for airport operations in 2008

Source	Tonnes per year		
	Carbon Monoxide	Oxides of Nitrogen	Total VOCs
Aircraft (flight operations)	2,407	1,771	253
Aircraft (ground operations)	1,823	255	99
Total	**4,230**	**2,026**	**352**

4.3.2 Future baseline emissions

To assess the impact of airport operations for a future scenario, it was necessary to apply projections to the 2008 baseline emission estimates. The EPA has developed future year annual emissions projections for 2031, which have been used to scale baseline emissions for the Stage 1 airport development, which is nominally assessed in 2030.

The EPA emission projections are consistent with the business as usual (BAU) scenario presented in the Economic Analysis which supports the Impact Statement for the proposed variation to the Ambient Air Quality NEPM[2]. The emission projections assume economic growth and also (importantly) emission factor development to account for improvements in emission standards and increased regulation. For example, despite projected growth in vehicle kilometres travelled (VKT) vehicle emissions are assumed to decrease as a result of improvements in emission standards.

The EPA has not developed emissions projections as far out as 2063, and no other robust method of projecting emissions for other sources (commercial, industrial etc.) was identified for 2063. Therefore, the 2031 emissions for all other sources are also used for the long term airport development scenario.

[2] http://www.environment.gov.au/protection/nepc/nepms/ambient-air-quality/variation-2014/impact-statement

A summary of the emissions projections for 2031 are presented in **Table 4-6** and used to derive scaling factors for the 2008 gridded emissions, as shown in **Table 4-7**.

Table 4-6: Summary of estimated annual baseline emissions for 2031 for the GMR

	Tonnes per year		
Source	**Carbon Monoxide**	**Oxides of Nitrogen**	**Total VOCs**
Commercial	461	599	7,635
Domestic-Commercial	119,461	4,069	81,860
Industrial	649,605	231,049	15,353
Off-Road Mobile	73,757	70,469	23,381
On-Road Mobile	38,453	18,889	10,446
Total	**881,736**	**325,074**	**138,675**

Table 4-7: Scaling factors used to scale 2008 baseline emissions for 2030 and 2063

	Tonnes per year		
Source	**Carbon Monoxide**	**Oxides of Nitrogen**	**Total VOCs**
Area source emissions (fugitive commercial, domestic, non-road emissions)	1.216	1.252	1.108
Point source emissions	1.059	1.207	1.333
Vehicle emissions	0.250	0.310	0.354

4.3.3 Stage 1 airport development (2030)

Aircraft are typically the largest contributor to airport emissions, however the majority of aircraft emissions occur in flight and are released at high altitude (Masiol & Harrison, 2014). Local and regional emission inventories for aircraft are therefore typically limited to emissions generated during the Landing/Take-Off (LTO) cycle, which includes idle, taxi, take off, climb-out and approach. These emissions are released near the ground and can be brought to ground level by turbulent mixing in the atmosphere. Emissions generated during the LTO cycle are generally considered in airport emission inventories up to 3,000 feet (~1,000 m). Other airport emissions sources include ground support equipment (GSE), aircraft auxiliary power units (APU) and other stationary sources on the ground (boilers, generators, training fires, maintenance).

Emissions estimates for the Stage 1 airport development (nominally 2030) have been made using the US Federal Aviation Administration *Emissions and Dispersion Modeling System* (EDMS). The EDMS emissions data are developed for the LAQA and have been provided for use in this assessment. Emissions are estimated for all airport operations and also for surrounding roadways out to radius of approximately 10 km, including the proposed M12 motorway and upgrades to the Northern Road and Bringelly Road. The emissions estimates for roadways are based on future projected traffic volumes, taking into account the operation of the airport. Details of the roadways included are provided in the local air quality assessment.

A summary of the annual airport emissions from EDMS are presented in **Table 4-8**.

Table 4-8: Stage 1 airport development emissions (2030)

Source	Tonnes per year		
	Carbon Monoxide	**Oxides of Nitrogen**	**Total VOCs**
Aircraft	126.5	335.9	26.5
GSE	48.6	4.5	2.0
APUs	4.7	17.3	0.5
Parking Facilities	9.4	0.4	1.0
Roadways[1]	2,355	847	269
Stationary Sources	2.4	4.4	62.0
Training Fires	3.1	0.0	0.1
Total	**2,460.7**	**1,180.5**	**351.6**

Note: [1] Includes total traffic. The incremental increase in roadway emissions for airport induced traffic only was estimated separately for regional modelling.

Adjustments have been made to the EDMS data for regional modelling. EDMS emissions were processed using the Emissions Processing System version 3 (EPS3) to generate CAMx model-ready emissions. Several EPS3 modules were used to perform the following tasks:

- Gridding.
- Temporal allocation.
- Chemical speciation of VOC and NOx.
- Adjusting emissions for growth and controls.
- Merging emissions from different sectors.
- Tabulating emissions for quality assurance and reporting.

Speciation profiles have been assigned for each source group to convert total VOC to individual VOC species needed for modelling. The speciation profiles used are listed in **Appendix 2**.

4.3.4 Long term airport development (2063)

EDMS emissions estimates for the long term airport development (nominally 2063) have also been developed for the LAQA and provided for the regional modelling. A summary of the annual airport emissions from EDMS are presented in **Table 4-9**. As discussed previously, in the absence of robust emission projections for all other sources, the 2063 Airport Case presents a hypothetical scenario with the long term airport development (year 2063) operating in the context of year 2030 emissions for all other sources.

Table 4-9: Long term airport development emissions (2063)

Source	Tonnes per year		
	Carbon Monoxide	**Oxides of Nitrogen**	**Total VOCs**
Aircraft	728.6	1,756.4	131.9
GSE	159.2	15.0	7.2
APUs	17.8	64.4	1.8
Parking Facilities	126.8	5.7	13.7
Roadways	2,329	895	268
Stationary Sources	15.3	21.6	507.0
Training Fires	61.1	0.5	2.0
Total	**3,518.8**	**2,759.6**	**939.6**

Note: [1] Includes total traffic. The incremental increase in roadway emissions for airport induced traffic only was estimated separately for regional modelling.

4.3.5 Emission estimates for airport induced traffic

The EDMS roadway emissions included all future traffic on the roads within 10 km of the airport, not just the incremental traffic attributable to the airport development. For regional modelling, only the incremental traffic emissions are needed because non-airport traffic is already accounted for in the 2030 Base Case emissions inventory for the GMR (the On-road mobile source in **Table 4-6**).

Additional roadway emissions data were provided by PEL as daily totals, for both a base case (no airport development) and a project case (with airport development). These daily traffic emissions data, in grams per kilometre, were combined with link length to derive a total traffic emission for each link, for the base case and project case.

The changes in traffic attributed to the airport were derived from the project minus base case emission totals and then allocated to each model grid cell using the spatial information provided for each link.

For most links, traffic increases with the airport but on some links traffic decreases when a road is used less in response to new roads being built. This results in a decrease in emissions for some links, however, these negative changes (for traffic) are generally small compared to positive changes (emission increases from all other sources).

The estimated airport roadway emissions for 2030 are presented in **Table 4-10**.

The NO_x emissions attributed to the airport are estimated as 2% of the total traffic emissions for the road links included in the assessment. As a comparison, the percentage change in daily traffic, between the base and the project case, over all roadway links combined, ranges from a small negative change to an increase of 1.5%.

Table 4-10: Disaggregated traffic emissions for regional modelling (2030)

Source	Tonnes per year		
	Carbon Monoxide	**Oxides of Nitrogen**	**Total VOCs**
Total estimated roadway emissions	2,355	850	270
Estimated emissions attributed to the airport	103	17.6	12.3

The estimated airport roadway emissions for 2063 are presented in **Table 4-11**. The 2063 NOx emissions attributed to the airport are estimated to be approximately 6% of the total traffic emissions. As a comparison, the percentage change in daily traffic, between the base and the project case, over all roadway links combined, ranges from a small negative change to an increase of approximately 6%.

Table 4-11: Disaggregated traffic emissions for regional modelling (2063)

Source	Tonnes per year		
	Carbon Monoxide	**Oxides of Nitrogen**	**Total VOCs**
Roadways in EDMS	2,319	890	269
Estimated emissions attributed to the airport	243	52	41

To derive temporal profiles for modelling, scaling factors provided by the traffic modeller were used to convert the traffic volumes for AM peak, inter period, PM peak and evening period to an hourly traffic volume. For example, the evening period (EV) corresponds to 13 hours from 6pm to 7am and has a scaling factor of 3. Therefore, traffic volumes for each hour in that evening period is calculated by multiplying the EV period total by 0.23 (3/13). Using this approach, an hourly traffic profile was derived for each link and used to generate hourly varying emissions for modelling based on the daily total traffic emissions.

It is noted that the emissions totals for all roadways in **Table 4-10** and **Table 4-11** differ slightly to the EDMS totals presented in the LAQA (and shown in **Table 4-8** and **Table 4-9**). This is mainly because a recent update to the traffic modelling has led to an update of emissions and modelling for the LAQA that was not necessary for the regional air quality assessment. The latest change in traffic modelling results in an overall change, across all links, of approximately ±0.1% for 2030 and 2063. The resultant change in total emissions is less than 1%, when aggregated across all links. This magnitude of emissions change would result in a change in ozone concentrations much smaller than the precision to which results are presented (i.e., much smaller than 0.1 ppb) and therefore updates to the modelling was not required.

It is noted that emissions estimates for some links do change more substantially than others, with some links having a large positive change and other links having have a large negative change. On the regional scale, these link by link changes are not relevant and the total change is more important. Furthermore, it is noted that the roadway emissions get aggregated into a 3 km x 3km grid cell with all other emission sources and therefore the change by grid cell, for these latest traffic change, may be even less.

The spatial allocation of emissions data for regional modelling is presented in **Appendix 3**.

4.4 Biogenic emissions

Vegetation is present throughout the Sydney GMR, even in urban and suburban environments, and the modelling domain includes areas of dense eucalypt forest that form part of the Blue Mountains national parklands. VOCs from these biogenic sources are an important component of the modelling. The biogenic emission data in the GMR air emissions inventory are provided as diurnal emission profiles averaged by month (based on monthly average temperature) and so do not take into account day-to- day variation in temperature.

To obtain date-specific and hourly varying gridded biogenic emissions, the Model of Emissions of Gases and Aerosols from Nature (MEGAN) is used, driven by temperature fields from TAPM.

MEGAN was developed by the Biological-Atmospheric Interactions (BAI) group of the Atmospheric Chemistry Division (ACD) at the US National Center for Atmospheric Research (NCAR). MEGAN estimates net emission of gases and aerosols from terrestrial ecosystems into the atmosphere (Guenther et al., 2006; Sakulyanontvittaya, et al., 2008) driven by land cover, weather, and atmospheric chemical composition. MEGAN is a global model with a base resolution of approximately 1 km.

4.5 Boundary conditions

Date specific boundary conditions for ozone and other pollutants entering the GMR CAMx domain were obtained from the global model MOZART (Model for Ozone and Related chemical Tracers; Emmons et al., 2010) available from the (US) National Center for Atmospheric Research (NCAR). The ozone boundary conditions generated from MOZART are consistent with the 20-30 ppb concentration range recommended by OEH for regional ozone modelling in Sydney.

5. EXISTING ENVIRONMENT

5.1 Defining areas of ozone attainment and nonattainment

The tiered procedure for ozone assessment requires classification of areas of Sydney as "attainment" or "non-attainment", based on meeting or exceeding an "acceptance limit" expressed as 82% of the NEPM goal (NEPC, 2007). If the maximum 5 year average is below the "acceptance limit" (1-hour average of 82 ppb or 4-hour average of 65.2 ppb) the area is in attainment. If the maximum 5 year average is above the "acceptance limit", the area is in non-attainment. Although the tiered procedure for ozone assessment is not directly applicable to this assessment, it is useful to classify areas of Sydney as attainment or non-attainment, to provide context on the existing ambient environment in terms of ozone pollution.

Ozone is currently measured at 15 Sydney monitoring sites, operated by the (OEH) and shown in **Figure 5-1**. Monitoring data are reported by the OEH in pphm and are converted to ppb for this report.

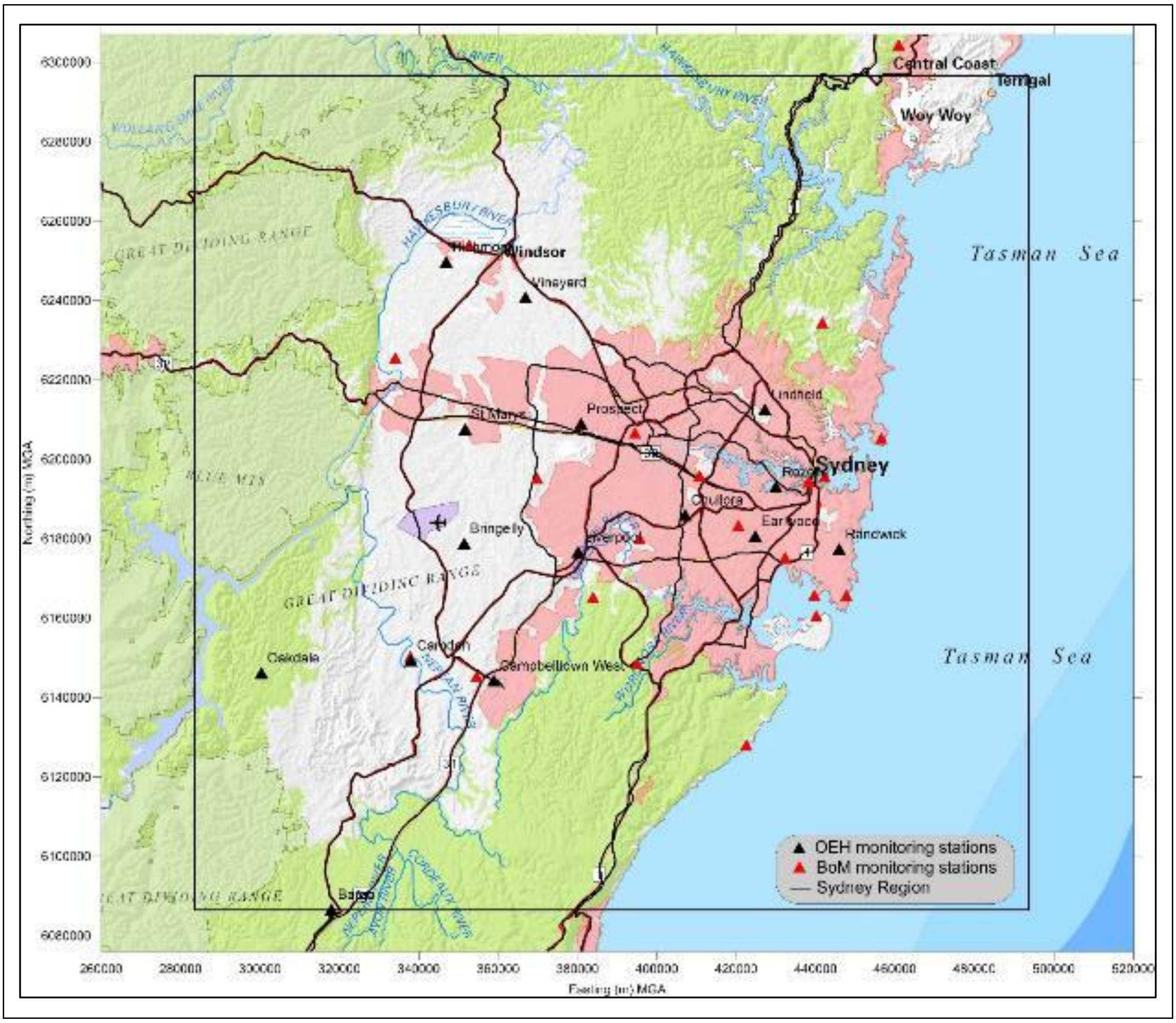


Figure 5-1: OEH monitoring sites in the Sydney Region

The maximum 1 hour and 4 hour average ozone concentrations for the most recent five years of monitoring data at these sites are presented in **Table 5-1** and **Table 5-2**. The average across the 5 years is taken and the maximum 5 year average is compared against the acceptance limits of 82 ppb (1-hour) and 65.2 ppb (4-hour). It is clear from the analysis that all areas of the Sydney region are currently classified as non-attainment.

Table 5-1: Classification of ozone nonattainment based on 1-hour average ozone concentrations

Station	Maximum ozone concentration (ppb)					Average
	2010	2011	2012	2013	2014	
Randwick	84	73	66	75	66	73
Rozelle	73	93	69	73	67	75
Lindfield	82	86	73	81	85	81
Chullora	83	114	80	105	79	92
Earlwood	85	99	82	101	69	87
Maximum 5 year average - Sydney central-east (nonattainment)						**92**
Richmond	89	116	85	95	90	95
St Marys	95	136	85	110	100	105
Vineyard	90	94	80	105	112	96
Propect	104	126	80	111	103	105
Maximum 5 year average - Sydney north-west (nonattainment)						**105**
Liverpool	91	103	79	117	103	99
Bringelly	104	125	88	108	124	110
Bargo	110	126	91	95	105	105
Macarthur	119	131				
Oakdale	99	126	89	95	110	104
Campbelltown west				94	124	
Camden				110	123	
Maximum 5 year average - Sydney south-west (nonattainment)						**110**

Table 5-2: Classification of ozone nonattainment based on 4-hour average ozone concentrations

Station	Maximum ozone concentration (ppb)					Average
	2010	2011	2012	2013	2014	
Randwick	77	69	63	67	61	67
Rozelle	67	80	54	63	60	65
Lindfield	79	84	71	74	75	77
Chullora	72	96	68	94	73	81
Earlwood	74	88	68	82	65	75
Maximum - Sydney central-east (nonattainment)						**81**
Richmond	82	88	70	76	73	78
St Marys	83	121	72	101	85	92
Vineyard	79	75	70	90	75	78
Prospect	97	114	73	104	97	97
Maximum - Sydney north-west (nonattainment)						**97**
Liverpool	81	95	71	110	87	89
Bringelly	89	118	72	102	113	99
Bargo	86	98	83	82	93	88
Macarthur	103	122				
Oakdale	88	98	81	81	88	87
Campbelltown west				82	111	
Camden				90	110	
Maximum - Sydney south-west (nonattainment)						**99**

5.2 Annual exceedances of 1-hour and 4-hour ozone standards

A review of the most recent 10 years of monitoring data reveals exceedances of the 1-hour and 4-hour standards occur in most years. The number of annual exceedances of the 1-hour and 4-hour ozone standards is presented in **Table 5-3** and **Table 5-4**. The exceedances are most frequent in areas of west and southwest Sydney. At Bringelly (near the airport site), there have been exceedances of the ozone standards in 8 of the past 10 years.

Table 5-3: Number of annual exceedances of the 1-hour ozone standard

Station	Number of annual exceedances of 1-hour ozone standard									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Randwick	0	0	0	0	0	0	0	0	0	0
Rozelle	0	0	0	0	0	0	0	0	0	0
Lindfield	-		-	0	1	0	0	0	0	0
Chullora	0	3	0	0	3	0	1	0	1	0
Earlwood	0	2	0	0	3	0	0	0	1	0
Richmond	3	2	4	0	1	0	1	0	0	0
St Marys	2	4	4	0	9	0	5	0	1	0
Vineyard	3	1	4	0	0	0	0	0	2	1
Prospect			-	1	4	3	5	0	2	2
Liverpool	3	11	3	0	3	0	1	0	5	1
Bringelly	6	10	5	0	7	2	5	0	3	4
Bargo	3	3	5	0	11	1	2	0	0	3
Macarthur	11	18	5	0	11	3	5	-		
Oakdale	7	1	8	0	10	0	4	0	0	1
Campbelltown west								-	0	3
Camden								-	1	4

Note: Blanks cells mean complete year of data missing. Cells with a dash indicate less than 75% complete for the year.

Table 5-4: Number of annual exceedances of the 4-hour ozone standard

Station	Number of annual exceedances of 1-hour ozone standard									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Randwick	0	0	2	0	0	0	0	0	0	0
Rozelle	0	1	0	0	0	0	0	0	0	0
Lindfield	-		-	0	3	0	1	0	0	0
Chullora	1	10	0	0	6	0	4	0	3	0
Earlwood	0	4	0	0	7	0	2	0	3	0
Richmond	7	8	13	0	7	2	3	0	0	0
St Marys	6	12	14	1	18	2	11	0	6	5
Vineyard	12	6	7	0	11	0	0	0	7	0
Prospect			3	2	18	7	13	0	6	5
Liverpool	6	16	7	1	10	1	5	0	6	3
Bringelly	13	17	14	0	14	7	8	0	6	11
Bargo	15	10	15	0	28	3	3	1	2	9
Macarthur	23	28	15	0	23	4	9	-		
Oakdale	16	3	20	0	24	5	10	1	1	4
Campbelltown west								-	1	10
Camden								-	15	9

Note: Blanks cells mean complete year of data missing. Cells with a dash indicate less than 75% complete for the year.

5.3 Temporal patterns in ozone concentration

Temporal variation in ozone concentrations are driven by a number of factors, including availability of sunlight, ambient temperature, atmospheric stability, wind direction and availability of precursor emissions.

As described in **Section 2.1**, peak ozone concentrations in Sydney tend to occur in the mid-afternoon and during summer months. This is clearly demonstrated in the polar plots shown in **Figure 5-2** which presents maximum hourly ozone concentrations at Bringelly, plotted by wind direction.

On the left panel, peak concentrations are plotted by hour of the day and on the right panel by month of the year. The colour gradient shows how the ozone concentrations vary temporally and by wind direction (the darker the shade the higher the ozone concentration).

On the left panel, peak ozone concentrations are represented by the dark band which clearly occurs when wind is blowing from the east through north, associated with the transport of precursor emissions from Sydney. This peak concentration band is also distributed between the hours of midday and 4 pm, as shown by the hour of day scale at each compass point.

On the right panel, similar peak ozone concentrations occur when winds are from the east through north, associated with the transport of precursor emissions from Sydney. In this case the scale at each compass point shows month of the year and there are two very clear peak concentration bands, representing the months of January/February and November/December.

5.4 Long term trends in ozone concentration

The most recently published "*State of the Air in Australia*" report (DSEWPC, 2011) found no obvious trends in 1-hour or 4-hour ozone concentration for NSW, for the 10 year assessment period examined (1999 – 2008). The report also noted that ambient ozone concentrations were unlikely to decrease in the foreseeable future because of growth in motor vehicle use and higher temperatures/drier weather from climate change resulting in more bushfires, higher photochemical activity and emissions of ozone precursors.

Analysis of ozone and NO_x monitoring data are presented in **Figure 5-2** to examine long term trends in the most recent ten years of monitoring data (2004-2014) for Bringelly (near the airport site). Long term trends were determined by accounting for seasonal variation using the procedure of Cleveland et al. (1990) implemented by Carslaw and Ropkins (2012).

The analysis shows a negative trend in the maximum monthly ozone concentration (approximately 1% decrease per annum) and a more pronounced negative trend in the NO_x data (~3% decrease per annum). Therefore, although exceedances of the 1-hour or 4 hour ozone standard have occurred in 8 of the previous 10 years, there is some evidence of decreasing trends in monthly maximum ozone concentrations at Bringelly. Analysis for other sites in southwest, northwest and central Sydney shows similar trends.

The Bureau of Meteorology (BoM) annual climate statement for 2014[3] reports that 2014 was the hottest year on record and seven of Australia's ten warmest years on record have occurred since 2002. As described previously, the most recent *State of the Air in Australia* report postulates that higher temperatures and drier weather might result in increased photochemical activity and emissions of ozone precursors. This hypothesis is not necessarily reflected in the trend analysis for the most recent 10 years of monitoring data at Bringelly.

[3] http://www.bom.gov.au/climate/current/annual/aus/

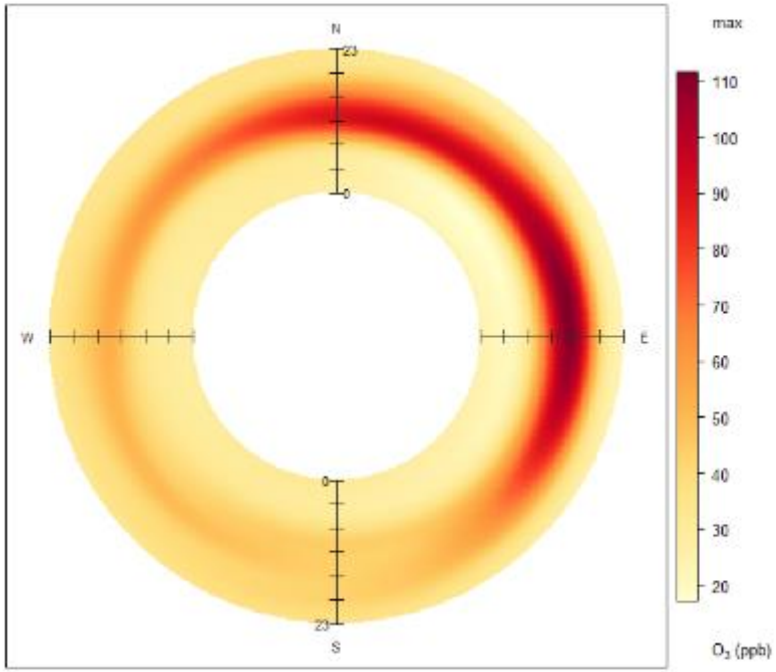
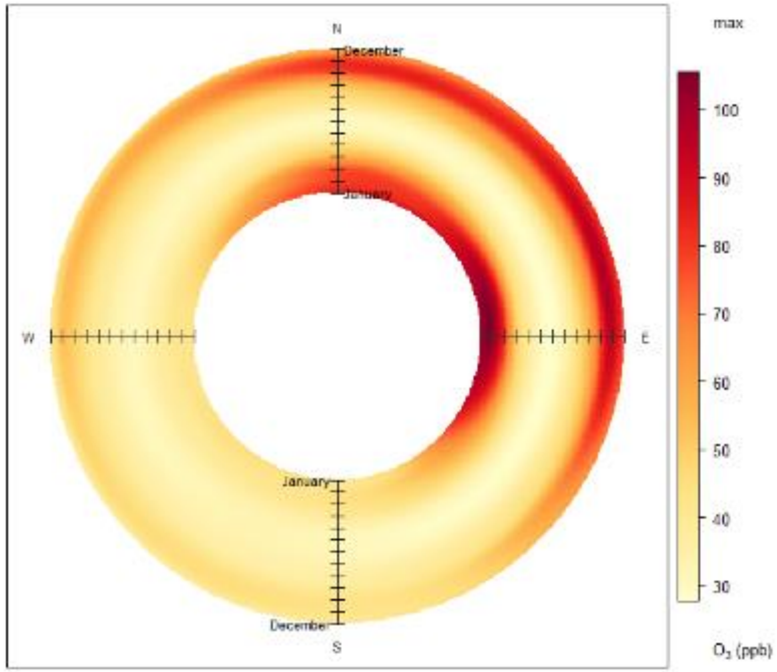
	
Maximum ozone concentration by hour of day	Maximum ozone centration by month of the year

Figure 5-2: Polar plot of maximum hourly and monthly ozone concentration (ppb) by wind direction at Bringelly (2004 to 2014)

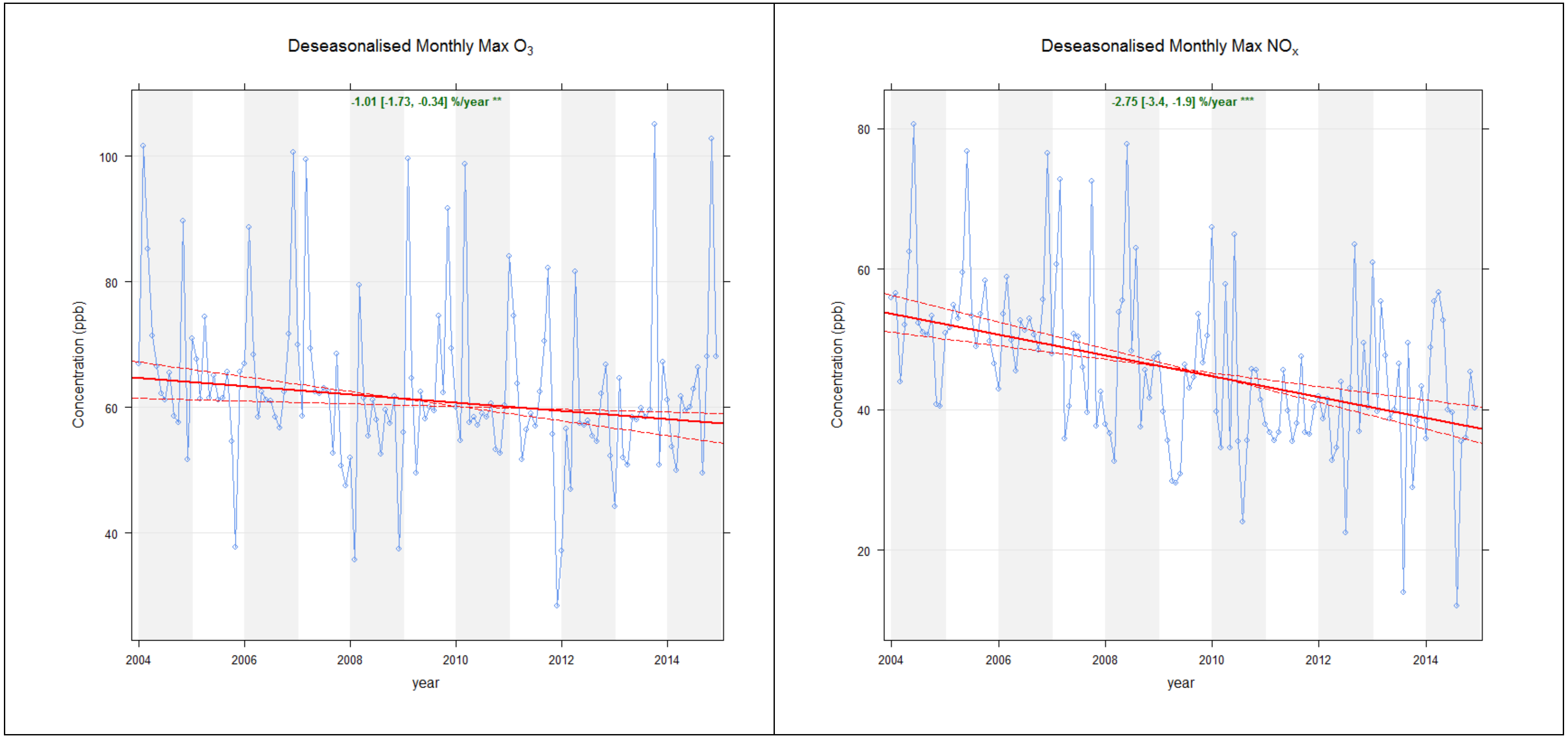


Figure 5-3: Trend in monthly max ozone and NO_x concentrations (ppb) at Bringelly (2004-2014) (% change per year with 95% confidence limits)

6. EVALUATION OF METEOROLOGICAL MODELLING

Meteorological model performance is critical to obtaining accurate photochemical model performance because ozone formation depends upon meteorological conditions (temperature, sunlight, dilution of emissions) and because source-receptor relationships are determined by wind fields.

TAPM has been found to overestimate solar radiation during both clear sky and cloudy conditions (Dehghan et al, 2014) while Hibberd et al (2011) found that TAPM underestimates cloudy days and overestimates net radiation (as reported in Dehghan et al, 2014). This may introduce a systematic bias towards over-predicting ozone production on days that were cloudy, and is discussed further in **Section 7**.

To evaluate TAPM performance for local meteorology, predicted meteorological parameters (wind speed, wind direction and temperature) were extracted from TAPM at four locations and compared with the closest observation sites that are considered to be generally representative of the area of interest. The locations selected for the evaluation are described in **Table 6-1**.

Table 6-1: Locations and observations sites for model evaluation

Area for TAPM extract	TAPM grid coordinate (Easting/Northing MGA)	Observation site for comparison
Area near the airport site, between Bringelly and Badgerys Creek	292500 / 6246000	- Badgerys Creek BoM site - Bringelly OEH site
Southwest Sydney, south of Camden Airport	286500 / 6228000	- Camden Airport BoM site - Campbelltown (Mt Annan) BoM site
Northwest Sydney, between Prospect and Vineyard	304500 / 6261000	- Vineyard OEH site - Prospect OEH site
Western Sydney, between Bankstown and Chullora	3165000 / 6246000	- Chullora OEH site - Bankstown Airport BoM site

An evaluation of the meteorological model performance is presented using visual analysis tools (wind roses, time variation plots and scatter plots) and statistical evaluation, based on the evaluation methods in **Table 6-2**. Indicative performance benchmarks for bias and error are provided, based on Emery et al. (2001). The purpose of these benchmarks was not to give a passing or failing grade to any one particular meteorological model application, but rather to put the model's results into the proper context of other models and meteorological data sets. Since 2001, the benchmarks have been promoted by the EPA-sponsored National Ad Hoc Meteorological Modeling Group and have been consistently relied upon to evaluate Pennsylvania State University / National Center for Atmospheric Research (MM5) and WRF model performance in many regulatory modelling projects throughout Texas and the U.S.

Table 6-2: Statistical evaluation for model performance

Statistical test	Description	
FAC2	$0.5 \le \frac{M_i}{O_i} \ge 0.5$	Fraction of model predictions (M) within a factor of 2 of the observed values (O)
Mean bias (MB)	$\boldsymbol{MB = \frac{1}{n}\sum_{i=1}^{N} M_i - O_i}$	MB provides an indication of the mean over or under estimate of model predictions and is expressed in the same units as the quantities being considered. Indicative performance benchmark for wind speed is ≤±0.5 m/s and for temperature is ≤± 0.5 K.
Mean Gross Error (MGE)	$\boldsymbol{MGE = \frac{1}{N}\sum_{i=1}^{N} \lvert M_i - O_i \rvert}$	MGE provides an indication of the mean error regardless of whether it is an over or under estimate and is in the same units as the quantities being considered. Indicative performance benchmark for wind speed is ≤ 2.0 m/s and for temperature is ≤ 2.0 K.
Pearson correlation coefficient (r)	$r = \frac{1}{n-1}\sum_{i=1}^{N}\left(\frac{M_i - \bar{M}}{\sigma_M}\right)\left(\frac{O_I - \bar{O}}{\sigma_O}\right)$	The (Pearson) correlation coefficient is a measure of the strength of the linear relationship between two variables. If there is perfect linear relationship with positive slope between the two variables, r = 1.
Index of Agreement (IOA)	$IOA = 1 - \frac{\sum_{i=1}^{N} \lvert M_i - O_i \rvert}{c\sum_{i=1}^{N} \lvert O_i - \bar{O} \rvert}$	Values approaching +1 representing better model performance. (Willmott et al. 2011).

6.1 Evaluation of model performance near the airport site

A comparison of observed and the TAPM predicted wind roses for the modelling period (November 2008 to February 2009) is presented in **Figure 6-1**. The TAPM predicted winds are extracted from a point between Bringelly OEH and the Badgerys Creek BoM observation sites.

The two observation sites themselves differ slightly, with stronger winds recorded at the Badgerys Creek BoM site. The mean wind speed for Badgerys Creek is 3.7 m/s, compared with 2.1 m/s at Bringelly. The percentage occurrence of calm winds (less than 0.5 m/s) is also higher at Badgerys Creek.

The TAPM average wind speed falls between the observations, while the percentage calms is closer to the Bringelly site. The TAPM wind direction reflects the general wind patterns for both sites with a relatively uniform distribution of winds from the southwest through northeast.

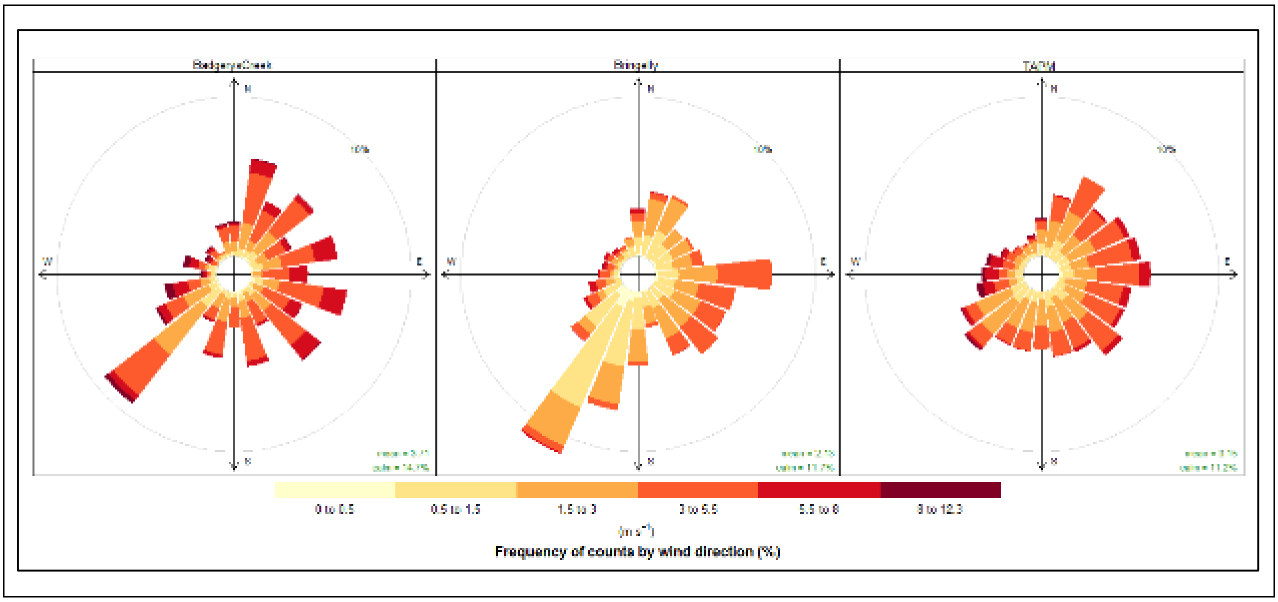


Figure 6-1: Wind rose comparison for proposed airport

Hourly variation in the observed and predicted wind speed and temperature is presented in **Figure 6-1**. TAPM predicted winds generally lie between the observations and appear closer aligned to the measurements at Badgerys Creek. Predicted hourly temperature tracks well with observations at both Badgerys Creek and Bringelly during the afternoon while the predicted night-time and early morning temperatures tend to be higher than observed. This is unlikely to affect ozone predictions as peak concentrations occur in the afternoon.

Scatter plots of the predicted and observed wind speed and temperature are shown in **Figure 6-3** and **Figure 6-4**. The correlation is high for wind speed and temperature at both sites.

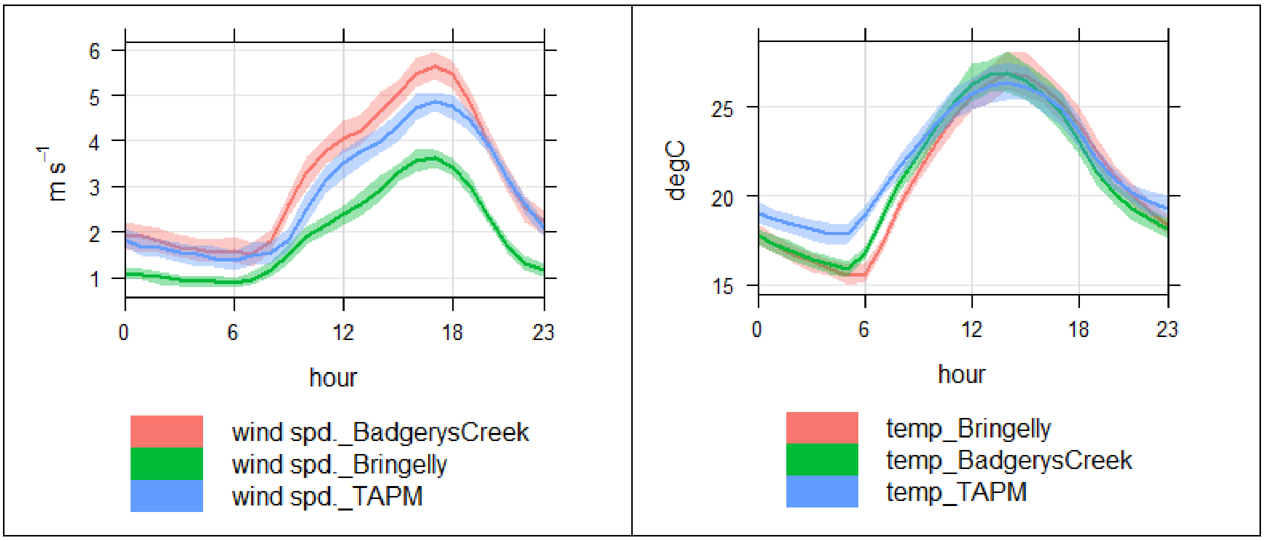


Figure 6-2: Time variation of observed and predicted wind speed and temperature for proposed airport

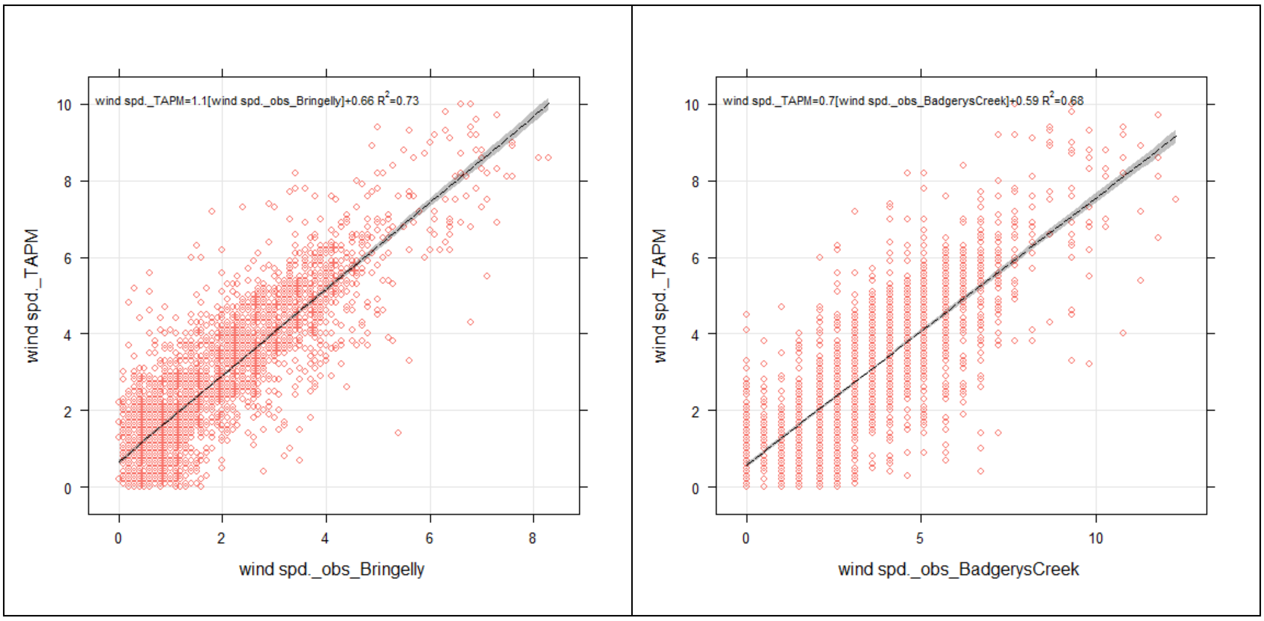


Figure 6-3: Scatter plot of observed and predicted wind speed for proposed airport

Note: Wind speed data recorded at BoM sites (Badgerys Creek) is provided in increments of 0.5, due to conversion from knots to m/s, resulting in a more defined bands seen in the scatter plot on the right.

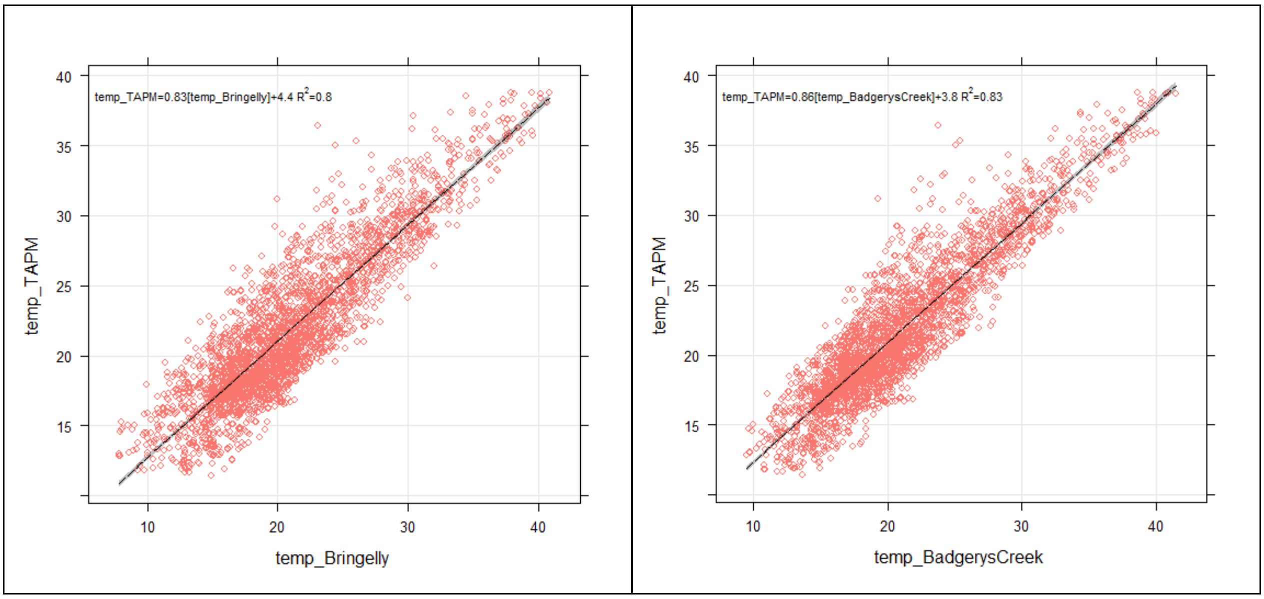


Figure 6-4: Scatter plot of observed and predicted temperature for proposed airport

A summary of the model evaluation statistics for TAPM predicted wind speed and temperature is presented in **Table 6-3**. The statistical evaluation for wind speed which shows more favourable FAC2, correlation and index of agreement and lower bias and error for observations at the Badgerys Creek site. The statistical evaluation for temperature is similar for both sites.

Table 6-3: Evaluation of TAPM wind speed and temperature against observations for Western Sydney Airport

Statistical test	Wind speed		Temperature	
	Badgerys Creek	Bringelly	Badgerys Creek	Bringelly
Fraction of predictions within a factor of 2 (FAC2)	0.82	0.70	1.00	1.00
Mean bias (MB)	-0.37	0.91	0.74	0.87
Mean Gross Error (MGE)	0.69	1.09	1.87	1.97
Pearson correlation coefficient (r)	0.93	0.85	0.91	0.90
Index of Agreement (IOA)	0.80	0.53	0.79	0.78

6.2 Evaluation of model performance in Southwest Sydney

A comparison of observed and the TAPM predicted wind roses for the modelling period (November 2008 to February 2009) is presented in **Figure 6-5**. The TAPM predicted winds are extracted from a point southwest of Camden.

The TAPM predicted mean wind speed and percentage occurrence of calm winds are closer to the observations at the Campbelltown site. As an airport site, it is not surprising that Camden records higher wind speeds. The TAPM wind direction reflects the general wind patterns for both sites with a relatively uniform distribution of winds from the southwest through northeast.

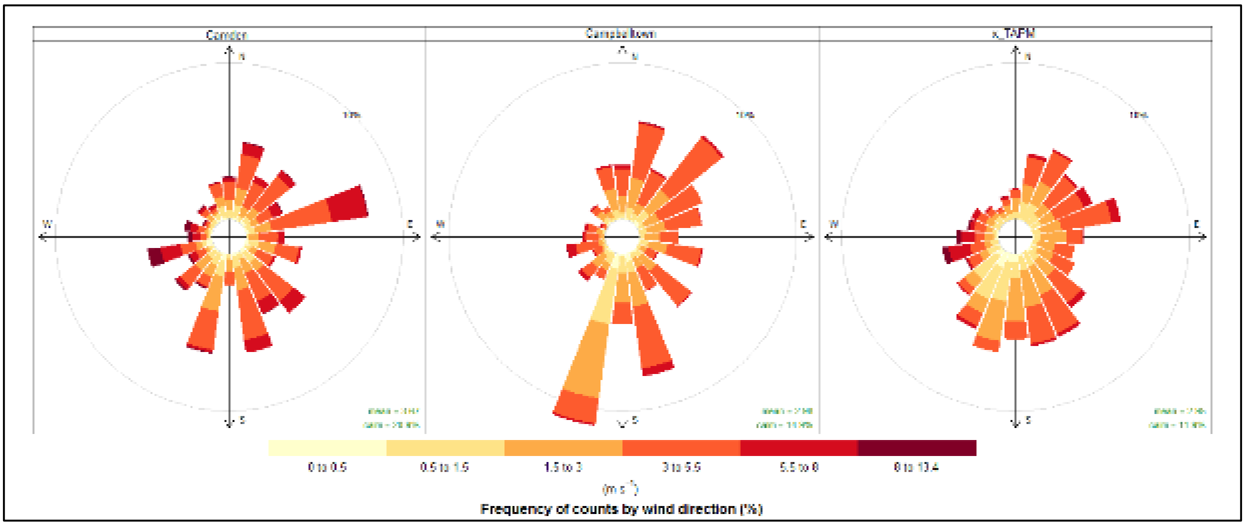


Figure 6-5: Wind rose comparison for Southwest Sydney

The hourly variation in observed and predicted wind speed and temperature is presented in **Figure 6-6**. TAPM predicted winds lie between the observations during the afternoons and track close to observations at other times. Predicted hourly temperature tracks well with observations at both Camden and Campbelltown for afternoon periods (most critical for peak ozone predictions). Predicted temperatures in the early morning tend to be higher than observed.

Scatter plots of the predicted and observed wind speed and temperature are shown in **Figure 6-7** and **Figure 6-8**. The plots show good correlation for wind speed and temperature at both sites.

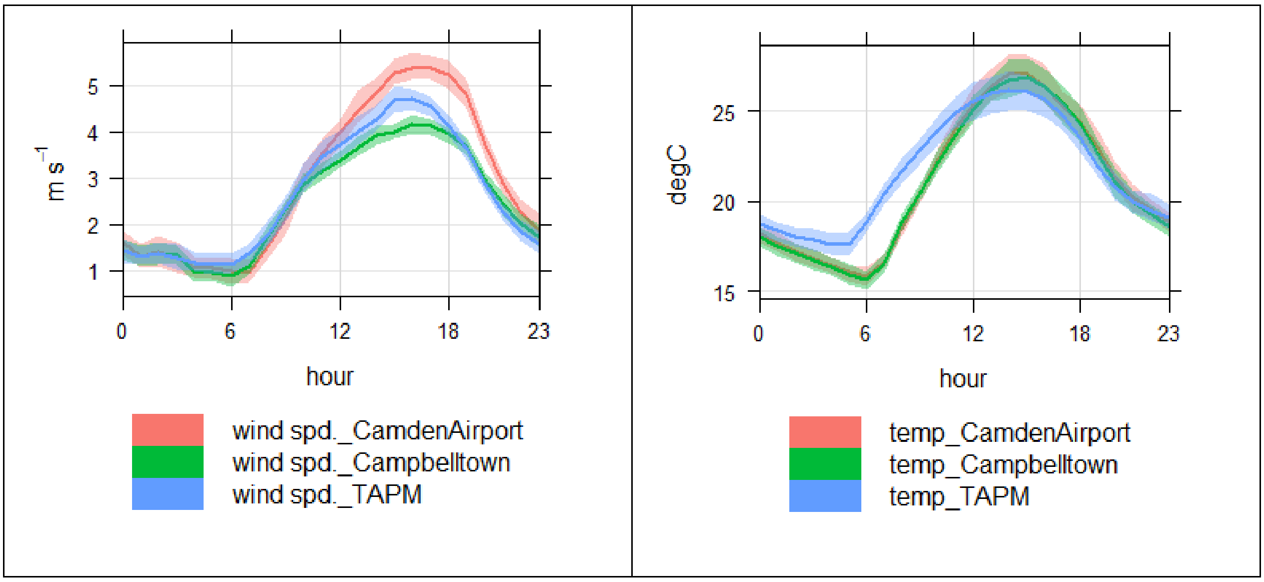


Figure 6-6: Time variation plot of observed and predicted wind speed and temperature for Southwest Sydney

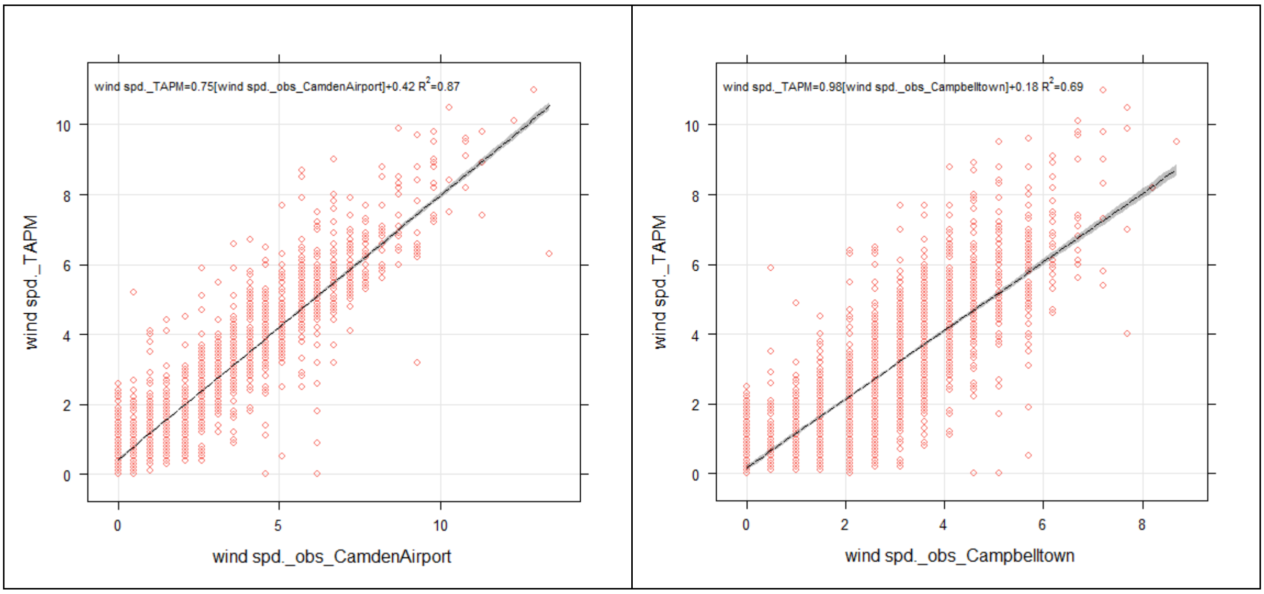


Figure 6-7: Scatter plot of observed and predicted wind speed for Southwest Sydney

Note: Wind speed data recorded at BoM sites is provided in increments of 0.5, due to conversion from knots to m/s, resulting in a more defined bands seen in the scatter plots.

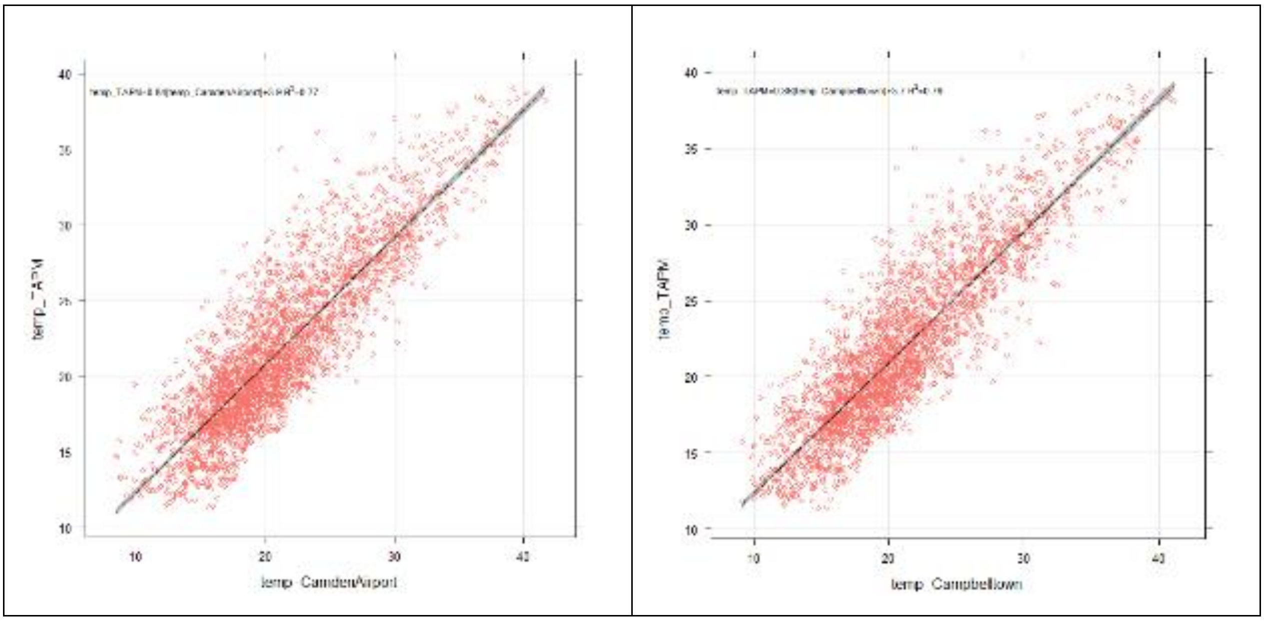


Figure 6-8: Scatter plot of observed and predicted temperature for Southwest Sydney

A summary of the model evaluation statistics for TAPM predicted wind speed and temperature is presented in **Table 6-4**. The statistical evaluation for wind speed shows more favourable FAC2, correlation and index of agreement for observations at the Camden site. Bias and error are similar at both sites. The statistical evaluation for temperature is similar for both sites.

Table 6-4: Evaluation of TAPM wind speeds against observations for Southwest Sydney

Statistical test	Wind speed		Temperature	
	Camden	Campbelltown	Camden	Campbelltown
Fraction of predictions within a factor of 2 (FAC2)	0.75	0.72	1.00	1.00
Mean bias (MB)	-0.29	0.13	0.58	0.78
Mean Gross Error (MGE)	0.71	0.82	2.09	2.06
Pearson correlation coefficient (r)	0.93	0.83	0.88	0.89
Index of Agreement (IOA)	0.81	0.69	0.76	0.76

6.3 Evaluation of model performance in Northwest Sydney

A comparison of observed and the TAPM predicted wind roses for the modelling period (November 2008 to February 2009) is presented in **Figure 6-9**. The TAPM predicted winds are extracted from a point northwest of Prospect.

The TAPM mean wind speeds are slightly higher than observations and the percentage occurrence of calm winds are lower. The TAPM wind direction reflects the general wind patterns for Prospect reasonably well.

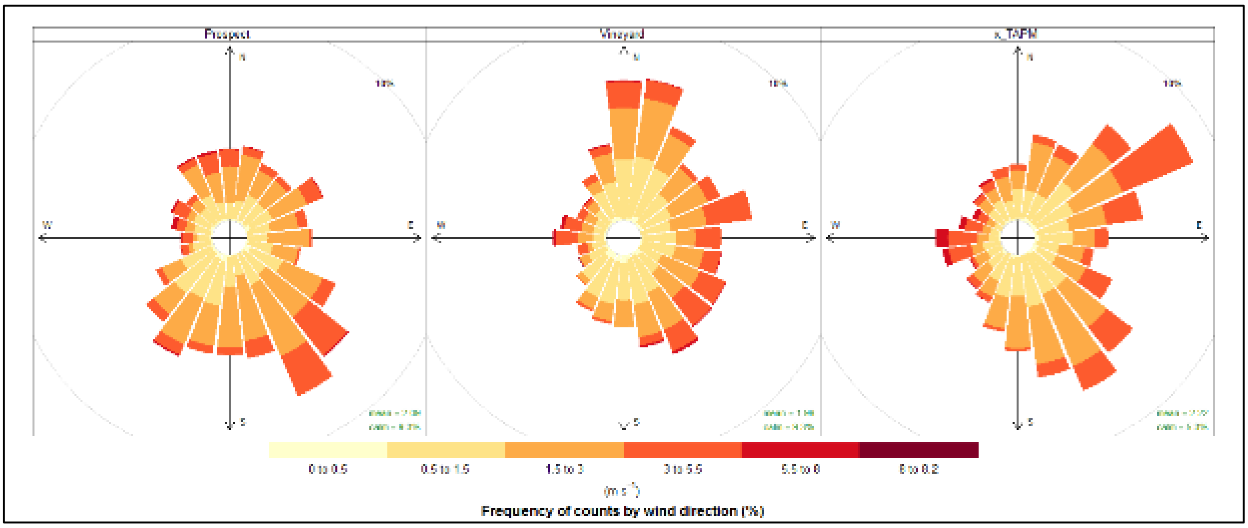


Figure 6-9: Wind rose comparison for Northwest Sydney

The hourly variation in observed and predicted wind speed and temperature is presented in **Figure 6-10**. It is evident that the TAPM predicted winds are higher during the afternoon and track close to observations at other times. Predicted hourly temperature tracks well with observations at both Prospect and Vineyard.

Scatter plots of the predicted and observed wind speed and temperature are shown in **Figure 6-11** and **Figure 6-12**. The correlation is stronger for Prospect, which is expected as the TAPM extraction is closer to and in an area more likely to be representative of the Prospect site.

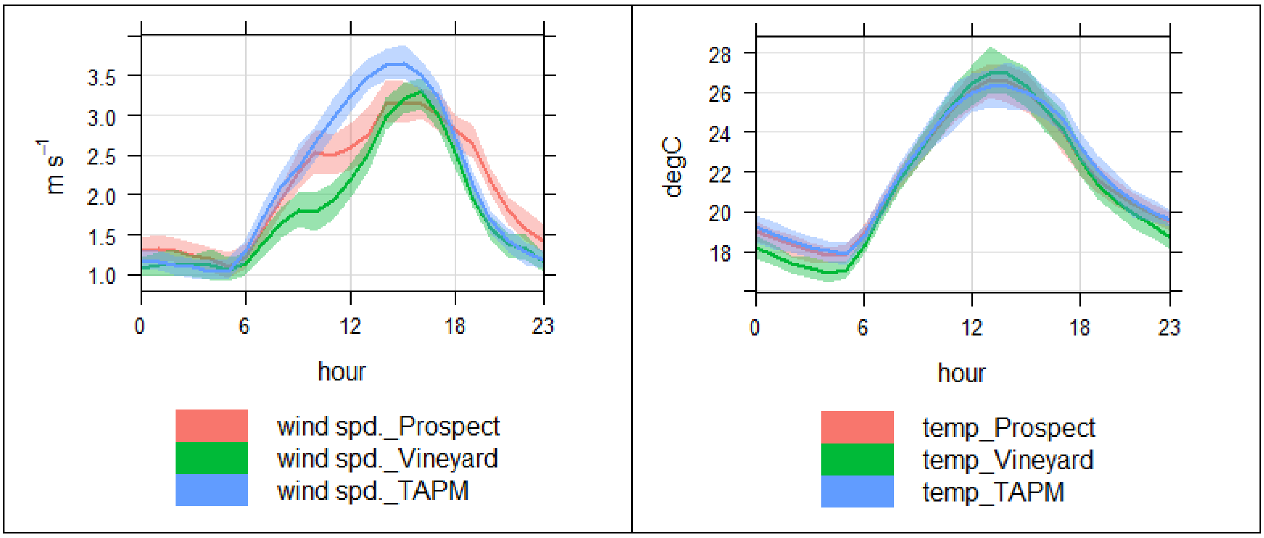


Figure 6-10: Time variation plot of observed and predicted wind speed and temperature for Northwest Sydney

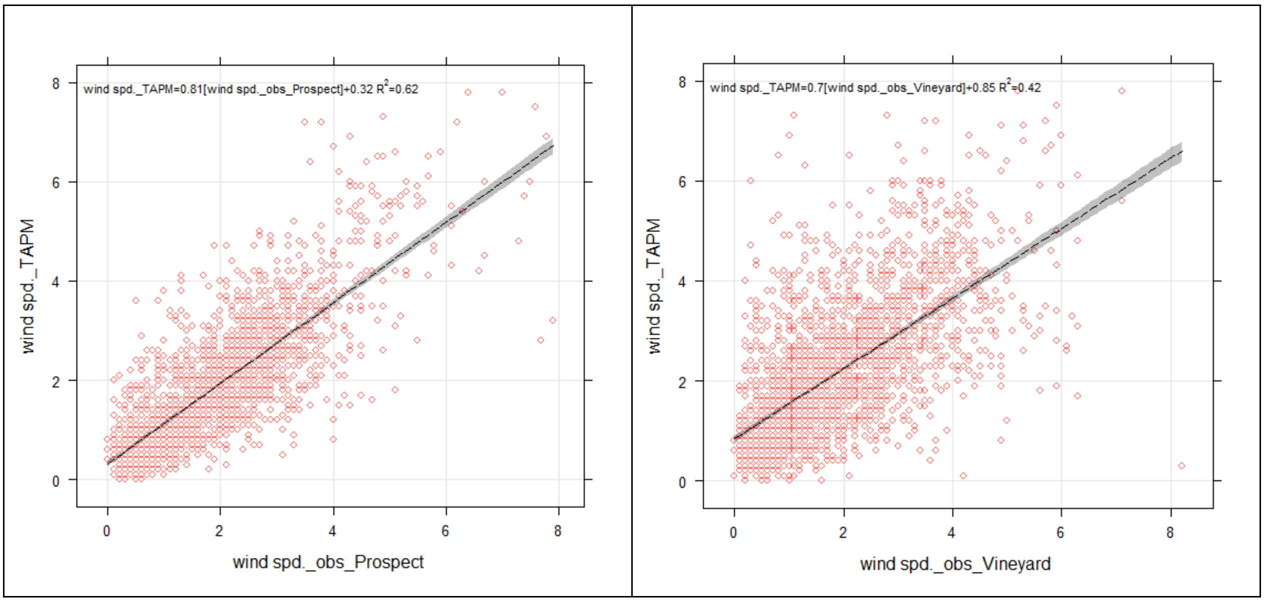


Figure 6-11: Scatter plot of observed and predicted wind speed for Northwest Sydney

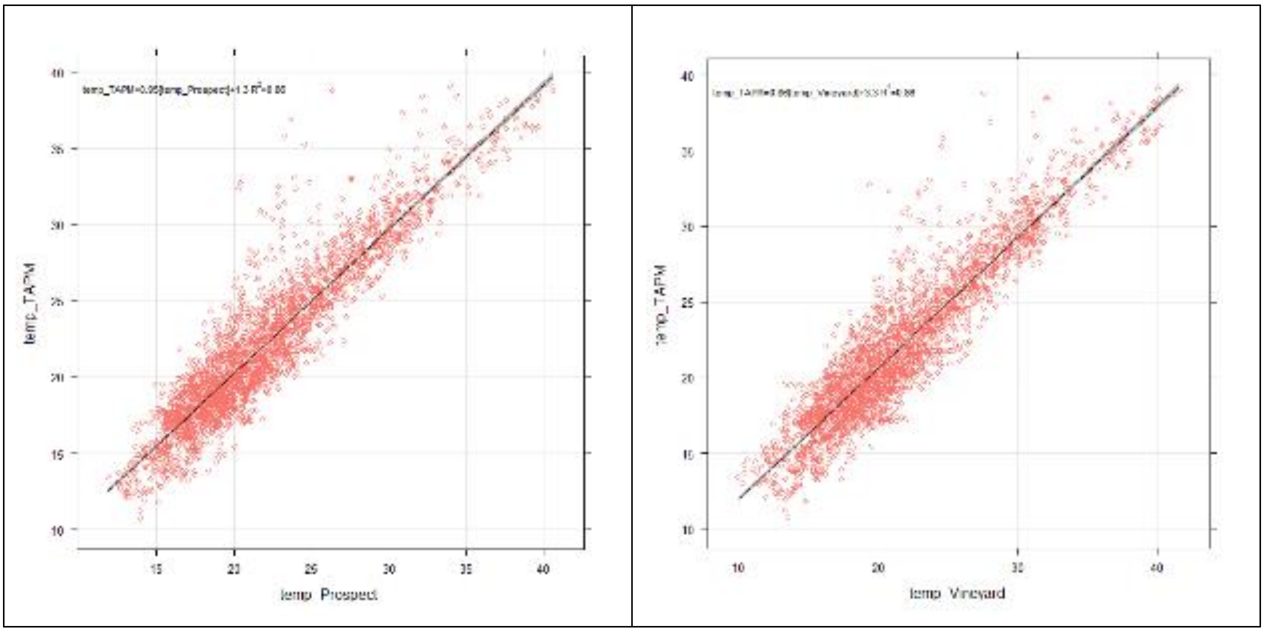


Figure 6-12: Scatter plot of observed and predicted temperature for Northwest Sydney

A summary of the model evaluation statistics for TAPM predicted win speed is presented in **Table 6-5**. The statistical evaluation for wind speed shows more favourable FAC2, correlation and index of agreement and lower bias and error for observations at the Prospect site. This is expected as the TAPM extraction is closer to and in an area more likely to be representative of the Prospect site. The statistical evaluation for temperature is similar for both sites.

Table 6-5: Evaluation of TAPM wind speed and temperature against observations for Northwest Sydney

Statistical test	**Wind speed**		**Temperature**	
	Prospect	**Vineyard**	**Prospect**	**Vineyard**
Fraction of predictions within a factor of 2 (FAC2)	0.90	0.75	1.00	1.00
Mean bias (MB)	-0.03	0.31	0.14	0.40
Mean Gross Error (MGE)	0.53	0.82	1.42	1.59
Pearson correlation coefficient (r)	0.83	0.65	0.93	0.93
Index of Agreement (IOA)	0.73	0.60	0.82	0.81

6.4 Evaluation of model performance in Western Sydney

A comparison of observed and the TAPM predicted wind roses for the modelling period (November 2008 to February 2009) is presented in **Figure 6-13**. The TAPM predicted winds are extracted from a point between the observation sites. The TAPM mean wind speeds are similar to observations at Chullora (the observed wind speed at the airport site is expected to be higher) and the percentage occurrence of calm winds lies in between the two observation sites. The TAPM wind direction reflects the general wind patterns for both sites reasonably well.

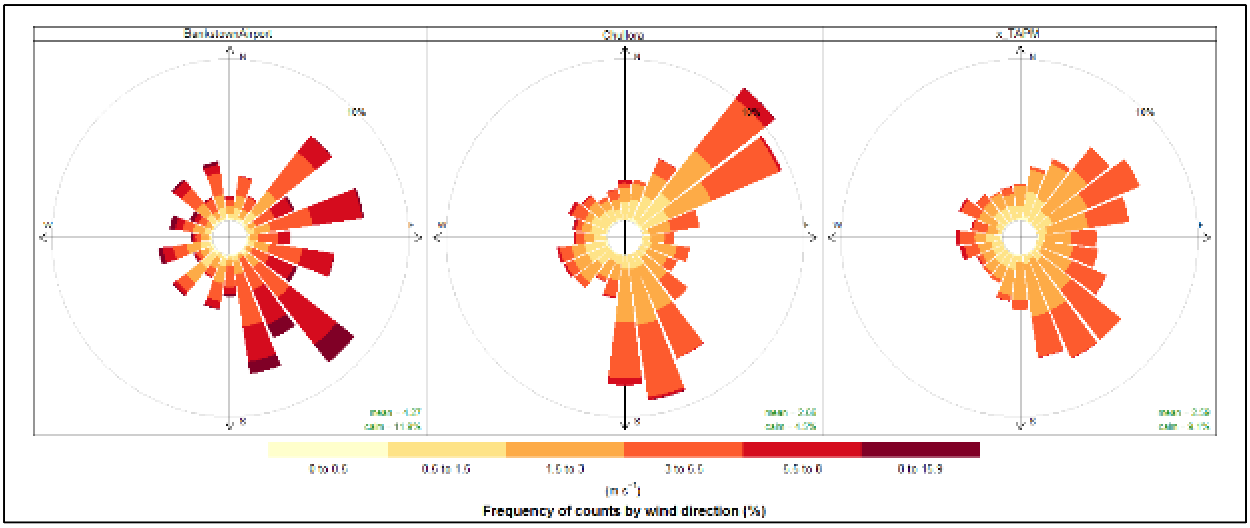


Figure 6-13: Wind rose comparison for Western Sydney

The hourly variation in observed and predicted wind speed and temperature is presented in **Figure 6-14**. It is evident that the TAPM predicted winds track closely to observations at Chullora. Wind speeds are higher at Bankstown Airport, but this is not uncommon for airport monitoring sites.

Predicted hourly temperature tracks well with observations at Bankstown Airport. Observations at Chullora are noticeably lower than observations at Bankstown Airport.

Scatter plots of the predicted and observed wind speed and temperature are shown in **Figure 6-15** and **Figure 6-16**. The plots indicate that correlation is slightly better for Bankstown Airport.

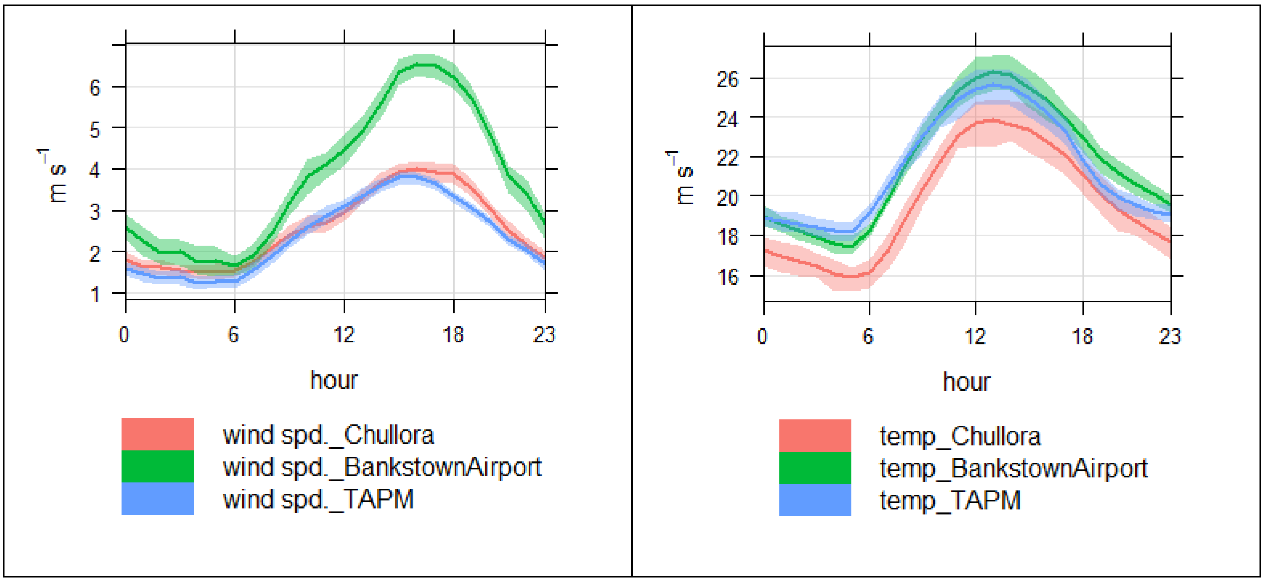


Figure 6-14: Time variation plot of observed and predicted wind speed and temperature for Western Sydney

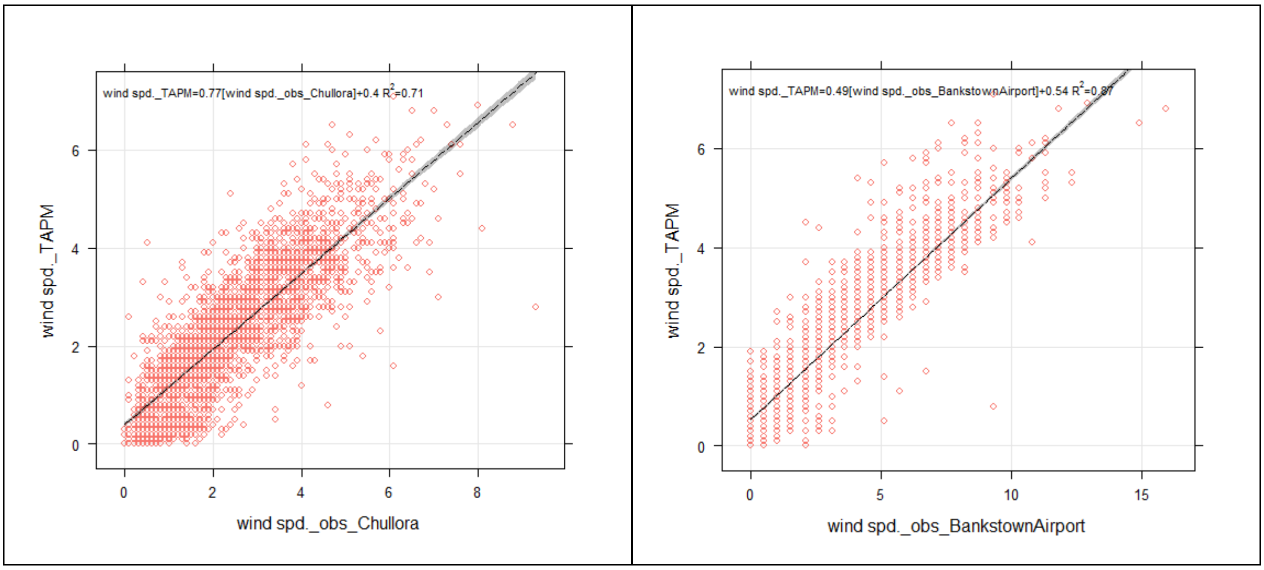


Figure 6-15: Scatter plot of observed and predicted wind speed for Western Sydney

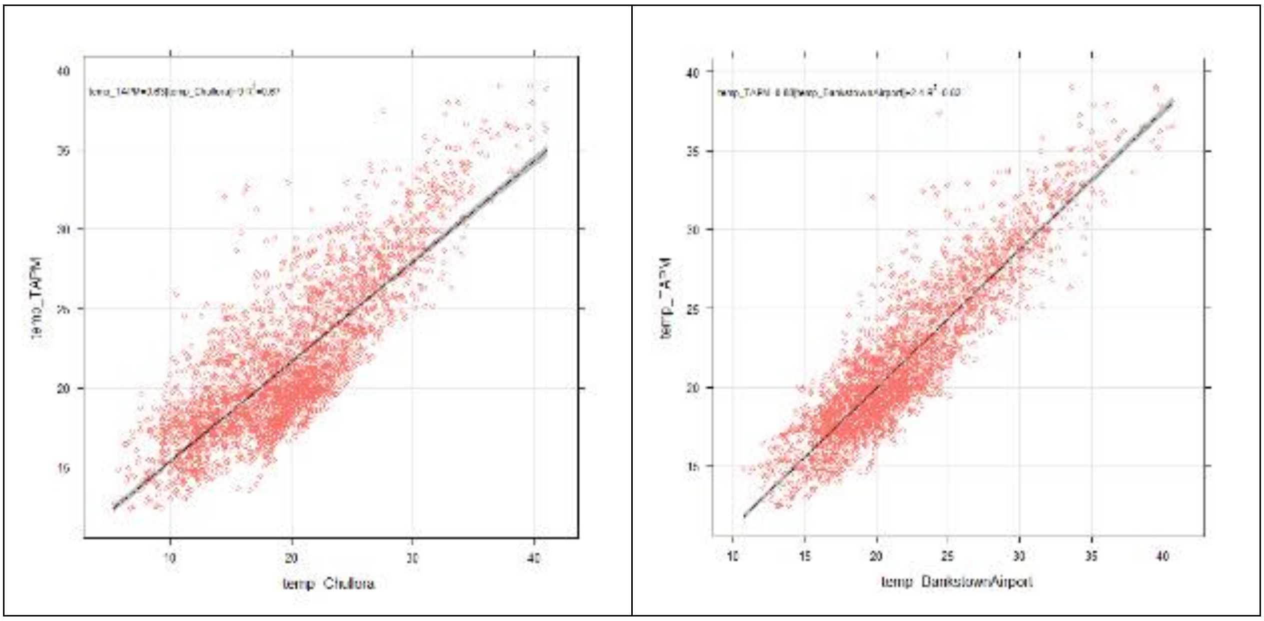


Figure 6-16: Scatter plot of observed and predicted temperature for Western Sydney

A summary of the model evaluation statistics for TAPM predicted wind speed and temperature is presented in **Table 6-6**. The statistical evaluation for wind speed shows mixed performance with a more favourable index of agreement for observations at Chullora but higher correlation for observations at Bankstown Airport. The statistical evaluation for temperature shows more favourable correlation and index of agreement and lower bias and error for observations at Bankstown Airport.

Table 6-6: Evaluation of TAPM wind speeds against observations for Western Sydney

Statistical test	Wind speed		Temperature	
	Chullora	Bankstown Airport	Chullora	Bankstown Airport
Fraction of predictions within a factor of 2 (FAC2)	0.83	0.81	0.99	1.00
Mean bias (MB)	-0.19	-1.39	1.77	-0.25
Mean Gross Error (MGE)	0.70	1.54	3.01	1.97
Pearson correlation coefficient (r)	0.79	0.93	0.82	0.87
Index of Agreement (IOA)	0.71	0.63	0.68	0.73

6.5 Summary

Overall, it is concluded that TAPM simulates the meteorology for the Sydney region with an acceptable degree of accuracy, based on an analysis of four locations considered to be generally representative of the area of interest to this study.

General wind patterns in the observation data were reflected reasonably well in the TAPM predictions and wind speed compared favourably. A statistical evaluation of the modelling predictions generally showed good correlation for wind speed and temperature with reasonably low bias and error.

7. MODEL EVALUATION BASE CASE SCENARIO

7.1 Introduction

The 2008/2009 Base Case is used to assess model performance by comparing predicted ozone concentrations against ambient monitoring data for the same period. The evaluation is presented for the complete modelling period (November 2008 to February 2009) and modelling predictions compared with observations at all monitoring sites. Additional individual comparisons are made at the Bringelly and St Marys monitoring sites because they are the closest monitoring sites to the airport site, and at Oakdale because it can be downwind of the airport site on high ozone days.

A statistical evaluation of model performance is presented based on a visual evaluation of spatially-paired daily maximum ozone and calculated normalised mean bias (NMB) and normalised mean error (NME) for spatially and temporally paired ozone (refer **Table 7-1)**.

The NMB and NME have been calculated for data pairs where the observed ozone is greater than 30 ppb to focus on periods of photochemical ozone production within the Sydney Region. The cut-off value of 30 ppb is representative of background ozone concentrations present in air entering the ozone modelling domain.

Table 7-1: Statistical metrics for model evaluation

Metric	Description
Normalised Mean bias (NMB)	$NMB = \frac{\sum_{i=1}^{N} M_i - O_i}{\sum_{i=1}^{N} O_i}$
Normalised Mean Error (NME)	$NME = \frac{\sum_{i=1}^{N} \lvert M_i - O_i \rvert}{\sum_{i=1}^{N} O_i}$

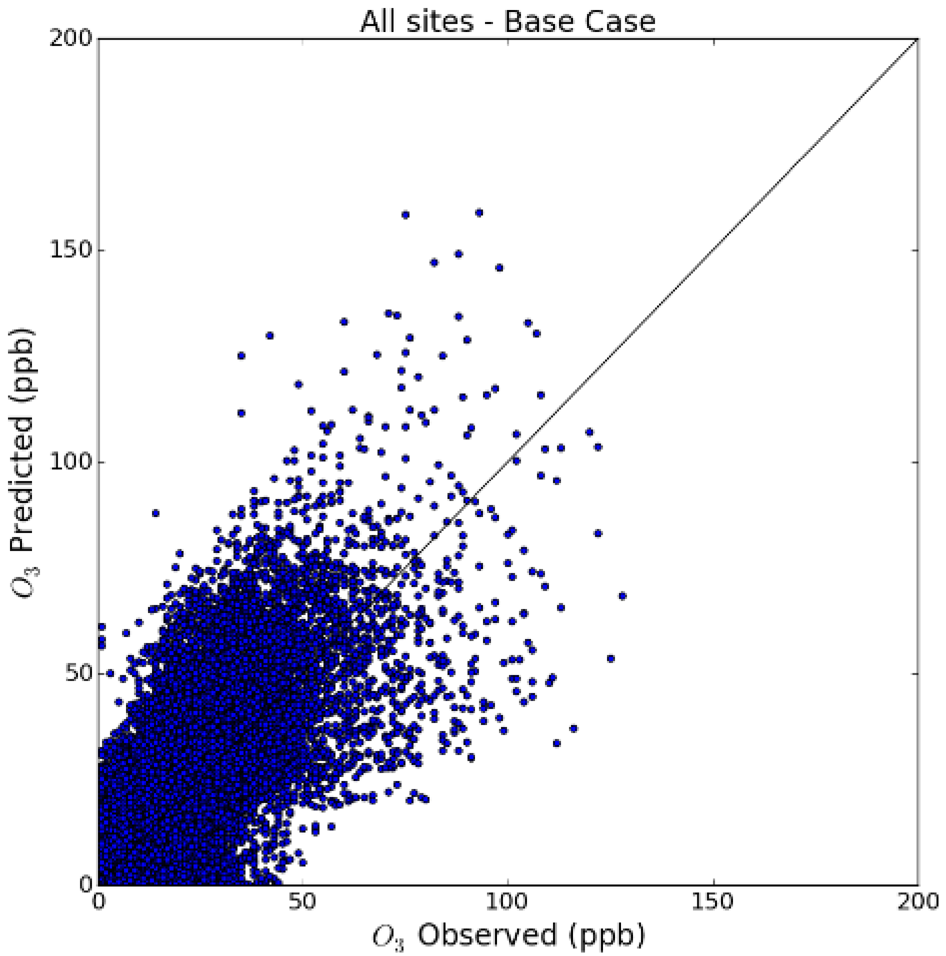
7.2 Graphical evaluation

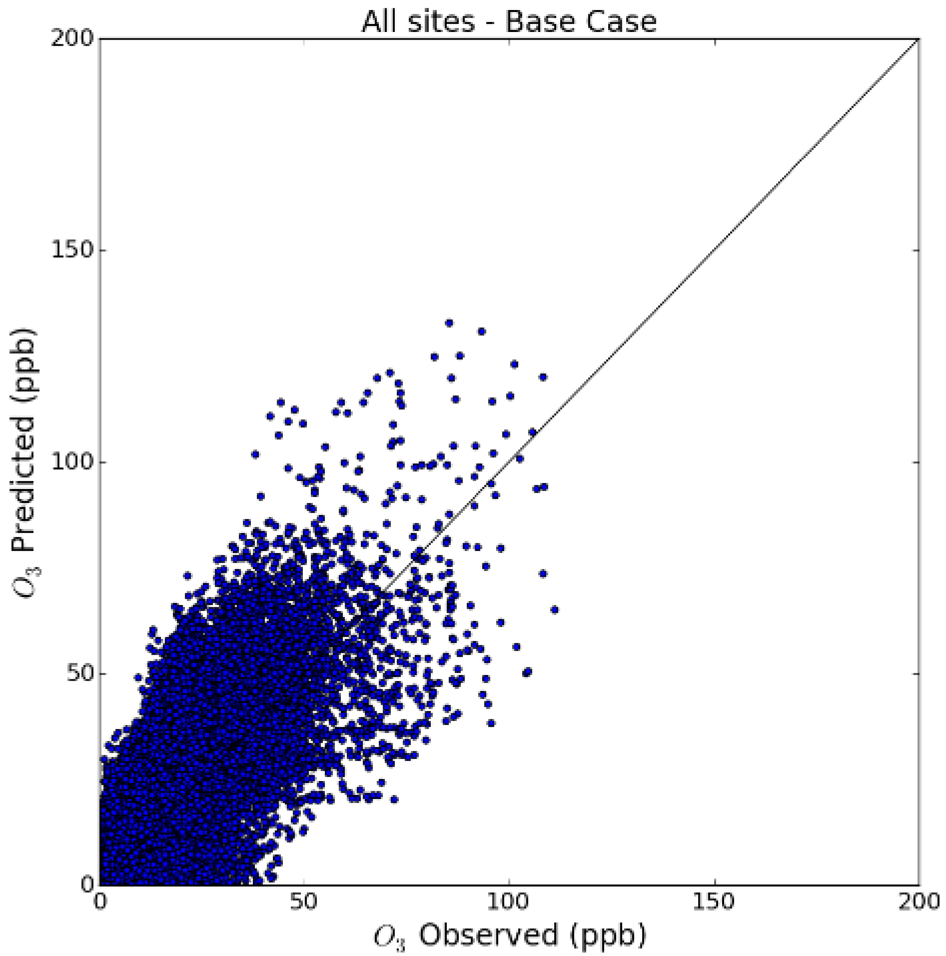
Scatter plots of predicted and observed 1-hour and 4-hour ozone concentrations for all monitoring sites within the domain are presented in **Figure 7-1**. Similar scatter-plots of predicted and observed ozone concentrations for the Bringelly, St Marys and Oakdale sites are show in **Figure 7-2** (1-hour average) and **Figure 7-3** (4-hour average).

The scatter plots demonstrate that modelled-observed data pairs are clustered around the 1:1 line showing that the model tends to correctly predict variability in ozone. At Bringelly and St Marys, observed ozone can be reduced to near zero due to titration of ozone by fresh NO_x emissions at night (also seen in **Figure 7-4**) whereas observed ozone were seldom reduced to zero at Oakdale, which is more rural and has less NO_x emissions. The model correctly captures the difference in ozone minimums between the Oakdale and Bringelly/St Marys sites.

Time-series of predicted and observed 1-hour ozone concentrations are shown in **Figure 7-4** for the Bringelly, St Marys and Oakdale sites. The model captures correctly periods of both higher and lower ozone showing that the model responds dynamically to changes in meteorology.

For example, a build-up of ozone occurred at the start of February 2009 followed by a period of low ozone (at background values) which the model reproduces. Time-series of 4-hour ozone concentration (**Figure 7-5**) show similar features.





1-hour	4-Hour

Figure 7-1: Scatter plot of modelled and observed ozone concentration for all sites

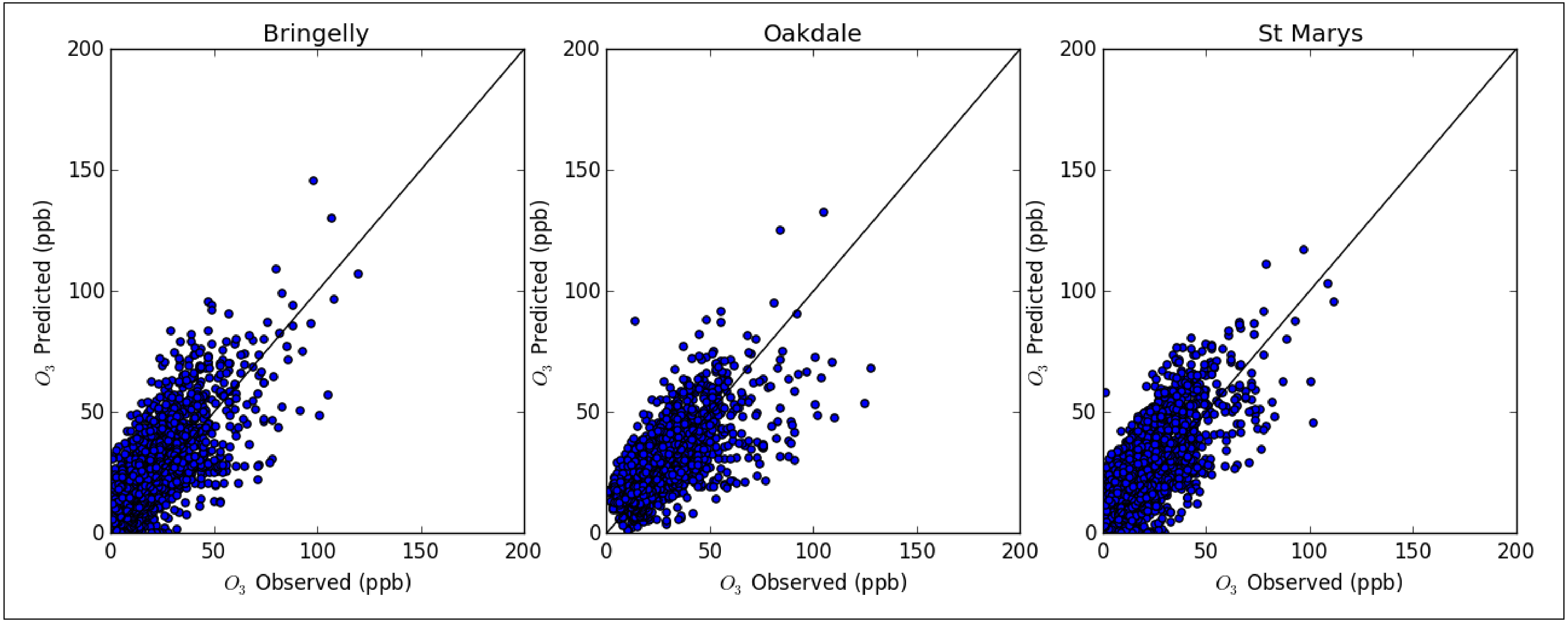


Figure 7-2: Scatter plots of modelled and observed 1-hour ozone concentration at Bringelly, Oakdale and St Marys

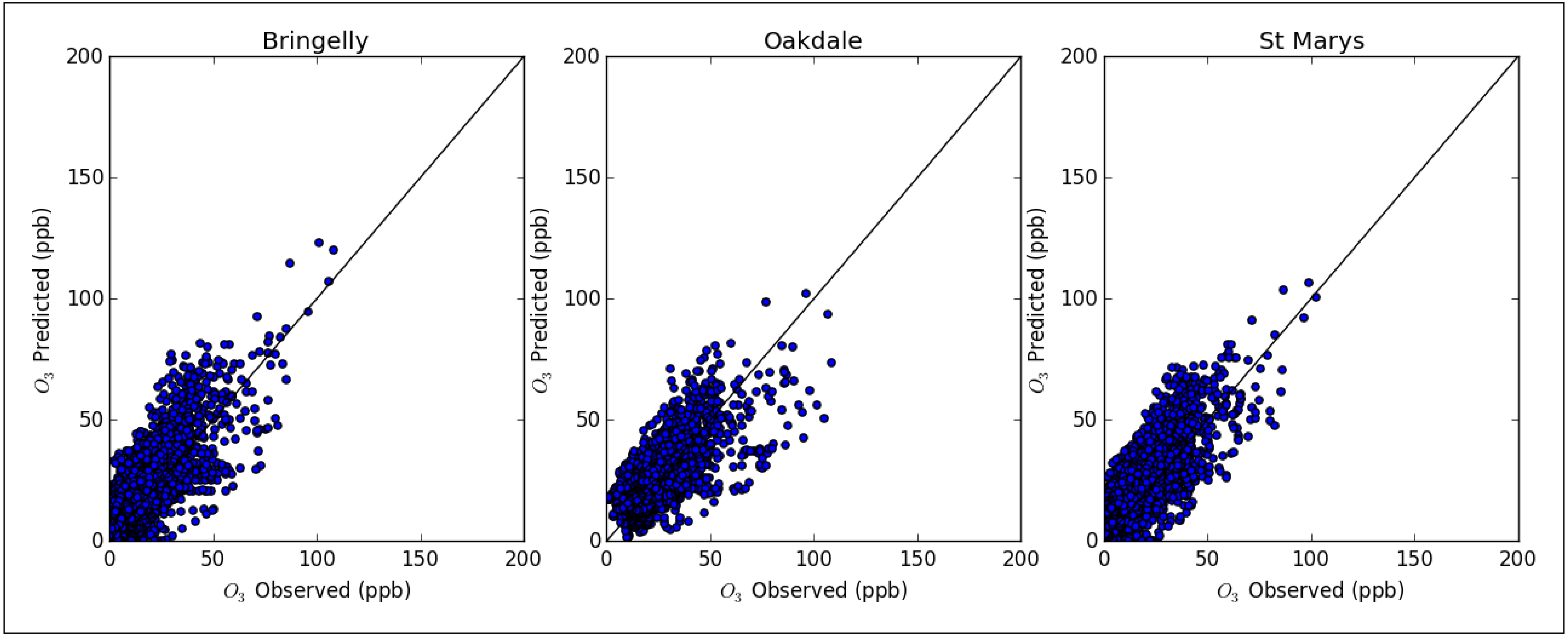


Figure 7-3: Scatter plots of modelled and observed 4-hour ozone concentration at Bringelly, Oakdale and St Marys

Figure 7-4: Time series of modelled and observed 1-hour ozone concentration at Bringelly, Oakdale and St Marys

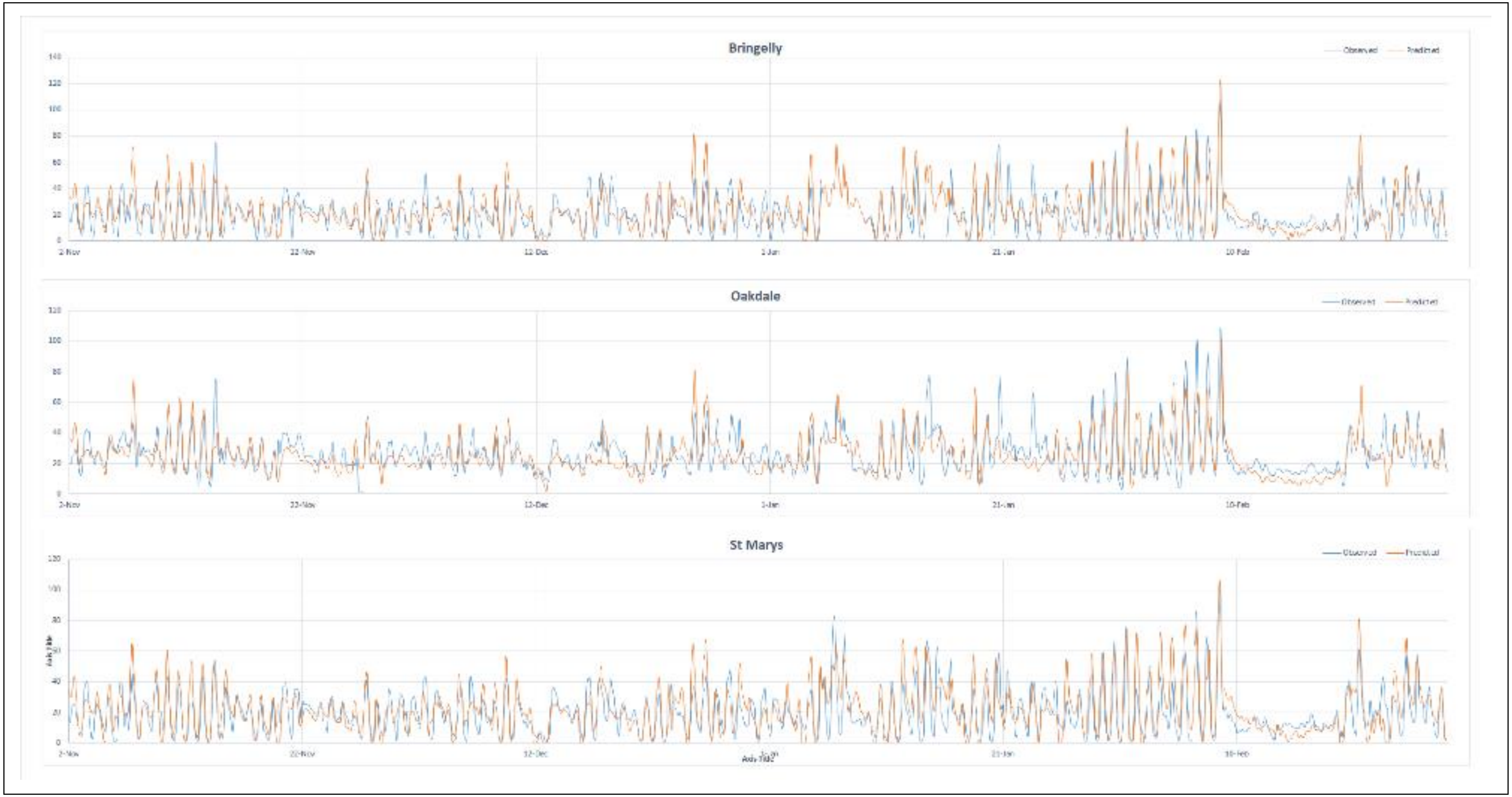


Figure 7-5: Time series of modelled and observed 4-hour ozone concentration at Bringelly, Oakdale and St Marys

7.3 Statistical evaluation

A statistical evaluation of ozone model performance was performed for the Bringelly, St Marys and Oakdale sites by computing metrics for bias (NMB) and error (NME). USEPA guidance for ozone model performance evaluation has aimed for bias within ±15% and error smaller than 35%, although the guidance also emphasizes that statistical metrics should not be used as pass/fail tests (USEPA, 2007; USEPA, 2014b).

The model exhibits little bias at Bringelly and St Marys with NMB for 1-hour ozone less than 2% and for 4-hour ozone less than 7%. The model has a tendency to under predict ozone at Oakdale by 11% for 1-hour ozone and 14% for 4-hour ozone. The model errors are larger, from 27% to 33% for 1-hour ozone and from 25% to 30% for 4-hour ozone, but still lower than the EPA suggested benchmark of 35%.

Table 7-2: Performance statistics for predicted 1-hour ozone concentration

Site	Peak observed (ppb)	Peak predicted (ppb)	NMB (%)	NME (%)
Bringelly	120	146	-1.1	32.5
St Marys	112	117	-1.8	30.4
Oakdale	128	133	-11.2	27.2

Note: NMB and NME were computed for all data pairs with observed ozone above 30 ppb

Table 7-3: Performance statistics for predicted 4-hour ozone concentration

Site	Peak observed (ppb)	Peak predicted (ppb)	NMB (%)	NME (%)
Bringelly	108	123	-5.8	29.5
St Marys	103	107	-6.6	27.0
Oakdale	108	102	-14.3	25.3

Note: NMB and NME were computed for all data pairs with observed ozone above 30 ppb

8. EVALUATION OF OZONE IMPACTS

8.1 Selecting days for detailed analysis

The NSW tiered procedure for ozone assessment described in **Section 3.4** outlines criteria for selecting dates for Level 2 assessment based on photochemical modelling. The criteria are:

- The maximum modelled ozone concentrations should be close to the NEPM standards to ensure that the conditions are relevant to non-attainment of the standards.
- The model should have acceptable performance, meaning low bias and error statistics, to gain confidence that the simulation provides a realistic representation of conditions on the high ozone day.
- The impacts of the new source should occur primarily over land, rather than over the ocean.
- Several days should be selected, and as a minimum at least three days, to enable comparison of source impacts across multiple high ozone days.

Based on the above criteria, days with high observed ozone (1-hour ozone concentrations greater than 70 ppb and 4-hour ozone concentrations greater than 65 ppb) and good model performance (bias within ±15% in these peak values) were selected for analysis. A summary of the analysis is presented in **Table 8-1**. The selected dates provide good coverage by day of the week, to account for any weekday vs. weekend differences, and include several periods of ozone build-up that allow for potential build-up of ozone impacts due to the airport.

The selection of historical dates in January and February 2009 may appear counter intuitive for the modelling future emissions in 2030 and 2063. However, the actual dates are arbitrary, and could be presented, for example as "Peak ozone day 1, Peak ozone day 2…etc.". They simply represent modelling periods when meteorological conditions are conducive to peak ozone formation and there is confidence in the model being able to accurately predict peak ozone formation with future emissions from the airport added.

Table 8-1: Date selection for detailed analysis

Date	Day of Week	Ozone concentration (ppb)			
		Max 1-hour	**Location**	**Max 4-hour**	**Location**
06/01/2009	Tue	90	Chullora	70	Liverpool
07/01/2009	Wed	80	Chullora	-	-
14/01/2009	Wed	83	Liverpool	77	Liverpool
29/01/2009	Thu	88	Bargo	76	Bargo
30/01/2009	Fri	77	Macarthur	76	Bargo
31/01/2009	Sat	113	Bargo	92	Bargo
04/02/2009	Wed	70	Oakdale	-	-
05/02/2009	Thu	88	Bringelly	85	Bargo
06/02/2009	Fri	89	St Marys	92	Bargo
07/02/2009	Sat	102	Chullora	79	Oakdale
08/02/2009	Sun	120	Bringelly	109	Bringelly
20/02/2009	Fri	86	Prospect	-	-

8.2 Approach to evaluating ozone impacts

The approach to evaluating ozone impacts attributable to the airport development is based on daily maximum 1-hour and 4-hour ozone concentrations, for which NEPM standards exist. Consequently, changes in ozone are computed as differences in daily maximum concentration. The highest daily maximum concentration on a day is referred to as the peak ozone. The assessment is restricted to days with good model performance, as discussed, to reduce the influence of model uncertainties on outcomes.

Changes in modelled ozone are evaluated throughout the modelling domain and are not restricted to ozone monitoring locations. This is because the spatial relationship between emissions and ozone formation varies from day-to-day, due to meteorology.

It is not recommended to use a single model result for ozone impacts (e.g., the largest ozone change) because reliance on a single model result could accentuate the influence of uncertainties in model input data or model formulation. For example, as discussed previously, TAPM can under estimate cloud cover which may introduce a systematic bias towards over-predicting ozone production.

It is recommended that discussion of ozone impacts focuses on a high percentile of modelled impacts, such as the 99th percentile, which represents the 4th highest of the daily maximum values for a full year. Although we have only modelled a few months of the year, the modelled period captures peak ozone days, so this approach is possible. The average of the 2nd to 4th highest ozone change is therefore used to assess the potential ozone impacts.

8.3 Stage 1 airport development

The daily maximum predicted 1-hour ozone concentrations are presented in **Table 8-2**. Results are presented as peak concentrations for the 2030 Future Base Case (no airport), the 2030 Airport Case (airport emissions plus 2030 Future Base Case) and the largest difference in daily maximums (the 2030 Airport Case – 2030 Future Base Case). The largest difference represents the maximum change in daily maximum ozone concentration, as a result of the additional emissions from the airport.

For each day of analysis, the peak predicted 1-hour ozone concentrations were unchanged between the 2030 Base Case and the 2030 Airport Case. This is because predicted ozone concentration changes from the airport occur in a different location to the predicted peak ozone concentrations (shown in the spatial plots presented in **Section 8.3.1**). Both the 2030 Base Case and the 2030 Airport Case were above the NEPM criterion of 100 ppb for all but one day of analysis.

To provide context, the predicted peak ozone concentrations presented in **Table 8-2** can be compared with measured peak 1-hour ozone concentrations at Bringelly. During 2014, there were two days when the maximum daily 1-hour ozone concentration was above the NEPM standard, with a peak concentration of 124 ppb measured in November 2014. It is noted that the modelled peak values are expected to be higher than observed peak values because monitoring networks never achieve full coverage of an airshed. In other words, modelling can predict higher peak ozone for areas not covered by monitoring networks.

The largest difference in daily maximum 1-hour ozone concentration, from the addition of 2030 airport emissions, was 5.5 ppb, however the second highest was significantly lower at 1.3 ppb. This highlights that reliance on a single model result (e.g. the largest ozone change) could accentuate the influence of uncertainties in model input data or model formulation. Therefore the average of the 2nd and 4th highest ozone change in daily maximum 1-hour ozone is used to describe ozone impacts, which in this case is 1.2 ppb. As described in **Section 3.4**, the NSW tiered procedure for ozone assessment sets a maximum allowable increment level of 1 ppb. Comparing this to the average of the 2nd to 4th highest change in daily maximum 1-hour ozone, indicates that a marginal impact is predicted from the 2030 Airport Case.

Table 8-2: Maximum daily predicted 1-hour ozone concentration (ppb) - 2030

Date	2030 Base Case Peak Value	2030 Airport Case Peak Value	2030 Airport Case – 2030 Base Case Largest Difference
06/01/2009	149.1	149.1	0.4
07/01/2009	129.8	129.8	5.5
14/01/2009	106.6	106.6	1.3
29/01/2009	124.1	124.1	0.3
30/01/2009	107.4	107.4	0.6
31/01/2009	109.4	109.4	0.6
04/02/2009	103.8	103.8	1.2
05/02/2009	119.6	119.6	0.3
06/02/2009	112.5	112.5	0.8
07/02/2009	133.7	133.7	0.3
08/02/2009	148.6	148.6	0.6
20/02/2009	98.3	98.3	1.0

The daily maximum predicted 4-hour ozone concentrations are presented in **Table 8-3**. The peak predicted 4-hour ozone concentration was unchanged on eight days and increased on four days, by a maximum of 0.1 ppb.

The highest change in daily maximum 4-hour ozone concentration, from the addition of airport emissions, was 2.4 ppb, while the second highest was 1.3 ppb. The average of the 2nd to 4th highest change in daily maximum 4-hour ozone was 0.9 ppb, which is below the maximum allowable increment of 1 ppb.

Table 8-3: Maximum daily predicted 4-hour ozone concentration (ppb) - 2030

Date	2030 Base Case Peak Value	2030 Airport Case Peak Value	2030 Airport Case – 2030 Base Case Largest Difference
06/01/2009	126.2	126.3	0.3
07/01/2009	115.3	115.4	2.4
14/01/2009	98.7	98.8	0.7
29/01/2009	95.9	95.9	0.5
30/01/2009	78.2	78.2	0.6
31/01/2009	99.9	99.9	0.5
04/02/2009	97.3	97.3	0.7
05/02/2009	108.7	108.7	0.4
06/02/2009	92.4	92.4	0.4
07/02/2009	121.0	121.0	0.7
08/02/2009	129.9	129.9	0.6
20/02/2009	83.9	84.0	1.3

8.3.1 Spatial variation in peak ozone concentrations

Locations of ozone differences due to 2030 airport emissions are shown in the spatial plots of the daily maximum predicted 1-hour and 4-hour ozone concentration, presented in **Figure 8-1** to **Figure 8-12**.

Decreases in daily maximum ozone occur only in the vicinity of the airport and are attributable to ozone suppression by NOx emissions. Increases in ozone occur downwind of the airport which, on most days, is to the south. Ozone increases on opposing sides of the airport within a single day indicate that changes in wind direction, such as a land/sea breeze reversal, carried airport emissions and/or ozone formed from airport emissions in different directions. The largest ozone differences are confined close to the airport. On this day, both the modelled and measured wind speeds were light during the morning until a change in the afternoon brought higher wind speeds and a change in wind direction.

Spatial plots of the maximum predicted 1-hour and 4-hour ozone concentration over all days of analysis is presented in **Figure 8-13**.

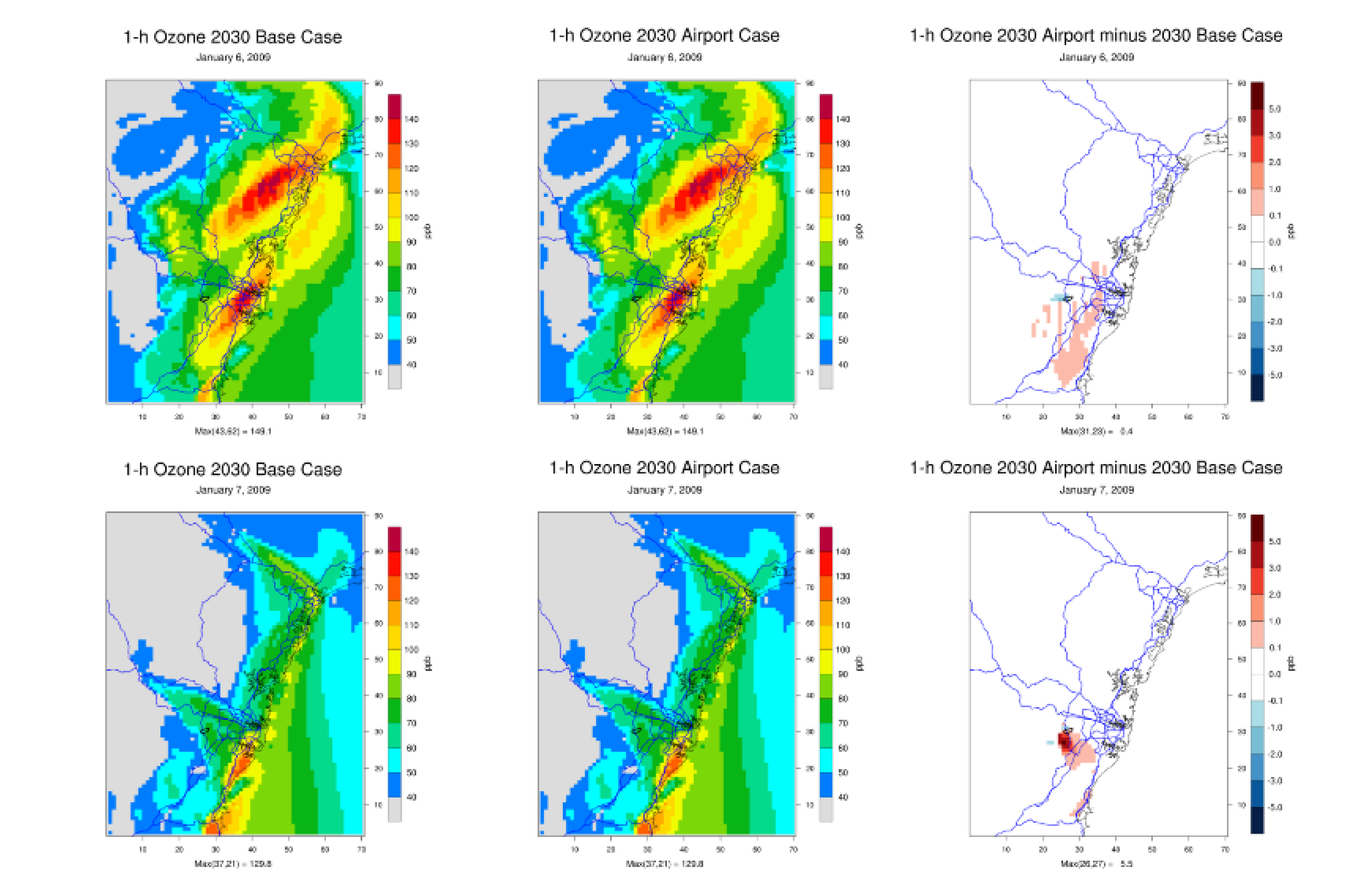


Figure 8-1: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 January

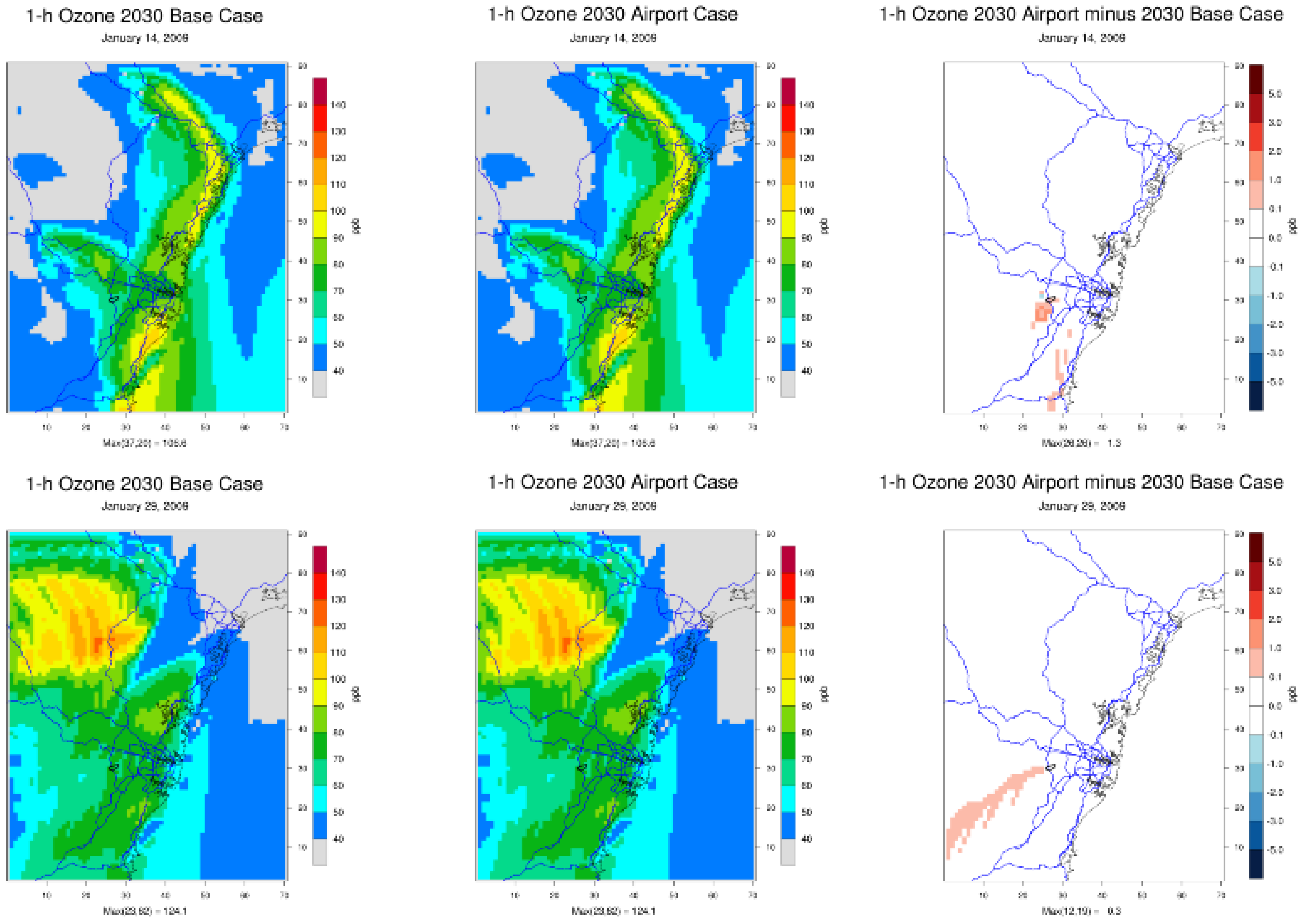


Figure 8-2: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 14 and 29 January

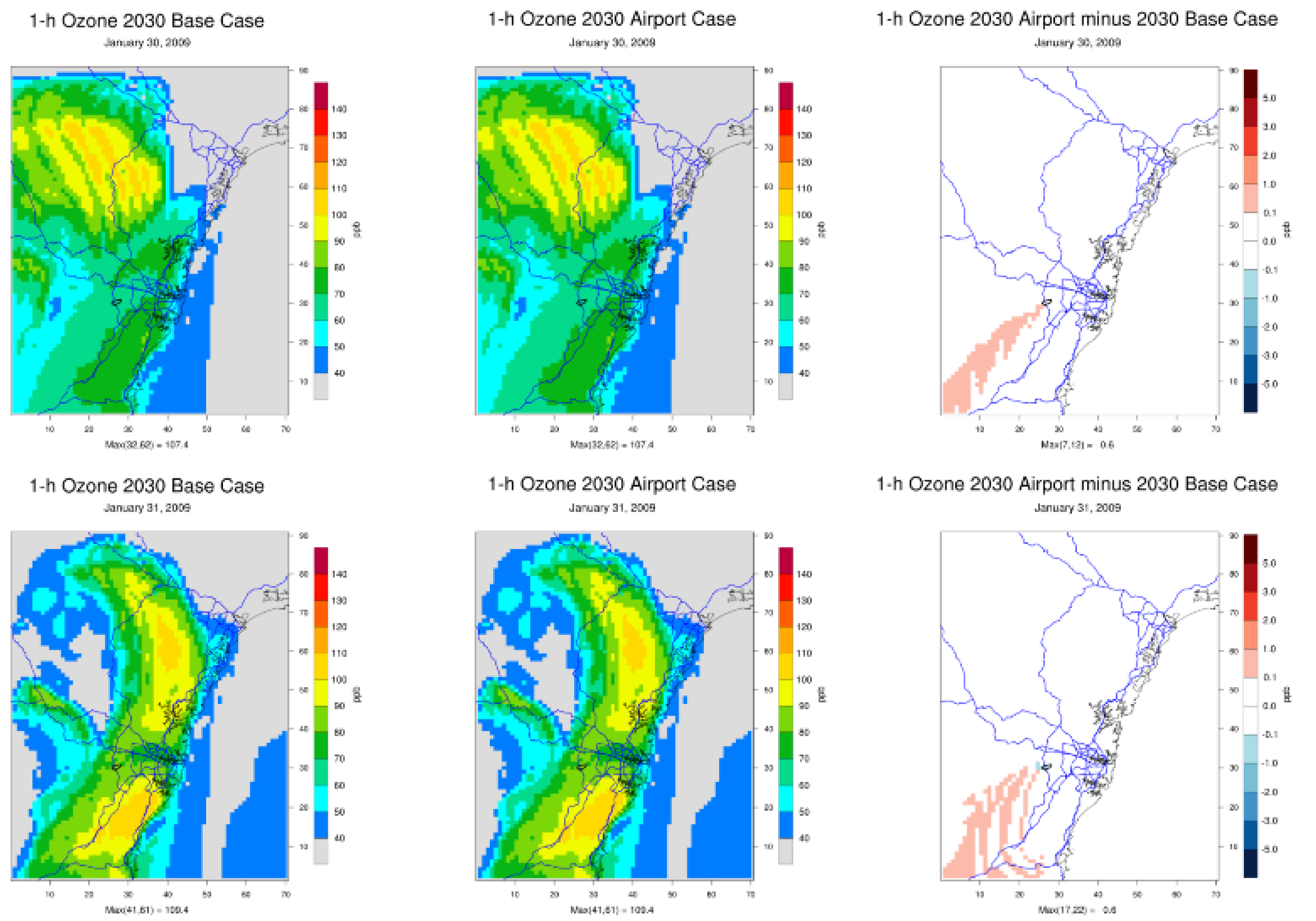


Figure 8-3: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 30 and 31 January

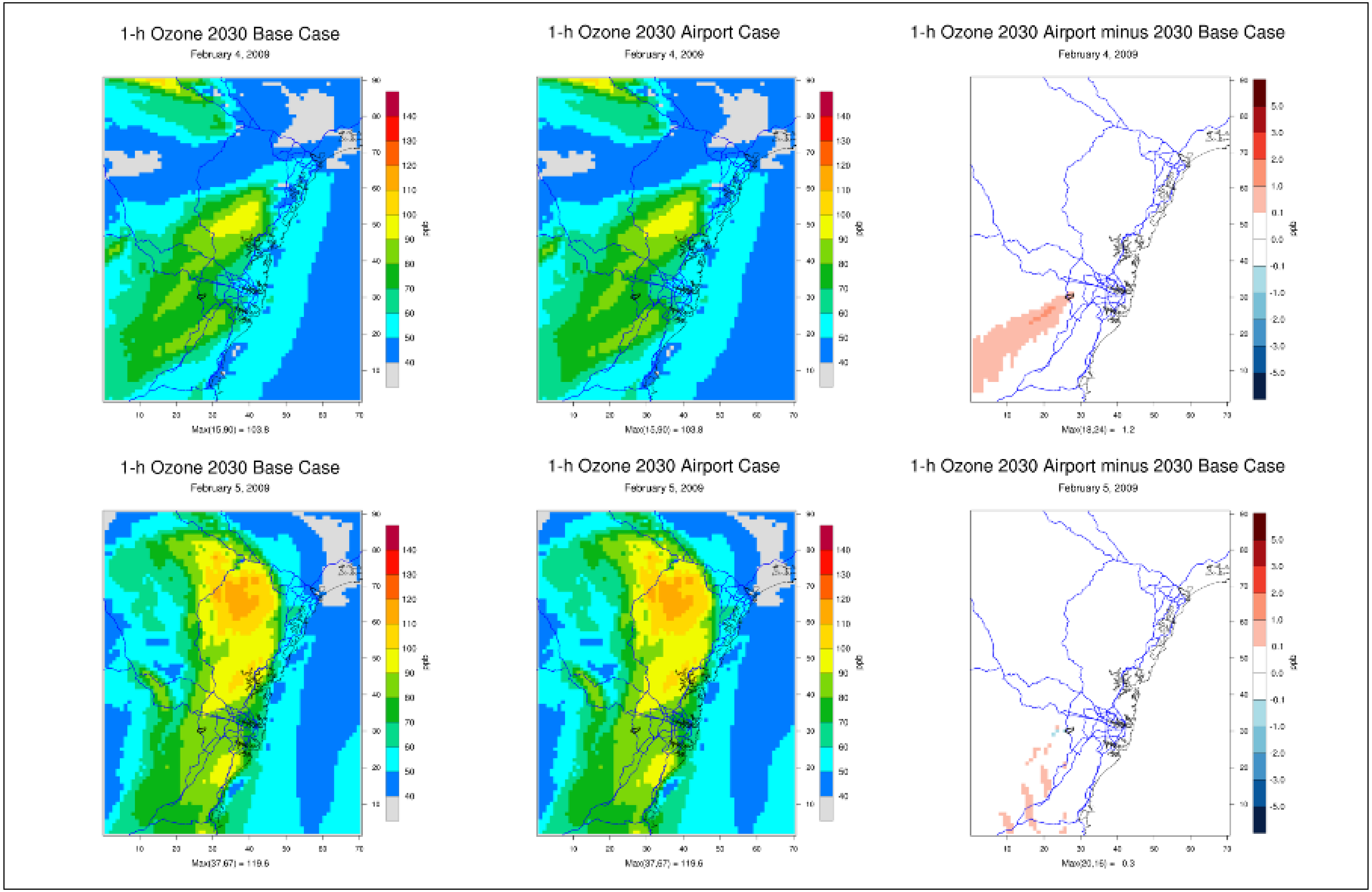


Figure 8-4: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 4 and 5 February

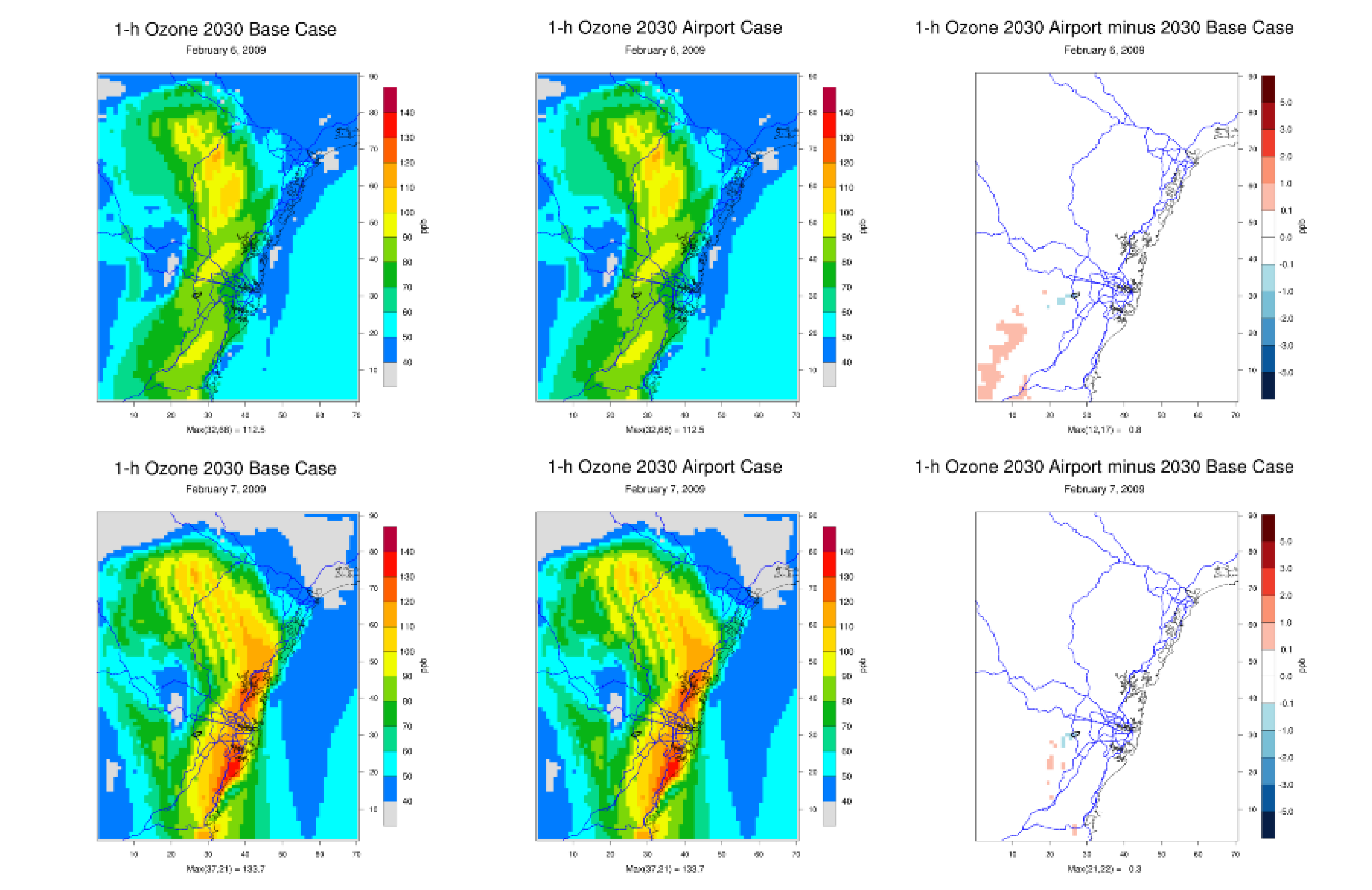


Figure 8-5: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 February

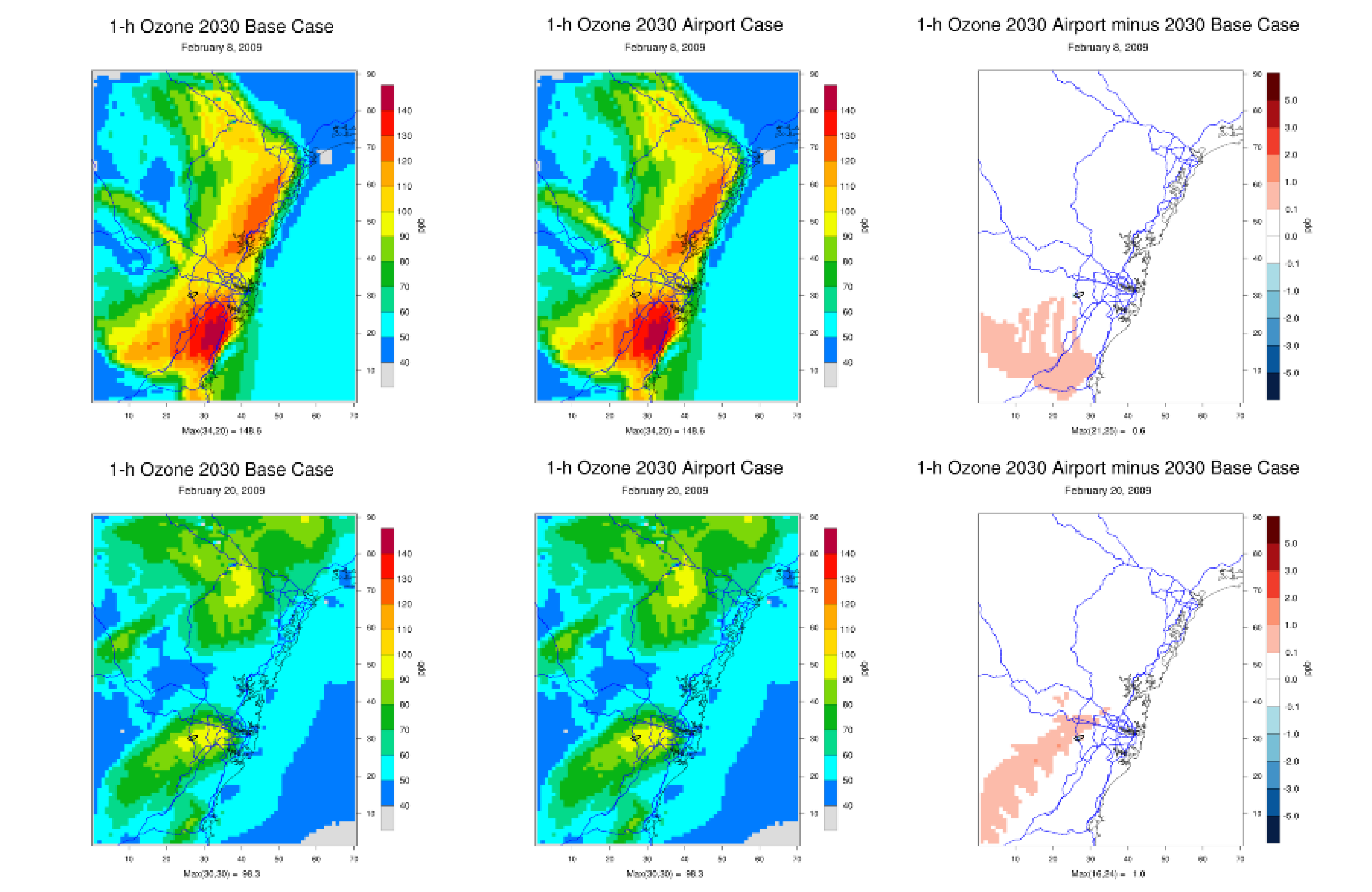


Figure 8-6: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 8 and 20 February

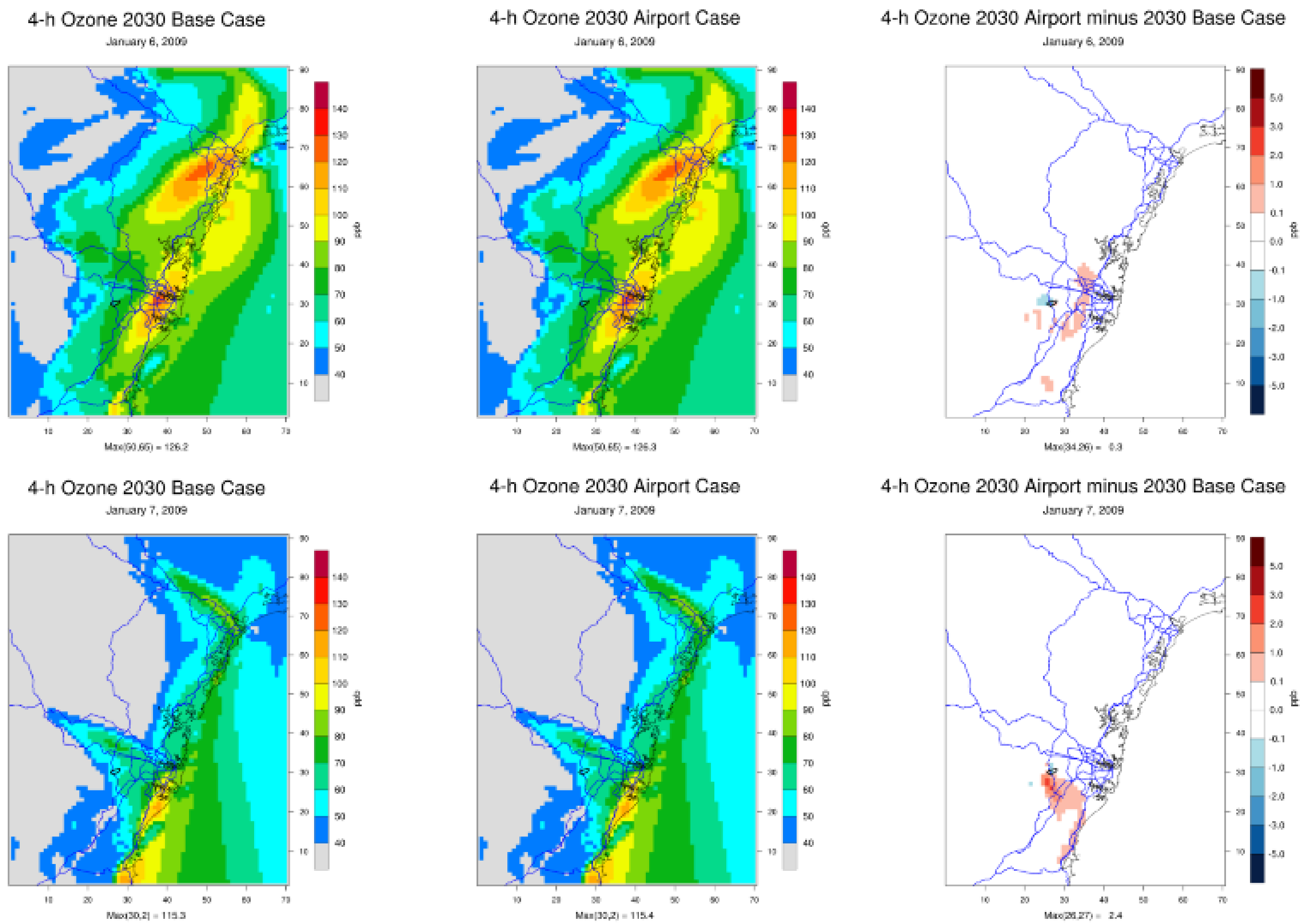


Figure 8-7: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 January

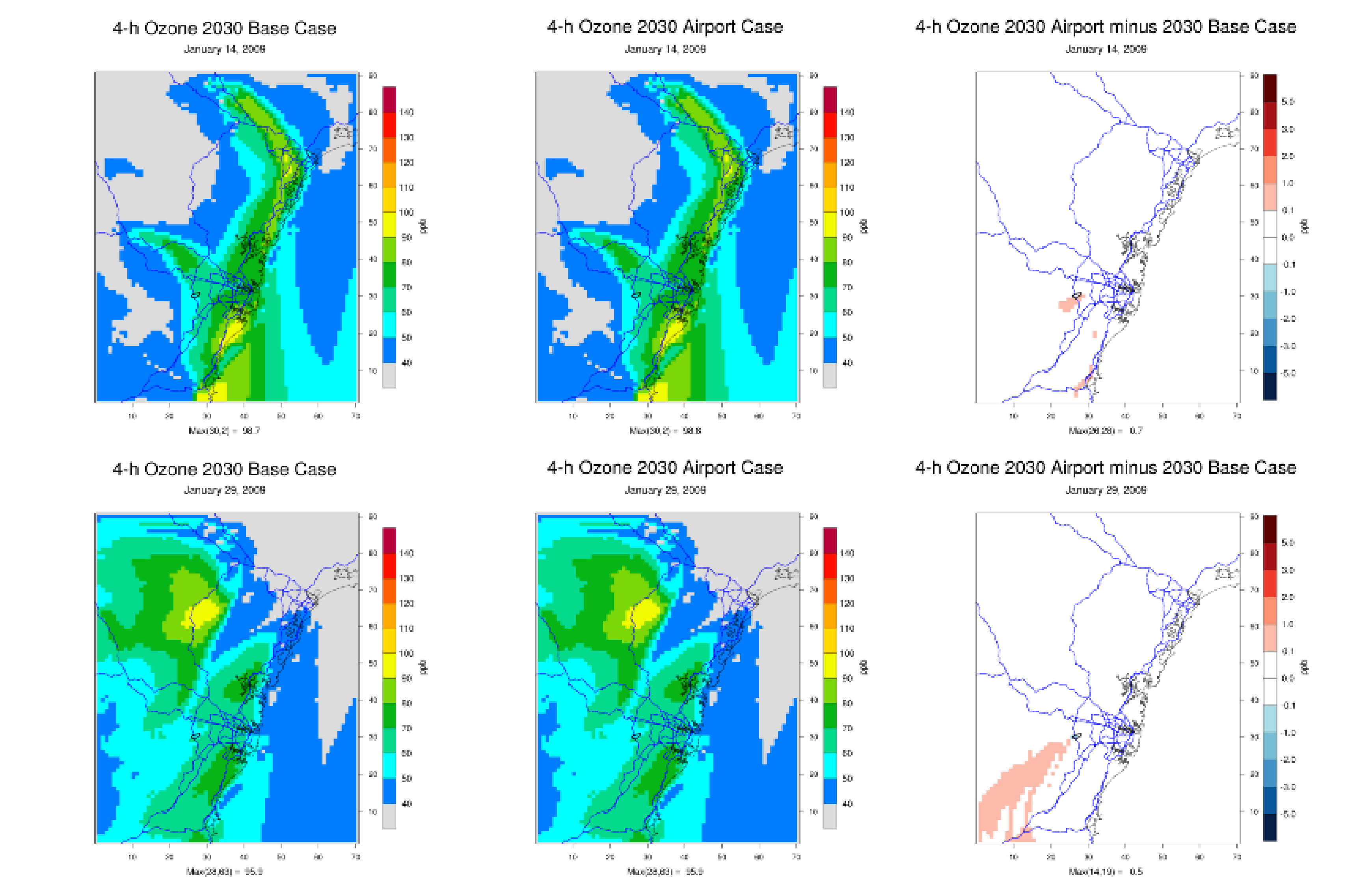


Figure 8-8: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 14 and 29 January

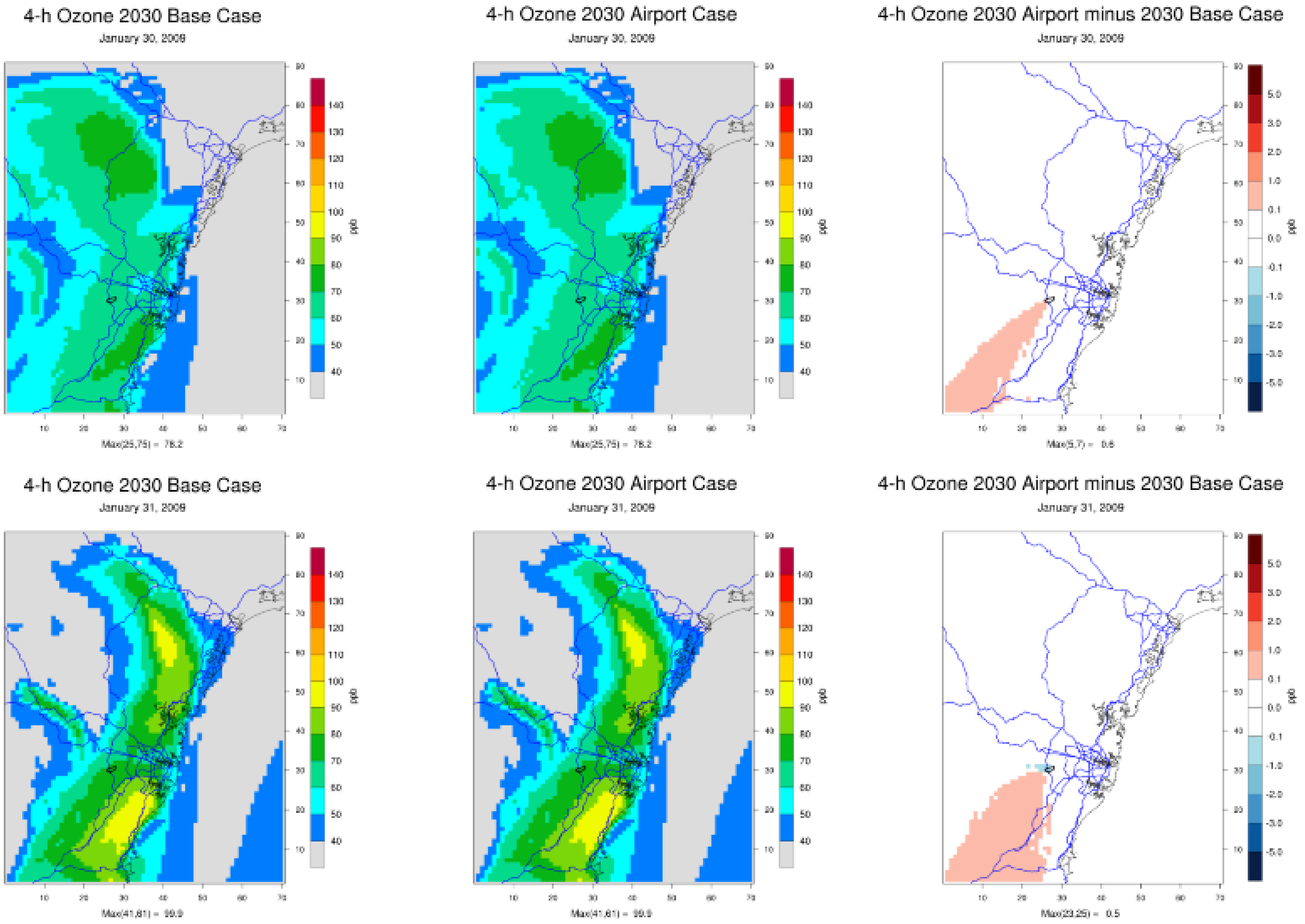


Figure 8-9: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 30 and 31 January

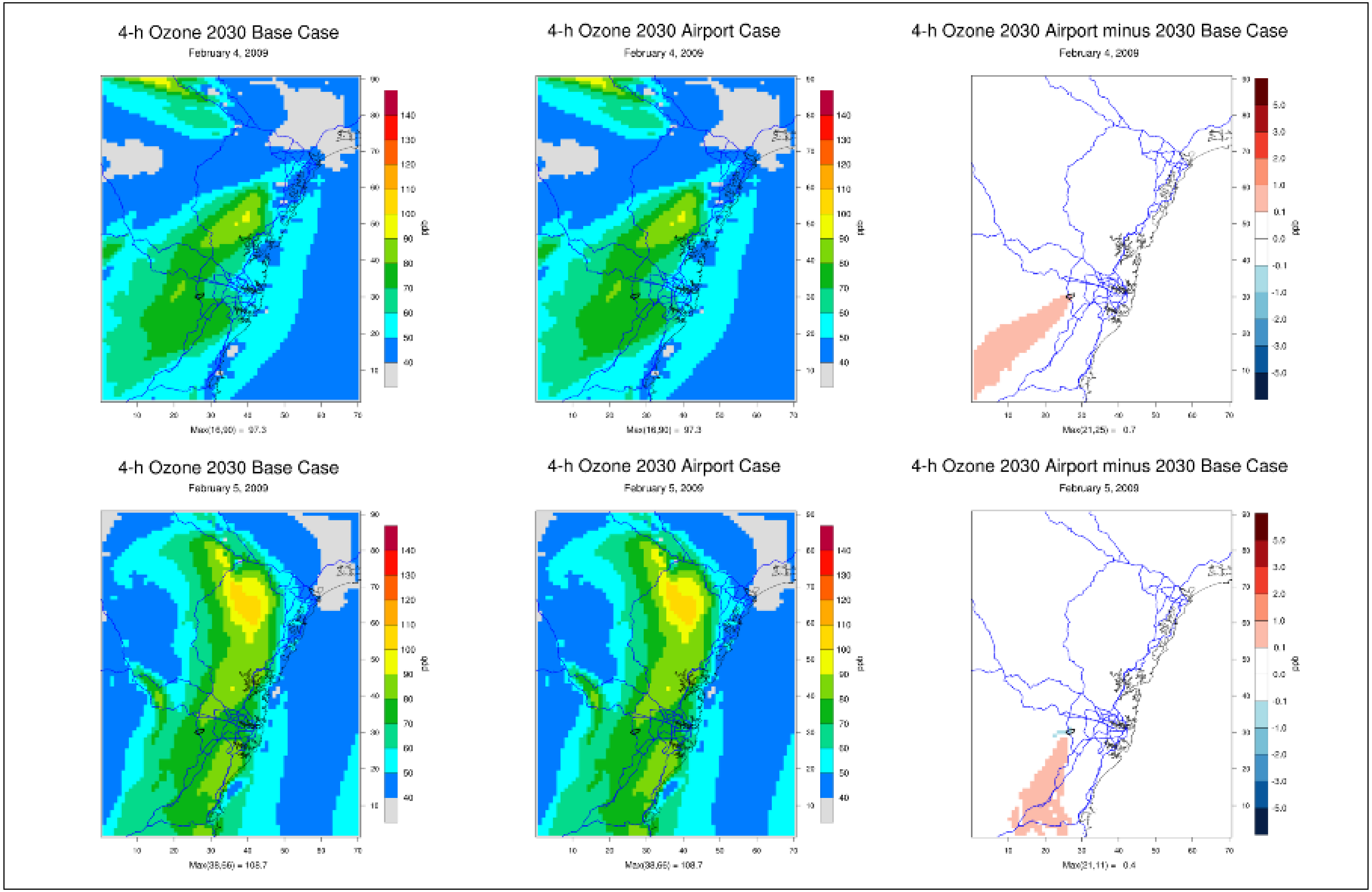


Figure 8-10: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 4 and 5 February

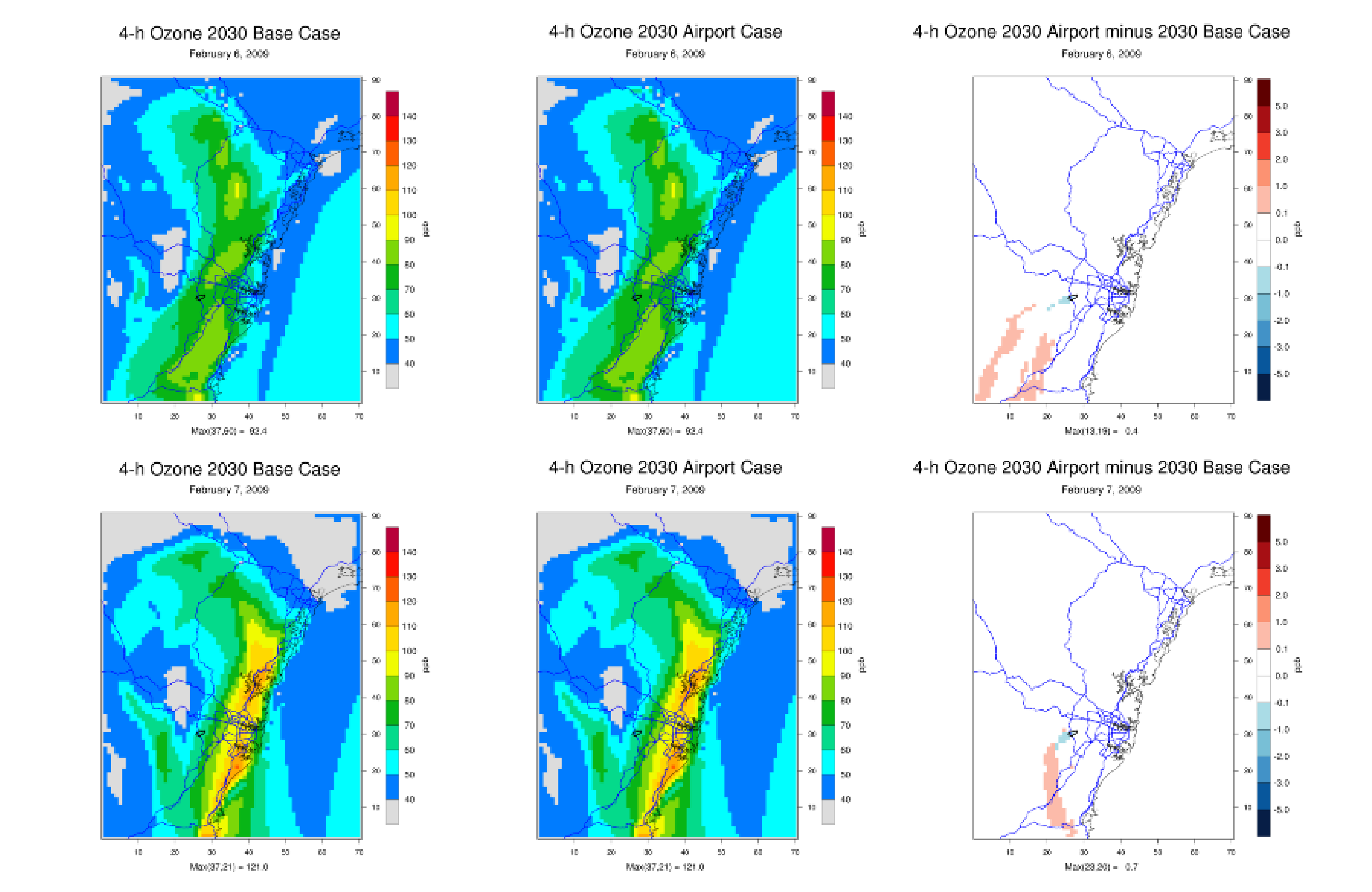


Figure 8-11: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 February

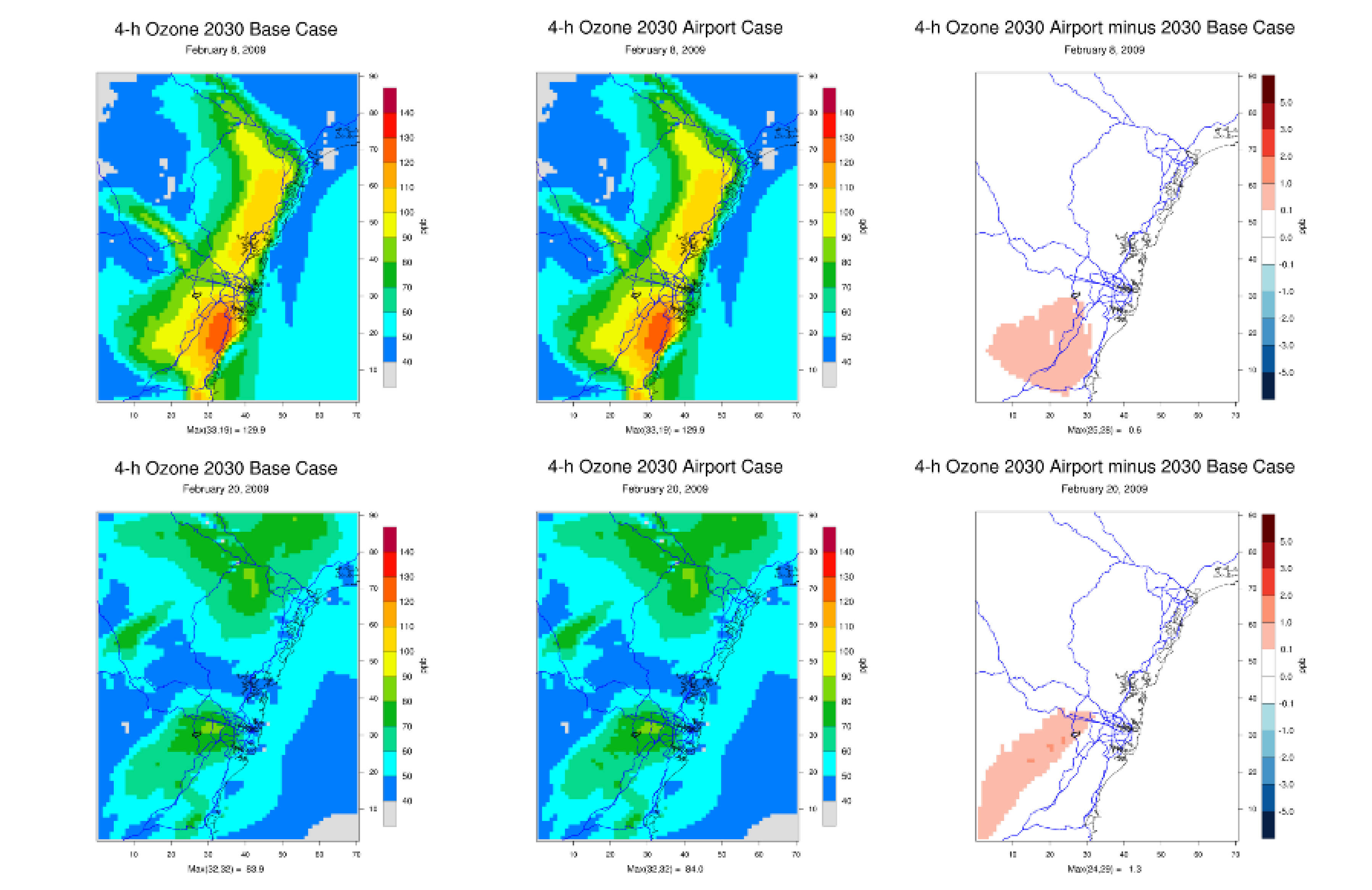


Figure 8-12: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 8 and 20 February

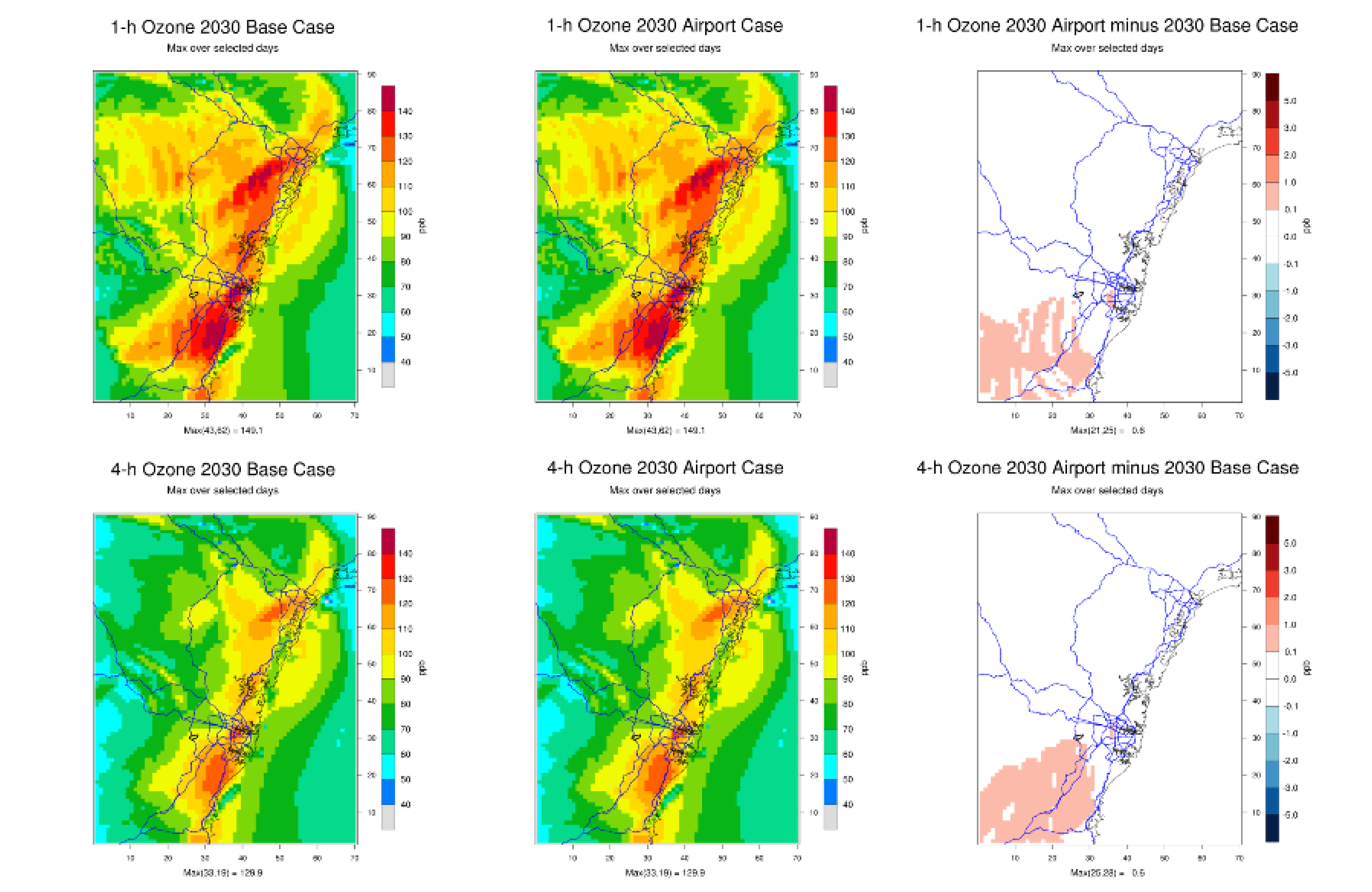


Figure 8-13: Maximum predicted 1-hour and 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for all days

8.4 Long term airport development

Future projected emissions for sources other than the airport (commercial, industrial, on-road mobile, etc.) are not available for the 2063 scenario, therefore the long term development scenario becomes a hypothetical scenario of long term airport development occurring within the context of 2030 Base Case emissions.

The daily maximum predicted 1-hour ozone concentrations are presented in **Table 8-4**. The maximum predicted 1-hour ozone concentration was unchanged between the 2030 Base Case and the 2063 Airport Case for eight of the analysis days. On four days, the peak predicted 1-hour ozone concentration increased, by a maximum of 0.2 ppb. Both the 2030 Base Case and the 2063 Airport Case were above the NEPM criterion of 100 ppb for all but one day of analysis.

The highest change in daily maximum 1-hour ozone concentration, from the addition of 2063 airport emissions, was 12.5 ppb, while the second highest was 5.7 ppb. The largest ozone differences are also confined close to the airport. Larger ozone increases are modelled for the 2063 Airport Case than the 2030 Airport Case. The average of the 2nd to 4th highest increases in daily maximum 1-hour ozone rose from 1.2 ppb for 2030 to 4.6 ppb for 2063. This is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

Table 8-4: Maximum daily predicted 1-hour ozone concentration (ppb) - 2063

Date	2030 Base Case Peak Value	2063 Airport Case Peak Value	2063 Airport Case – 2030 Base Case Largest Difference
06/01/2009	149.1	149.2	2.0
07/01/2009	129.8	130.0	12.5
14/01/2009	106.6	106.6	5.7
29/01/2009	124.1	124.1	1.6
30/01/2009	107.4	107.4	2.4
31/01/2009	109.4	109.4	2.2
04/02/2009	103.8	103.8	3.4
05/02/2009	119.6	119.6	1.7
06/02/2009	112.5	112.5	3.4
07/02/2009	133.7	133.7	1.7
08/02/2009	148.6	148.7	2.6
20/02/2009	98.3	98.4	4.6

The daily maximum predicted 4-hour ozone concentrations are presented in **Table 8-5**. The peak predicted 4-hour ozone concentration was unchanged on seven days and increased on five days, by a maximum of 0.3 ppb.

The highest change in daily maximum 4-hour ozone concentration, from the addition of 2063 airport emissions, was 6.5 ppb, while the second highest was 5.9 ppb. The average of the 2nd to 4th highest increases in daily maximum 4-hour ozone is 3.8 ppb, which is significantly greater than the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

Table 8-5: Maximum daily predicted 4-hour ozone concentration (ppb) - 2063

Date	2030 Base Case Peak Value	2063 Airport Case Peak Value	2063 Airport Case – 2030 Base Case Largest Difference
06/01/2009	126.2	126.5	1.9
07/01/2009	115.3	115.6	5.9
14/01/2009	98.7	98.9	1.7
29/01/2009	95.9	95.9	2.3
30/01/2009	78.2	78.2	2.5
31/01/2009	99.9	99.9	2.3
04/02/2009	97.3	97.3	3.1
05/02/2009	108.7	108.7	1.7
06/02/2009	92.4	92.4	1.7
07/02/2009	121.0	121.0	2.4
08/02/2009	129.9	130.0	2.3
20/02/2009	83.9	84.2	6.5

8.4.1 Spatial variation in peak ozone concentrations

Locations of ozone differences due to 2063 airport emissions are shown in the spatial plots of the daily maximum predicted 1-hour and 4-hour ozone concentration, presented **Figure 8-14** to **Figure 8-25**.

Decreases in daily maximum ozone, due to ozone suppression by NOx emissions, occur in the vicinity of the airport and on some days extend to the aircraft flight corridor and areas downwind of the airport. Areas of ozone decrease are more extensive for the 2063 Airport Case than for the 2030 Airport Case because NO_x emissions from aircraft are 5.2 times larger in 2063. Increases in ozone occur downwind of the airport and also are larger for the 2063 Airport Case than for the 2030 Airport Case.

Spatial plots of the maximum predicted 1-hour and 4-hour ozone concentration over all days of analysis is presented in **Figure 8-26**.

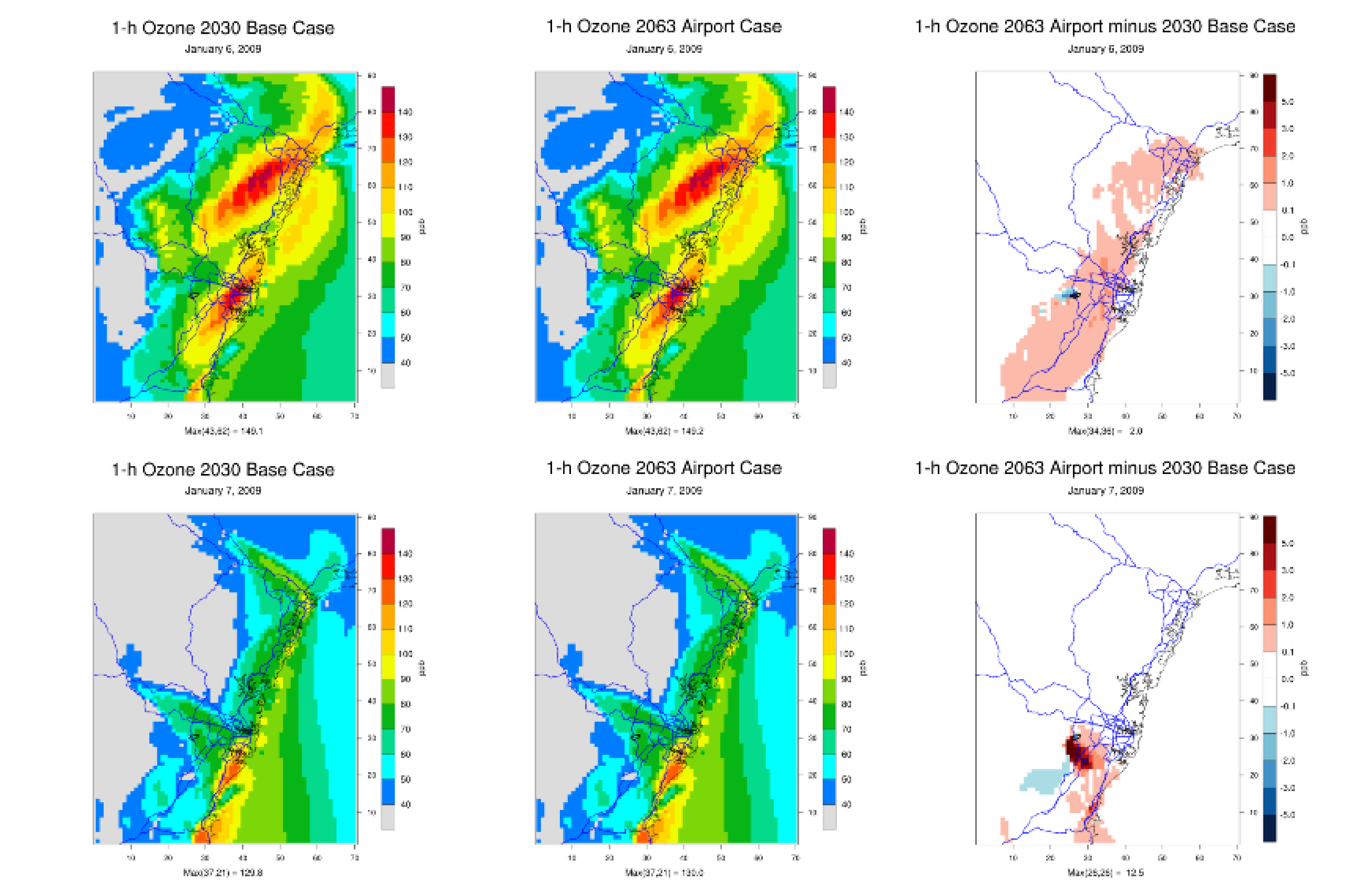


Figure 8-14: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 January

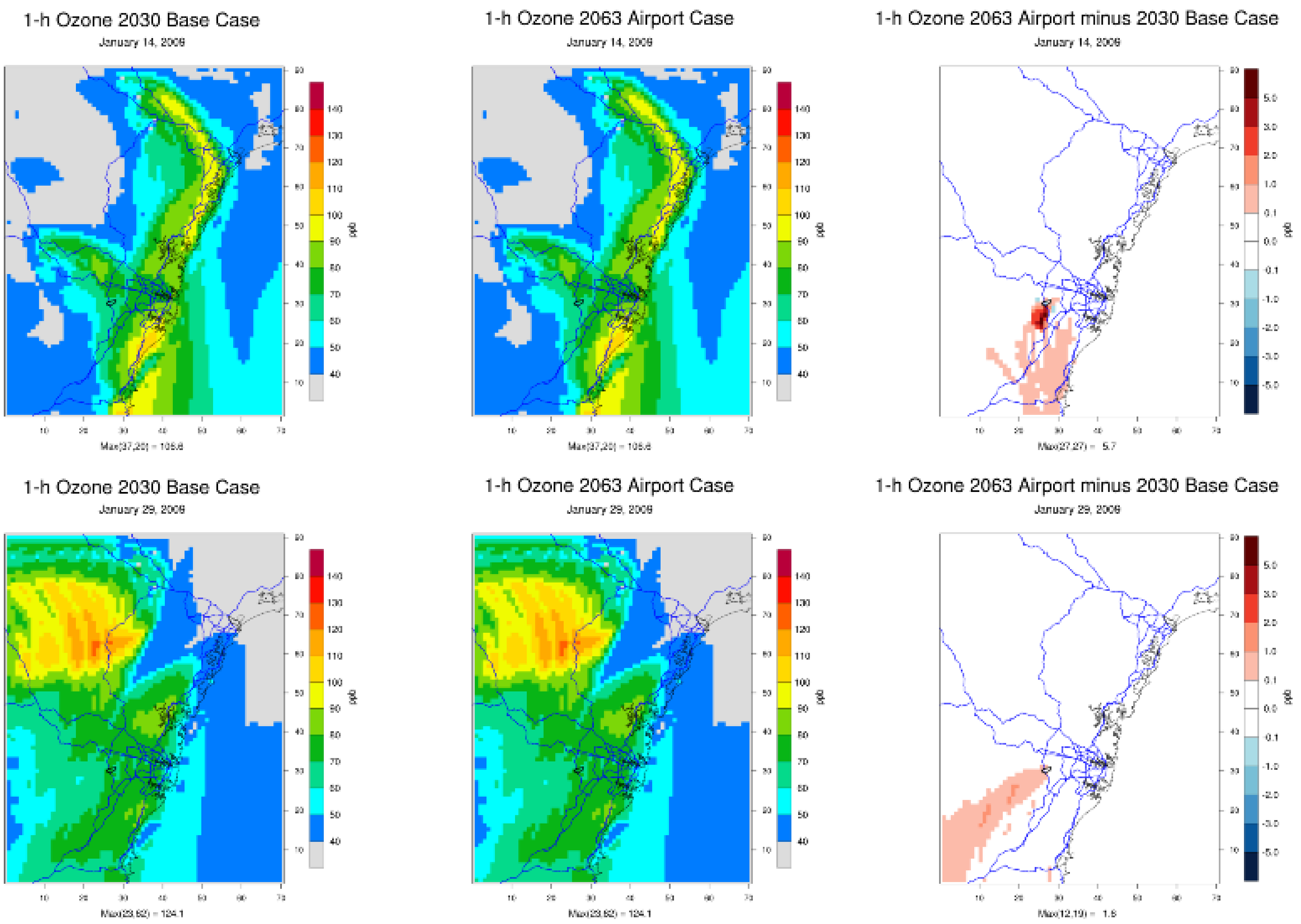


Figure 8-15: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 14 and 29 January

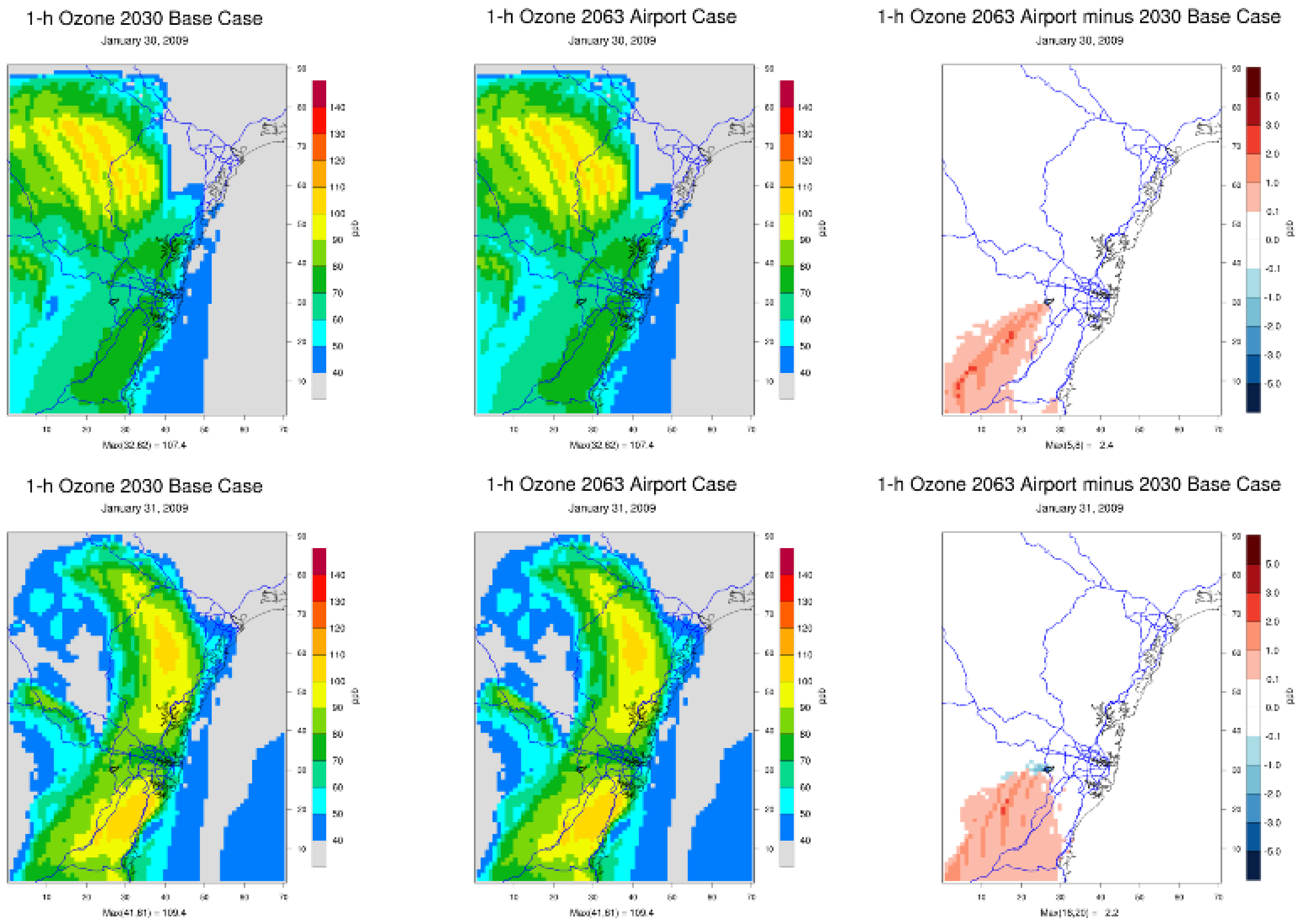


Figure 8-16: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 30 and 31 January

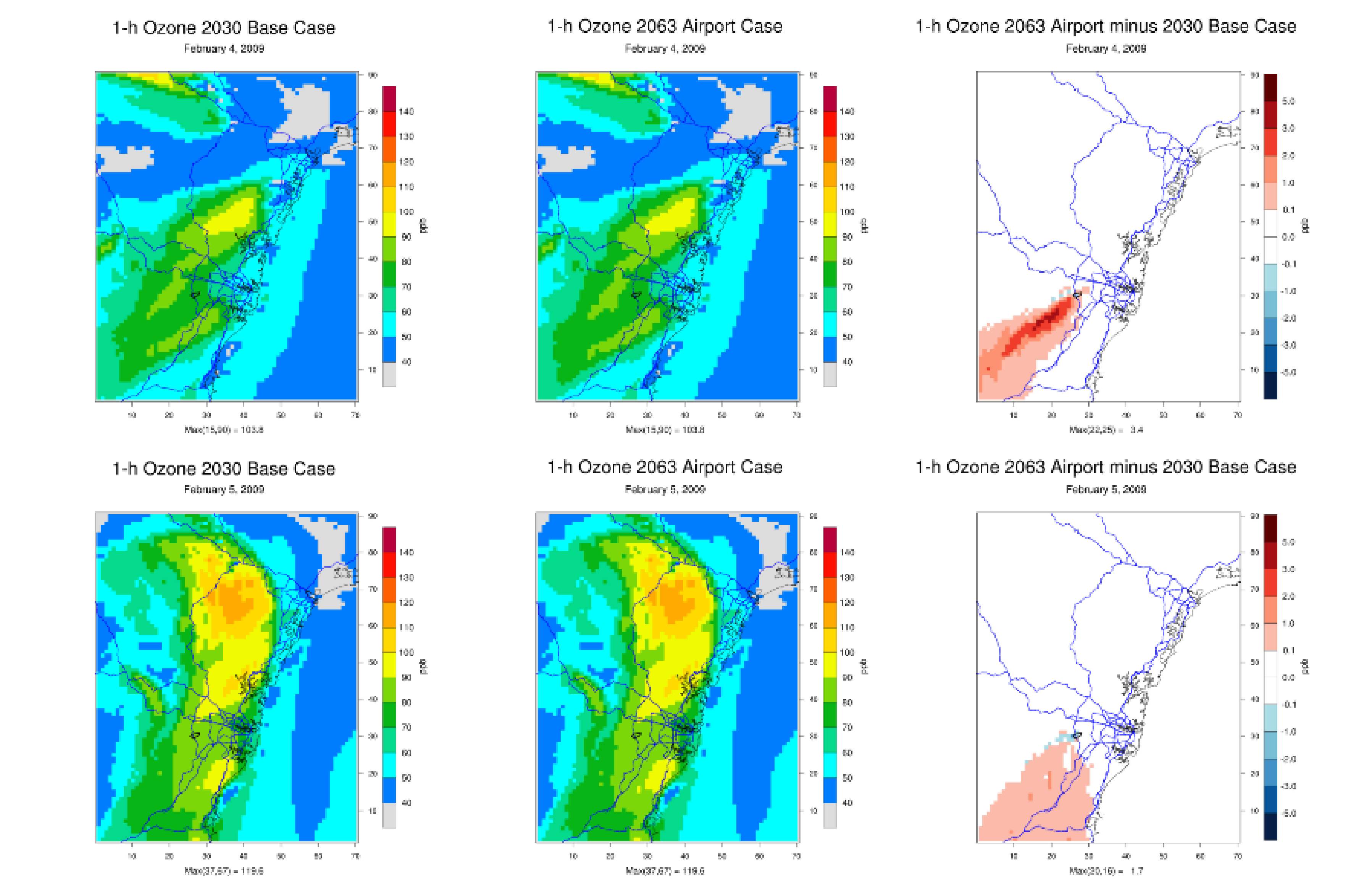


Figure 8-17: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 4 and 5 February

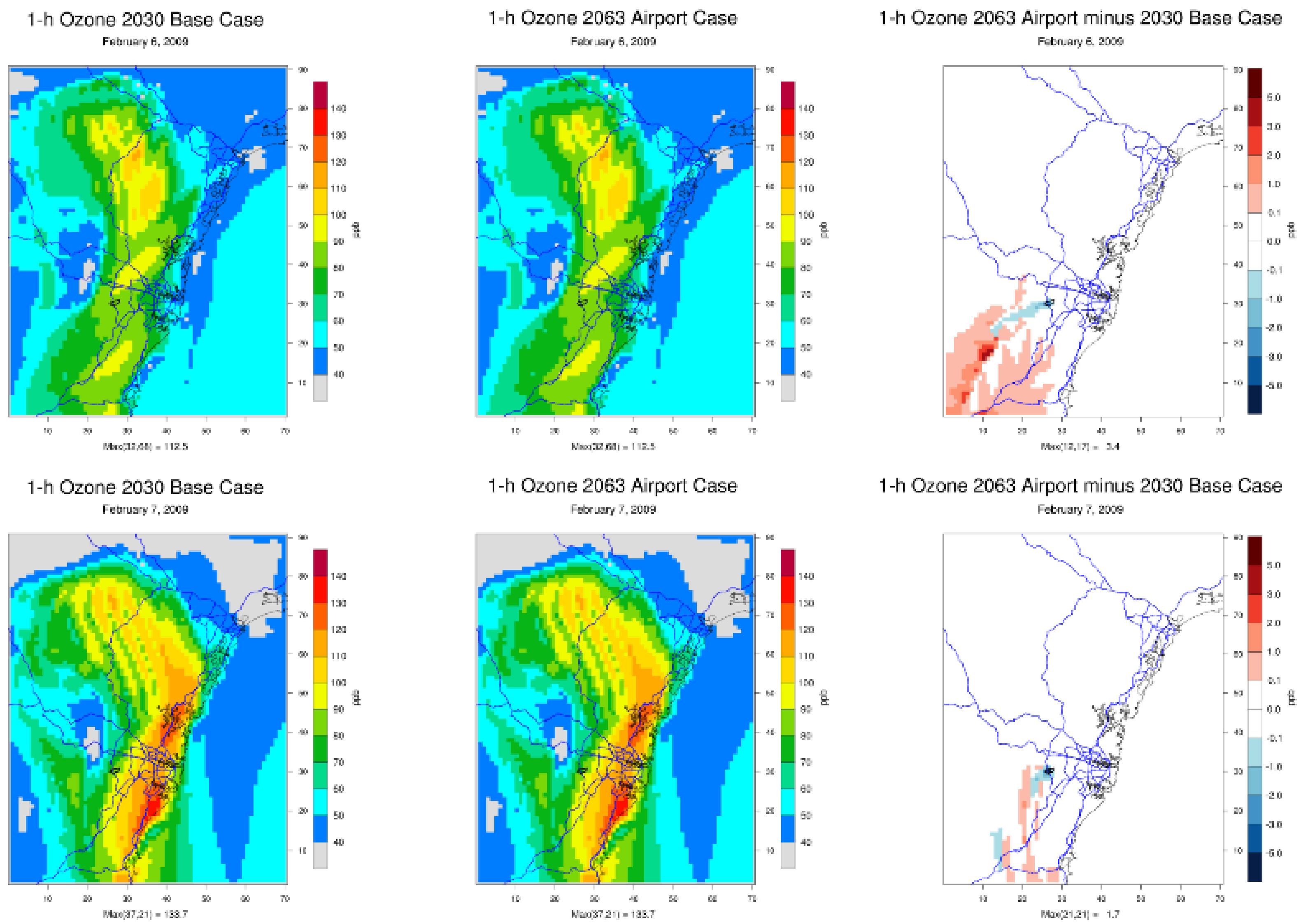


Figure 8-18: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 February

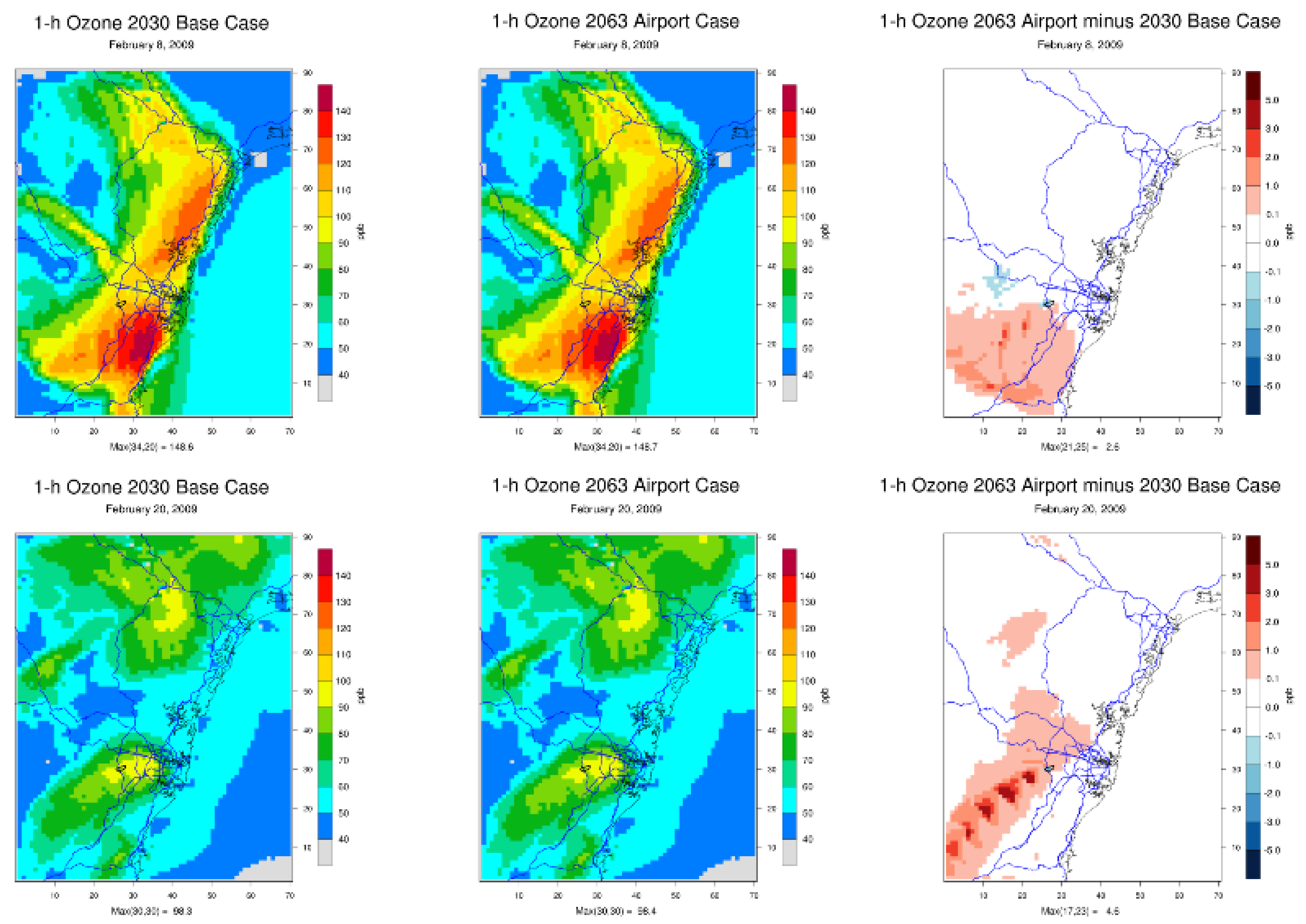


Figure 8-19: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 8 and 20 February

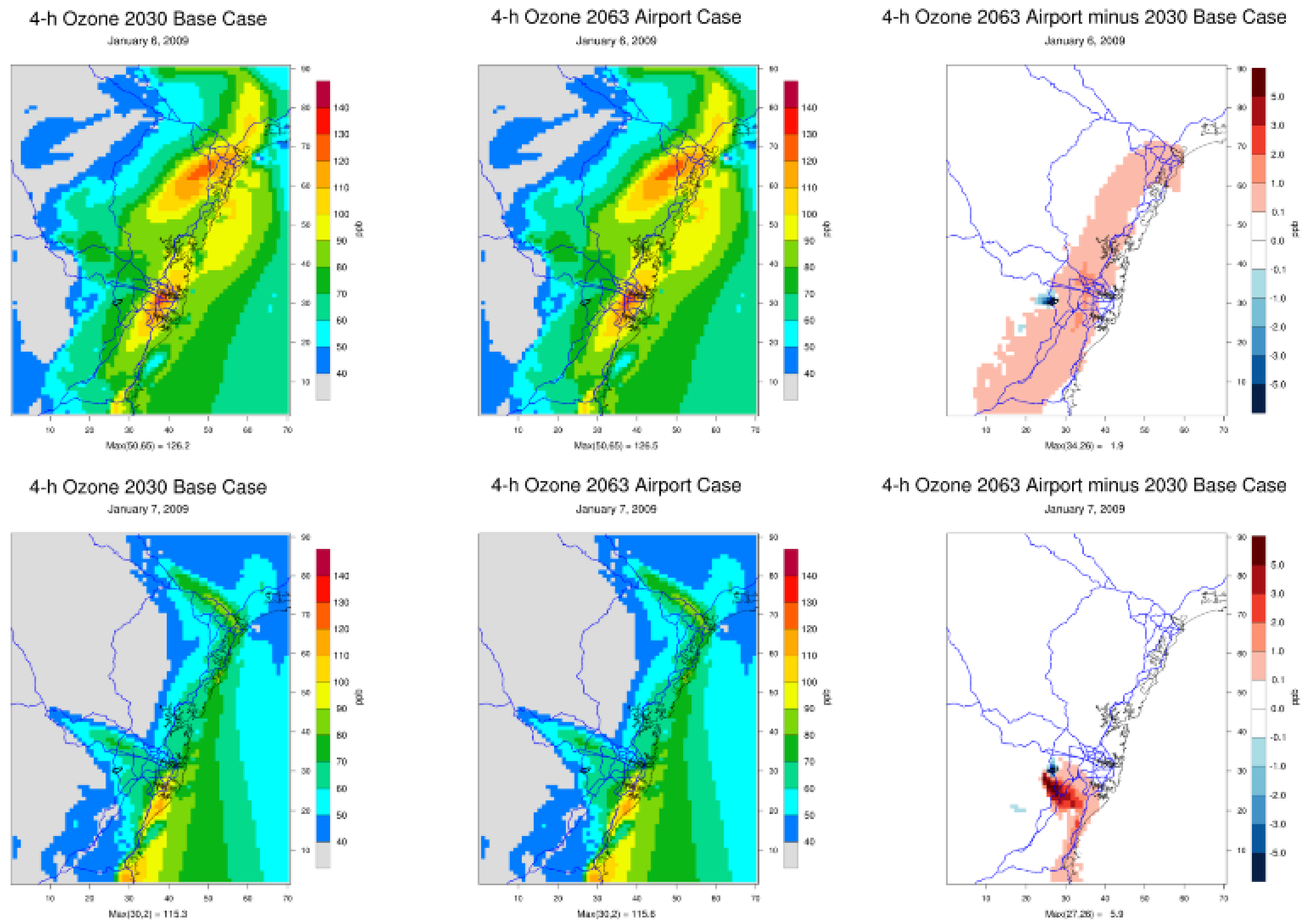


Figure 8-20: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 January

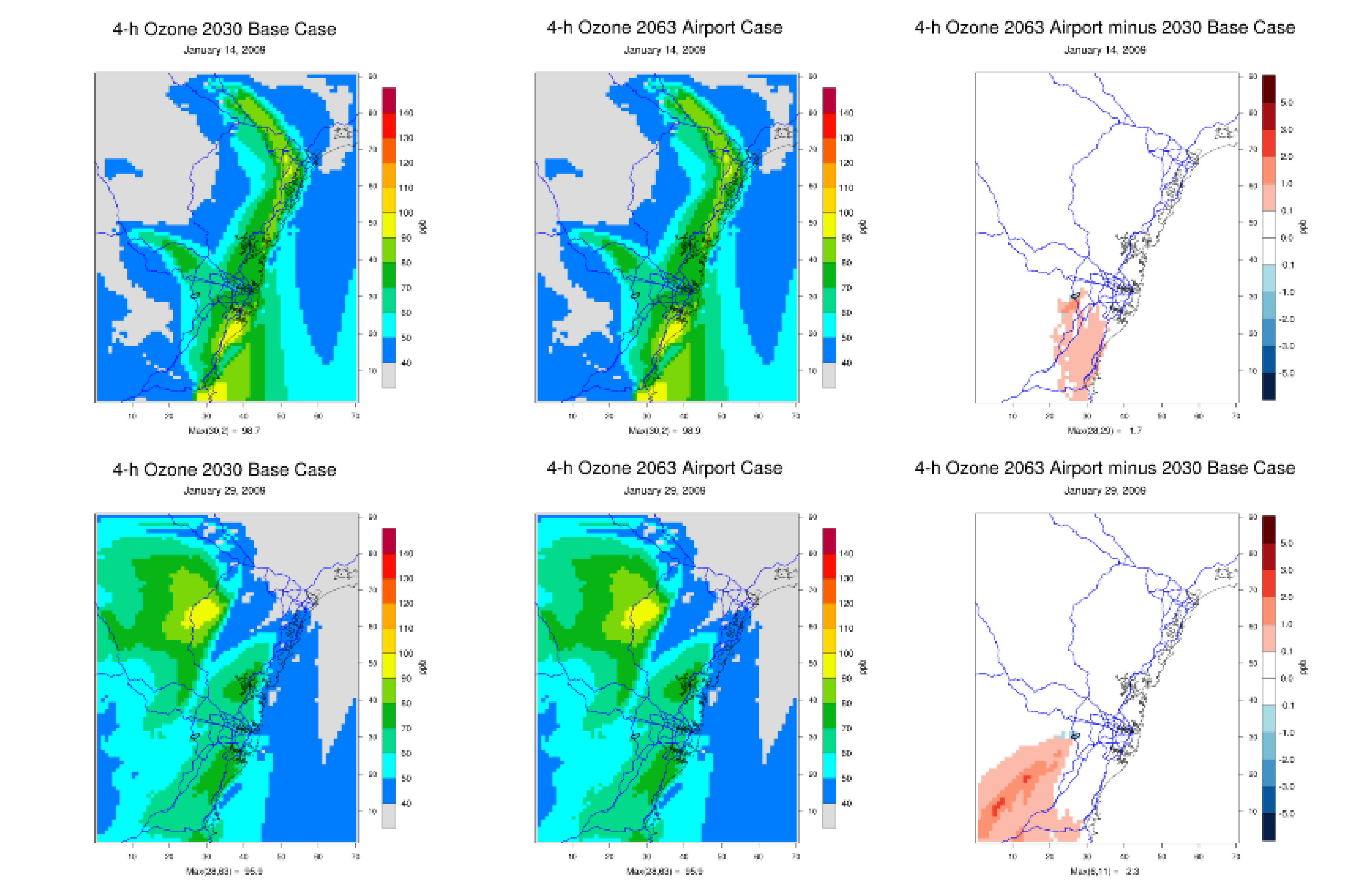


Figure 8-21: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 14 and 29 January

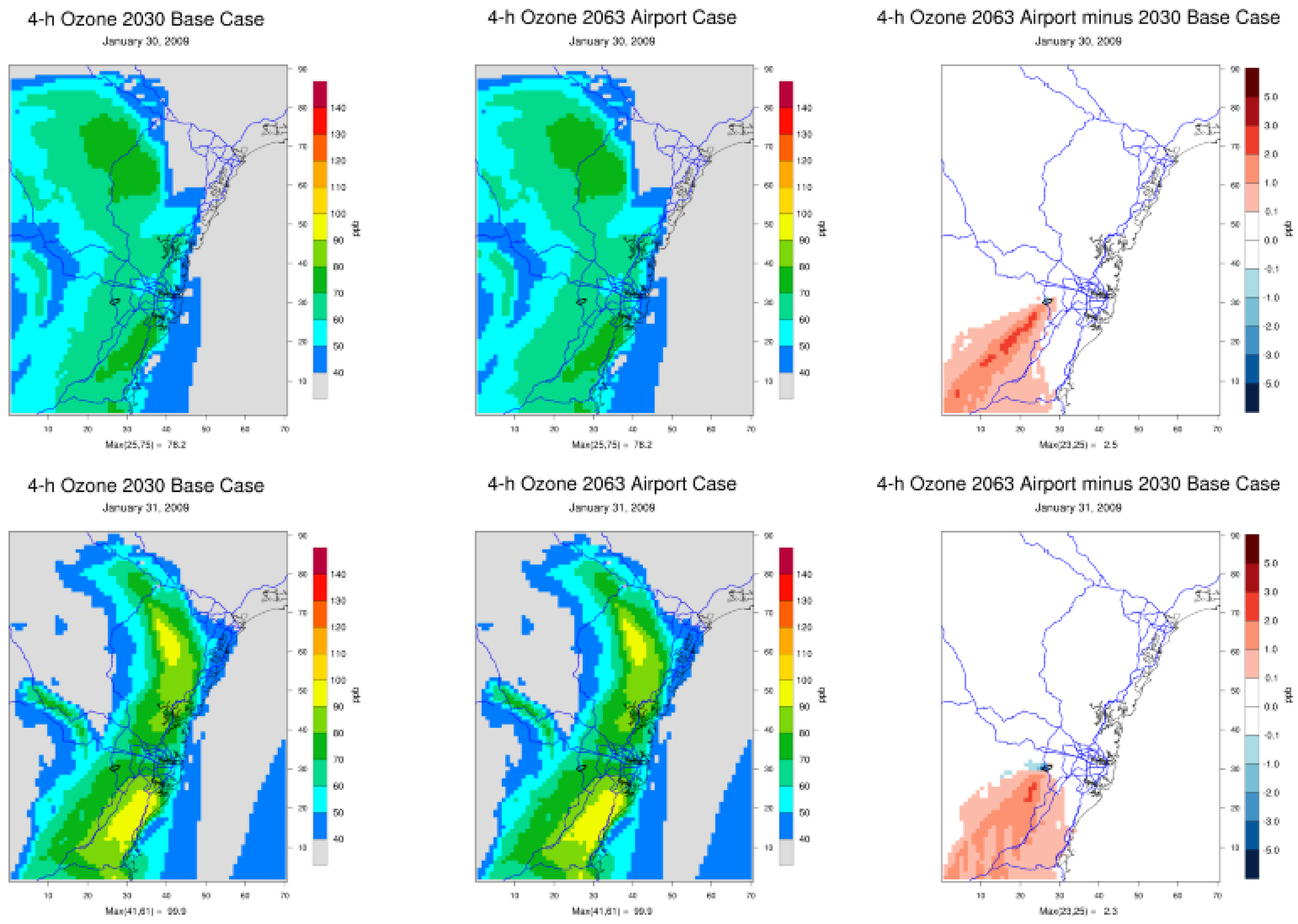


Figure 8-22: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 30 and 31 January

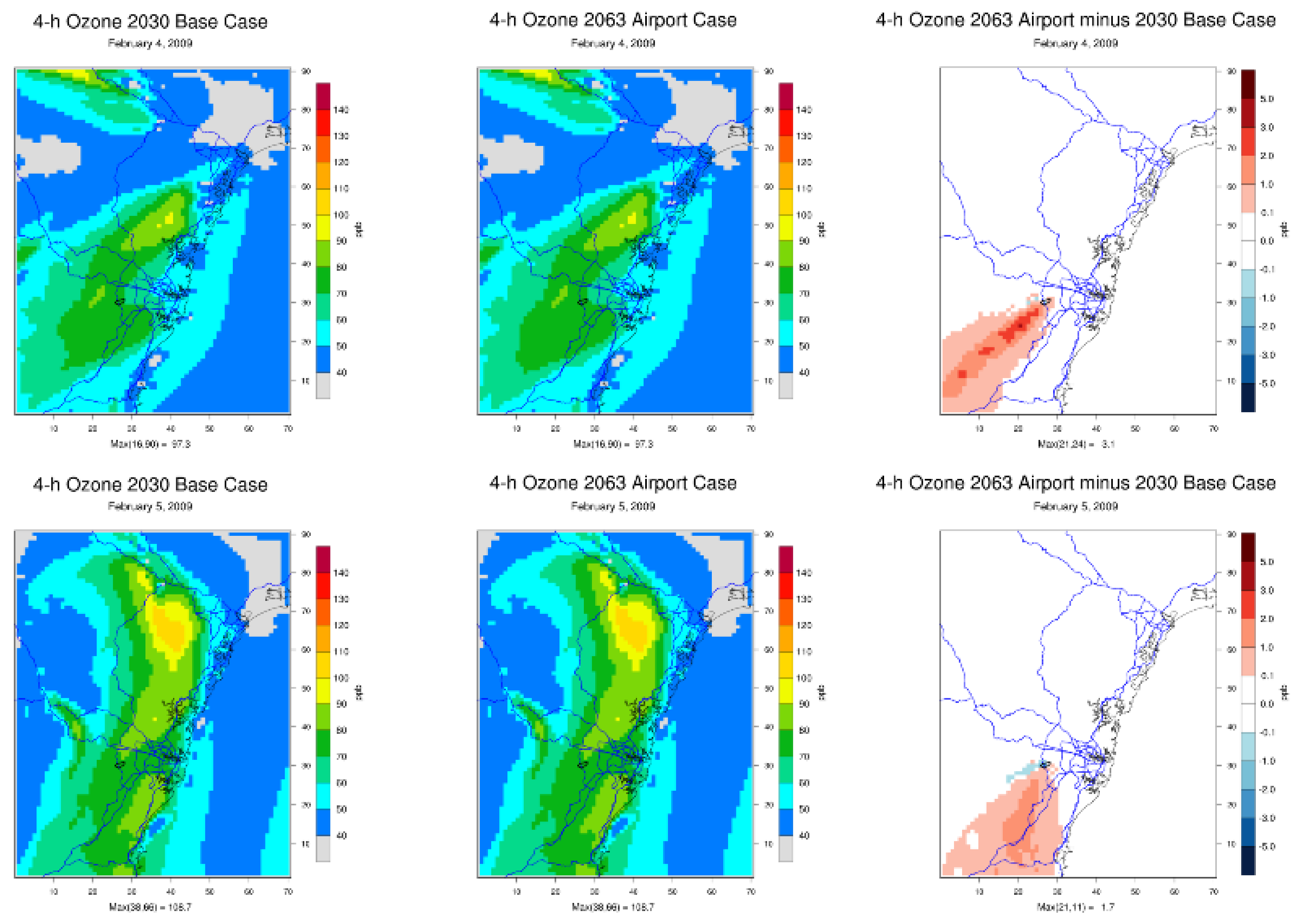


Figure 8-23: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 4 and 5 February

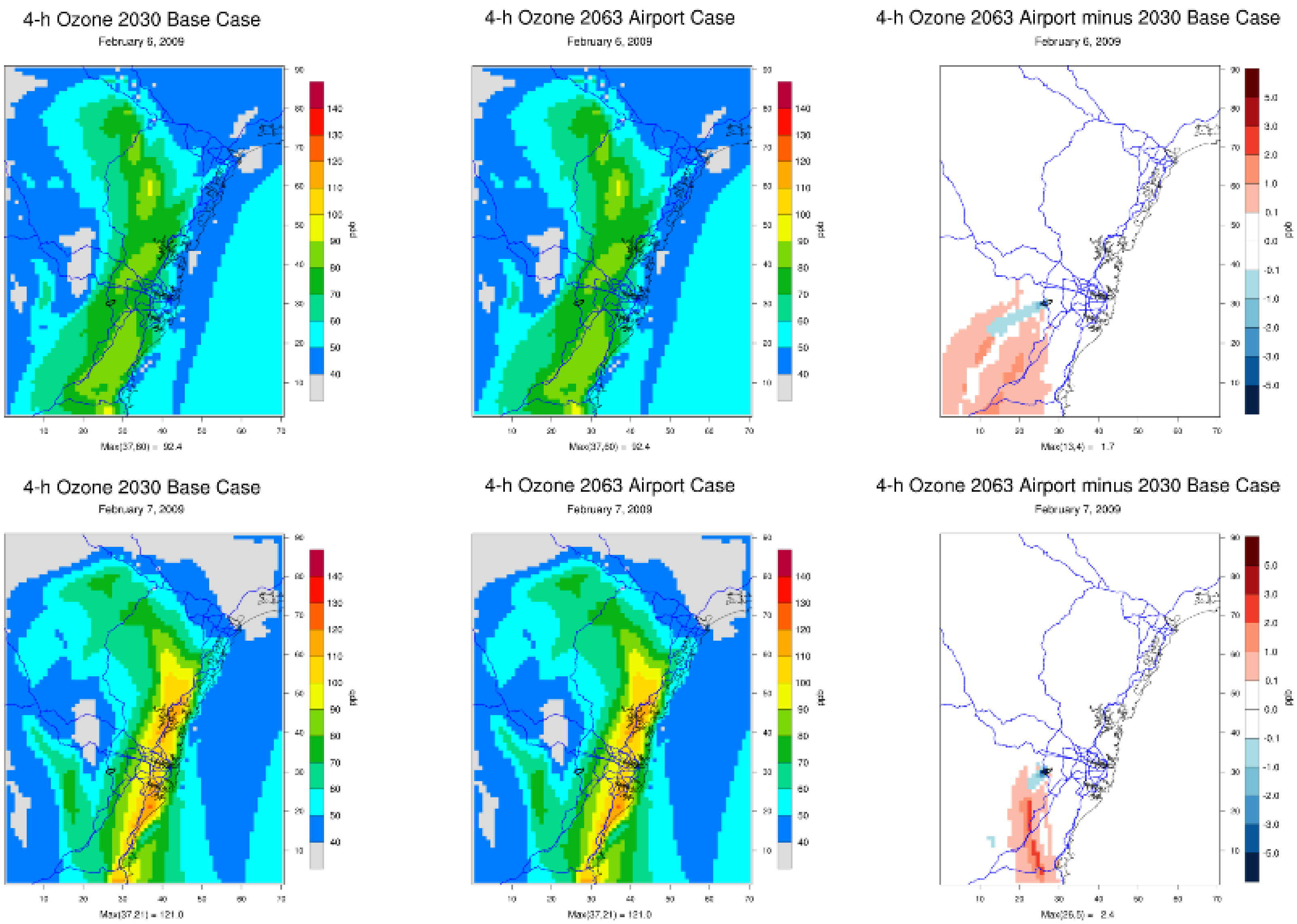


Figure 8-24: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 February

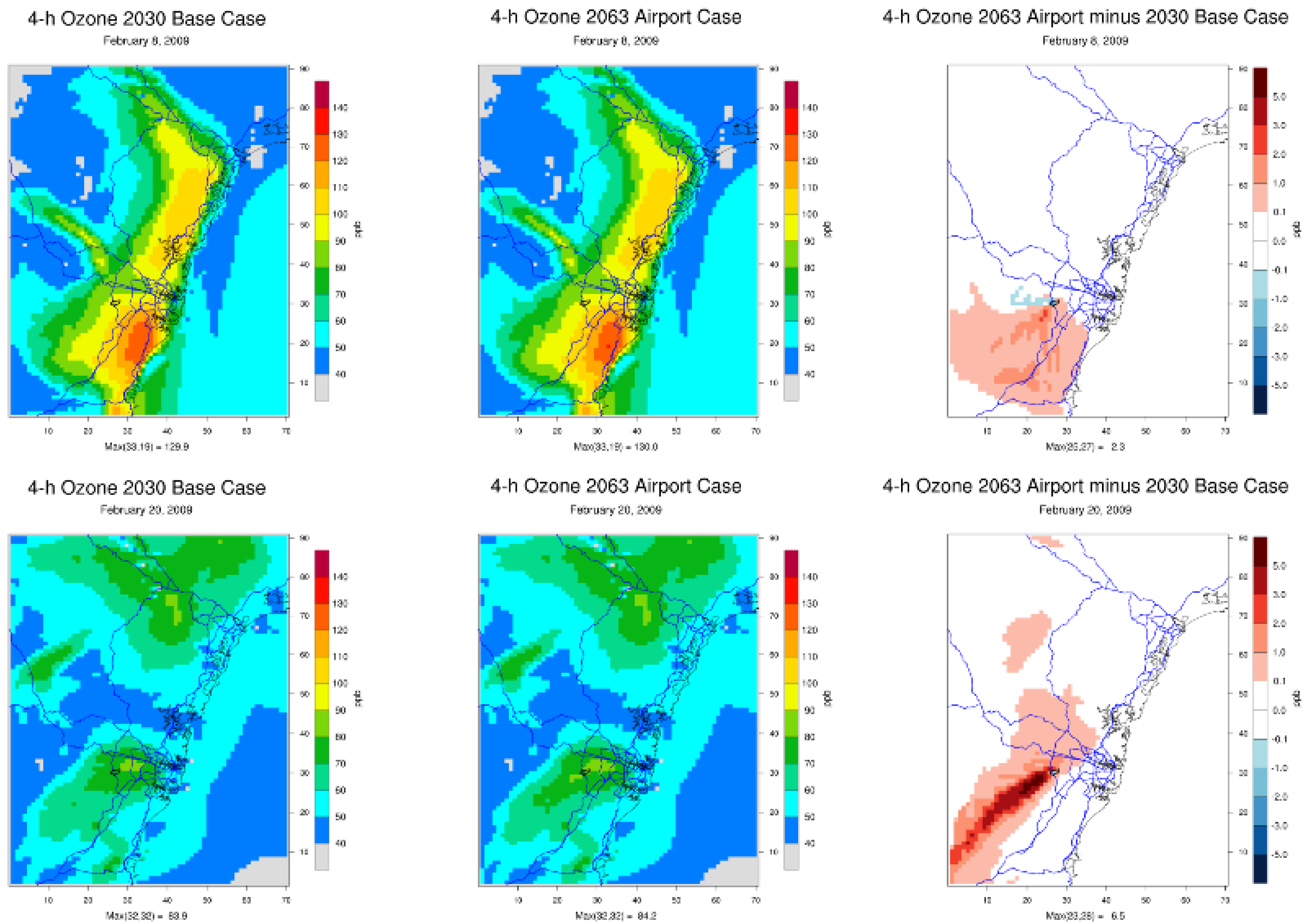


Figure 8-25: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 8 and 20 February

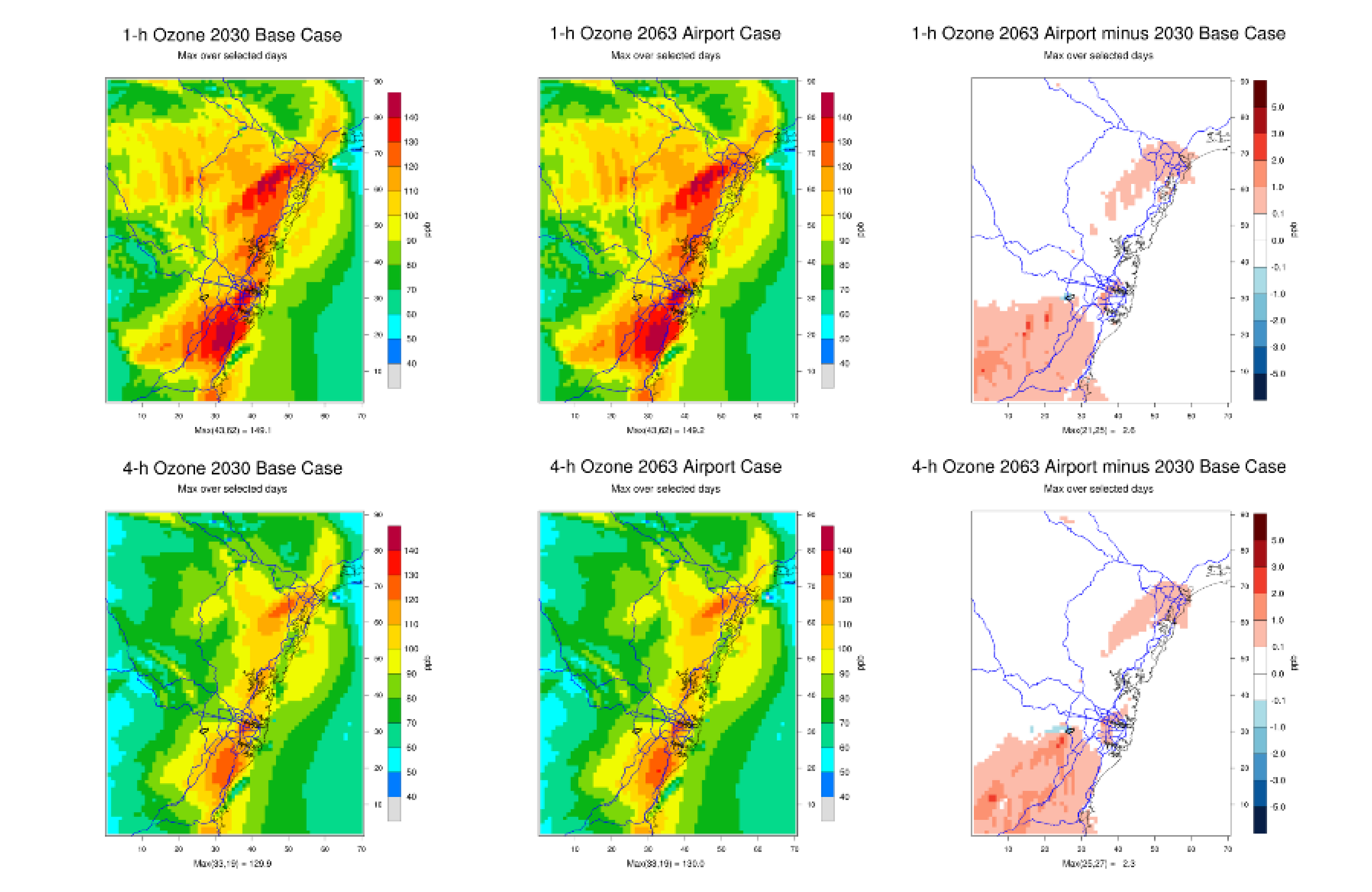


Figure 8-26: Maximum predicted 1-hour and 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for all days

9. MITIGATION MEASURES

The ozone modelling for the Stage 1 airport development predicts a marginal exceedance of the maximum allowable increment level of 1 ppb, based on the average of the 2nd to 4th highest change in daily maximum 1-hour ozone. For the long term airport development, the change in daily maximum 1-hour ozone is significantly above the maximum allowable increment.

Mitigation for ozone impacts should therefore be considered for the proposed Stage 1 development and, if a decision is made to expand the airport beyond Stage 1, for the long term development. Mitigation should focus primarily on measures which result in reductions in NO_x emissions and, to a lesser extent, VOC emissions.

The NSW tiered procedure for ozone assessment requires new or modified facilities located within ozone non-attainment areas to consider best available techniques (BAT) and/or emission offsets when undertaking best management practice (BMP) determinations. The effectiveness of any proposed management measures could be quantified in tonnes of emissions reduced, however it is more relevant to consider the resultant reduction in ozone concentrations. The sensitivity of ozone concentrations to reductions in NO_x and VOCs (i.e., ppb ozone per tonne of emissions) should be evaluated for future years, in particular for the long term airport development, when total regional NO_x emissions may be lower than they are today. Therefore, a BMP determination should consider both effectiveness in reducing ozone and cost-effectiveness.

The largest source of NO_x emissions for the Stage 1 airport development are the external roadways. The future operator of the airport would have no operational control over emissions from external roadways and emission reductions from this source would be driven by progressive improvements in emissions standards for on-road vehicles. NO_x emissions from on-road transportation are already projected to decline for future years, as discussed in **Section 4.3.2**. Emissions from roads have a much wider spatial distribution than sources at the airport which could influence their relative effectiveness in forming ozone. The second largest source of NO_x emissions for the Stage 1 airport development is aircraft engines, the majority of which would occur during landing and take-off. Similar to roadways, the future operator of the airport would have no operational control over emissions from jet engines and emissions reductions would be driven by technological advances, emission standards and aviation jet fuel standards.

The next largest source of NO_x emissions are ground support equipment and auxiliary power units while the aircraft is at the gate. EDMS emission estimates presented in this report include APUs powered by jet fuel and diesel and gasoline powered GSE equipment. These emissions would be reduced were the airport operator to implement best available technology such as mains powered APUs at airport gates. Other emission reduction options for the airport operator to consider, which would have associated benefits in NO_x and VOC emissions reduction include:

- Replacing conventionally fuelled GSE with electric or hydrogen powered belt loaders, pushback tractors, bag tugs, cargo loaders.
- Providing remote ground power for remote aircraft parking positions.
- Installing co-generation or tri-generation in-lieu of traditional gas fired boilers or solar hot water systems to replace gas fired boilers.
- Avoiding certain activities, such as training fires, maintenance (spray painting) during the ozone season.
- Using underground fuel hydrant systems and / or vapour recovery systems for refuelling and fuel storage.
- Promoting the use of public transport to the airport.

NO_x control measures are also outlined in the local air quality assessment, as well as recommendations for the installation of an air quality monitoring station. Ozone is already measured in the vicinity of the airport site (at Bringelly), however if an air quality monitoring station is installed at the airport site, an ozone monitoring sensor could be included in the station.

10. CONCLUSION

Regional air quality considers the formation of secondary pollutants (such as ozone) through photochemical reactions from primary emissions of precursor gases. The primary emissions of precursor gases considered in this assessment include nitrogen oxides (NOx), volatile organic compounds (VOCs) and carbon monoxide (CO), and the assessment focuses on the regional impacts from ozone formation. Ozone air quality impacts from the proposed Western Sydney Airport were evaluated using the Comprehensive Air quality Model with extensions (CAMx).

TAPM was used to simulate meteorology within the study area. Surface observation data from meteorological stations located in the modelling domain were included in the modelling. The performance of TAPM in simulating meteorology for the Sydney region was evaluated. General wind patterns in the observation data were reflected reasonably well in the TAPM predictions and wind speed compared favourably. A statistical evaluation shows good correlation for wind speed and temperature with reasonably low bias and error.

The ozone modelling assessment considered emissions data for the following scenarios:

- 2008/2009 Base Case - for model evaluation.
- 2030 Future Base Case - for comparison with future airport operations.
- 2030 Airport Case – for the Stage 1 airport emissions.
- 2063 Airport Case – for the long term airport emissions.

The 2008/2009 Base Case scenario was used to assess model performance, by comparing predicted ozone concentrations against ambient monitoring data for the same period. Scatter plots presented for the evaluation demonstrate that modelled-observed data pairs are clustered around the 1:1 line, showing that the model tends to correctly predict variability in ozone. The model exhibits little bias at Bringelly and St Marys with normalised mean bias less than 2% for 1-hour ozone and for 4-hour ozone less than 7%.

To assess the impact of airport operations for a future scenario, it was necessary to apply projections to the 2008/2009 emissions. The EPA provided future year emissions projections for 2031, which were used to scale baseline emissions for the 2030 Future Base Case, to allow direct comparison with the Stage 1 airport development year (2030). A number of days were selected for detailed analysis. Twelve days with high observed ozone (1-hour ozone concentrations greater than 70 ppb and 4-hour ozone concentrations greater than 65 ppb) and good model performance (bias within ±15% in peak values) were selected for analysis. The selection of historical dates in January and February 2009 may appear counter intuitive for the modelling future emissions in 2030 and 2063. However, these dates simply represent the meteorological conditions that have historically led to peak ozone formation and which the model has effectively captured for peak ozone formation with future emissions added. They represent days when worst case ozone impacts may be expected.

10.1 Results for Stage 1 airport development

For each day of analysis, the peak predicted 1-hour ozone concentrations were unchanged between the 2030 Base Case and the 2030 Airport Case. This is because the predicted ozone concentrations from the airport occur in different locations to where ozone peaks occur. Both the 2030 Base Case and the 2030 Airport Case were above the NEPM criterion of 100 ppb for all but one day of analysis.

The largest difference in daily maximum 1-hour ozone concentration, from the addition of airport emissions, was 5.5 ppb. However, reliance on a single model result (e.g., the largest ozone change) could accentuate the influence of uncertainties in model input data or model formulation, therefore the average of the 2nd to 4th highest ozone change (1.2 ppb) is used to describe ozone impacts. This approach is similar to the use of a 99th percentile to describe maximum ozone impacts. When compared to the maximum allowable increment level of 1 ppb, prescribed by the

NSW tiered procedure for ozone assessment, a marginal impact is predicted from the 2030 Airport Case.

The peak predicted 4-hour ozone concentration were unchanged between the 2030 Airport Case and the 2030 Base Case on eight days and increased on four days, by a maximum of 0.1 ppb. The highest change in daily maximum 4-hour ozone concentration, from the addition of airport emissions, was 2.4 ppb, while the second highest change was 1.3 ppb. The average of the 2^{nd} to 4^{th} highest change in daily maximum 4-hour ozone was 0.9 ppb, which is below the maximum allowable increment of 1 ppb.

Locations of ozone differences due to 2030 airport emissions are shown in the spatial plots of the daily maximum predicted 1-hour and 4-hour ozone concentration. Decreases in daily maximum ozone would only occur in the vicinity of the airport site for the 2030 Airport Case and are attributable to ozone suppression by NOx emissions. Increases in ozone would occur downwind of the airport which, on most days, is to the south. The largest ozone differences are confined close to the airport site.

10.2 Results for long term airport development

Future projected emissions for sources other than the airport (commercial, industrial, on-road mobile, etc.) are not available for the 2063 scenario. Therefore the long term development scenario becomes a hypothetical scenario of long term airport development occurring within the context of 2030 Base Case emissions.

The maximum predicted 1-hour ozone concentration was unchanged between the 2030 Base Case and the 2063 Airport Case for eight of the analysis days. On four days, the peak predicted 1-hour ozone concentration increased by a maximum of 0.2 ppb. Both the 2030 Base Case and the 2063 Airport Case were above the NEPM criterion of 100 ppb for all but one day of analysis.

Larger ozone increases are modelled for the 2063 Airport Case than the 2030 Airport Case. The average of the 2^{nd} to 4^{th} highest increases in daily maximum 1-hour ozone rose from 1.2 ppb for 2030 to 4.6 ppb for 2063. This is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

The peak predicted 4-hour ozone concentration was unchanged on seven days and increased on five days, by a maximum of 0.3 ppb. The highest change in daily maximum 4-hour ozone concentration, from the addition of 2063 airport emissions, was 6.5 ppb, while the second highest change was 5.9 ppb. The average of the 2^{nd} to 4^{th} highest increases in daily maximum 4-hour ozone is 3.8 ppb, which is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

Decreases in daily maximum ozone, due to ozone suppression by NOx emissions, would occur in the vicinity of the airport site and on some days extend to the aircraft flight corridor and areas downwind of the airport for the 2063 Airport Case. Areas of ozone decrease are more expansive for the 2063 Airport Case than for the 2030 Airport Case because NO_x emissions from the airport site are higher in 2063. Increases in ozone occur downwind of the airport and also are larger for the 2063 Airport Case than for the 2030 Airport Case.

It is noted that emission data provided for airport operations assumes worst case operations, for example by including emissions from APUs rather than the use of mains powered APUs at the airport gates. Furthermore, for the long term airport development we have not accounted for changes in emissions from all other sources (commercial, industrial, on-road mobile, etc.), some of which may increase and some of which may decrease. The modelling predictions for the long term development should therefore be viewed in this context.

10.3 Mitigation

Mitigation for ozone impacts should be considered for the Stage 1 development and, if a decision is made to expand the airport beyond Stage 1, the long term development. Mitigation should focus primarily on measures which result in reductions in NO_x emissions.

The NSW tiered procedure for ozone assessment requires that a best management practice (BMP) determination, for facilities located within ozone non-attainment areas, should consider best available techniques (BAT) and/or emission offsets. As recommended in the local air quality assessment, emissions would be reduced were the proposed airport operator to implement BAT where it can, for example through the use of mains powered APUs at airport gates. It is recommended that any assessment of the effectiveness of any proposed management measures include an evaluation of the sensitivity of ozone concentrations to reductions in NO_x and VOCs (i.e., ppb ozone per tonne of emissions) for future years.

11. GLOSSARY OF TERMS AND ACRONYMNS

1997-99 EIS	PPK 1997, Draft Environmental Impact Statement Second Sydney Airport Proposal, Commonwealth Department of Transport and Regional Development and PPK Environment and Infrastructure Pty Ltd 1999, Supplement to Environmental Impact Statement Second Sydney Airport Proposal, Volume 3 Supplement. Prepared on behalf of the Department of Transport and Regional Services.
$\mu g/m^3$	Micrograms per cubic metre
µm	Micron
Airport site	The site for Sydney West Airport as defined in the Airports Act.
Airports Act	Airports Act 1996 (Commonwealth)
Airports Act amendment	Airports Amendment Bill 2015
APU	Auxiliary power units
BoM	Bureau of Meteorology
CAMx	Comprehensive Air quality Model with extensions
CB05	Carbon Bond chemical mechanism 2005
CB4	Carbon Bond chemical mechanism version 4
CFR	Code of Federal Regulations (United States)
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
COAG	Council of Australian Governments
DoE	Department of Environment
DSEWPC	Department of Sustainability, Environment, Water, Population and Communities
EDMS	Emissions and Dispersion Modeling System
EIS	Environmental Impact Statement
EPA	New South Wales Environment Protection Authority
EPP (Air)	Environment Protection Policy (Air)
EPS3	Emissions Processing System version 3
FAC2	Fraction of model predictions within a factor of 2
g/m^3	grams per metre cubed
GMR	Greater Metropolitan Region in New South Wales
GSE	ground support equipment
HRA	Health Risk Assessment
IOA	Index of Agreement
ISA	Integrated Science Assessment
K	Kelvin
km	kilometre
Long term development	The long term development of the airport, including parallel runways and facilities for up to 82 million passengers annually (nominally occurring in 2063).
LTO	Landing/Take-Off
m	metre
m/s	meters per second
m^2/s	metre squared per second
mb	millbar
MB	Mean bias
MEGAN	Model of Emissions of Gases and Aerosols from Nature

MGE	Mean Gross Error
Mitigation	The action of reducing the severity, seriousness, or painfulness of something.
MNES	Matters of national environmental significance
Monotonic	Continuously increasing (or continuously decreasing)
MOZART	Model for Ozone and Related chemical Tracers
NAAQS	National Ambient Air Quality Standards
National environmental protection measure	Broad framework-setting statutory instruments which outline agreed national objectives for protecting or managing particular aspects of the environment. NEPMs are similar to environmental protection policies and may consist of any combination of goals, standards, protocols, and guidelines.
NCAR	National Center for Atmospheric Research
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NO	nitrogen oxide
NO_x	nitrogen oxides
NW	northwest
O_3	ozone
OEH	NSW Office of Environment and Heritage
PEL	Pacific Environment Limited
PM	particulate matter
PM_{10}	Particulate matter with an aerodynamic diameter of less than 10 μm
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 2.5 μm
POEO Act	Protection of the Environment Operations Act 1997 (NSW)
ppb	parts per billion
pphm	parts per hundred million
ppm	parts per million
Proposed airport	The proposed airport at Badgerys Creek and assessed in the Western Sydney Airport Environmental Impact Statement.
ROI	Radius of Influence
SIL	screening impact level
SO_2	sulphur dioxide
Stage 1 development	The initial stage in the development of the proposed airport, including a single runway and facilities for 10 million annual passengers. (the EIS assumes the airport could be operating at this level approximately 5 years after operations commence which for assessment purposes has been assumed to be 2030).
Stage 1 operations	The airport operating at the Stage 1 capacity as defined in the revised draft Airport Plan.
SW	southwest
Sydney West Airport	The proposed airport. Note: this is the name used in the Act. The Airport is also commonly known as Western Sydney Airport.
TAPM	The Air Pollution Model
The proposed airport	The proposed Western Sydney Airport.
USEPA	United States Environment Protection Agency
VKT	vehicle kilometres travelled
VOC	volatile organic compounds
Western Sydney Airport	The proposed airport. The airport is referred to as Sydney West Airport under the Airports Act.
WSU	Western Sydney Unit, Australian Government Department of Infrastructure and Regional Development

12. LIMITATIONS

Ramboll Environ has prepared this report pursuant to the conditions in the Department of Infrastructure and Regional Development Deed of Standing Quotation (SON2030181), the Commonwealth RFQTS Number 2014/7540/001, the subsequent response accepted and referenced in the relevant Official Order (collectively the "Contract"): In particular, this report has been prepared by Ramboll Environ for the Commonwealth and may only be used and relied on by the Commonwealth and the party or parties identified in the Contract (Other Parties) in accordance with the Contract for the purpose agreed between Ramboll Environ and the Commonwealth as set out in the Contract and **Section 1.2** of this report.

Other than as stated in the Contract, Ramboll Environ disclaims responsibility to any person other than the Commonwealth (or the Other Parties) arising in connection with this report. Ramboll Environ also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by Ramboll Environ in connection with preparing this report were limited to those specifically detailed in the Contract and are subject to the scope limitations set out in the Contract and this report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. Ramboll Environ has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by Ramboll Environ described in this report. Ramboll Environ disclaims liability arising from any of the assumptions being incorrect.

Ramboll Environ has prepared this report on the basis of information provided by Western Sydney Unit and others who provided information to Ramboll Environ (including Government authorities), which Ramboll Environ has not independently verified or checked beyond the agreed scope of work. Ramboll Environ does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

No field surveys were undertaken by Ramboll Environ as part of this assessment and the opinions, conclusions and any recommendations in this report are based on information obtained from desktop assessment only.

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APPENDIX 1
EPA TIERED PROCEDURE FOR OZONE ASSESSMENT

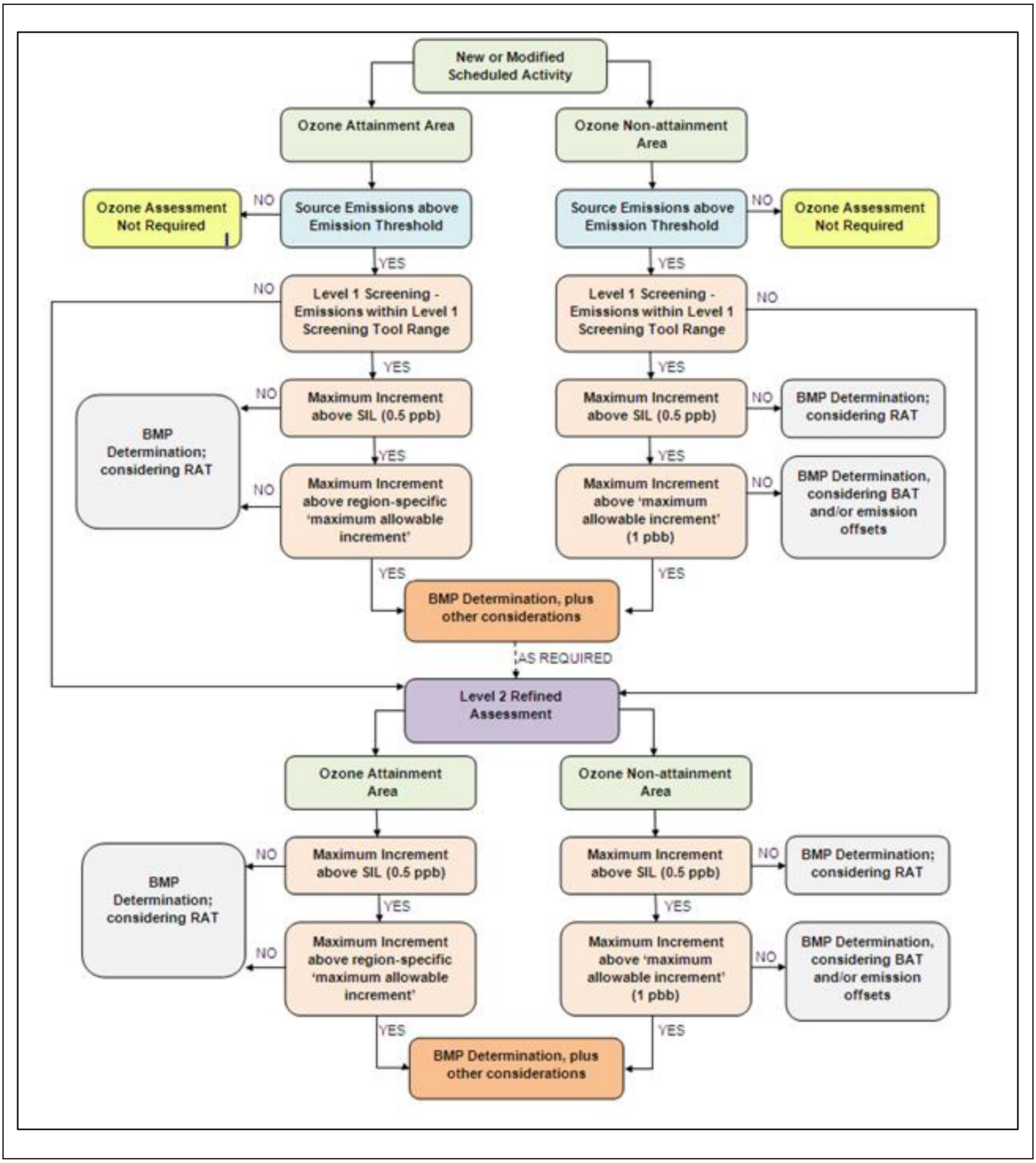


Figure 13-1: Tiered procedure for ozone assessment in NSW

APPENDIX 2
SPECIATION PROFILES FOR VOC EMISSIONS

VOC speciation source-profile cross references

Source ID	Source Description	Profile	Profile Description
AIRBORNE_L	Airborne Landing	5565	Aircraft Landing/Takeoff (LTO) - Commercial
AIRBORNE_T	Airborne Takeoff	5565	Aircraft Landing/Takeoff (LTO) - Commercial
FIRE	Training Fire	0122	Bar Screen Waste Incinerator
GATEAPU	APUs at the Gate	5565	Aircraft Landing/Takeoff (LTO) - Commercial
GATEGSE	GSE at the Gate	EXHDS[a]	Diesel Vehicle Exhaust
PARKINGE00	Parking Facilities - Ethanol free (E0) Petrol	EVE00[a]	Petrol Vehicle - Evaporative emission - E0 ethanol petrol
PARKINGE10	Parking Facilities - E10 Ethanol Petrol	EVE10[a]	Petrol Vehicle - Evaporative emission - E10 ethanol petrol
ROADDSL	Roadway Sources - Diesel	EXHDS[a]	Diesel Vehicle Exhaust
ROADE00EV	Roadway Sources - Ethanol free (E0) Petrol Evap	EVE00[a]	Petrol Vehicle - Evaporative emission - E0 ethanol petrol
ROADE00EX	Roadway Sources - Ethanol free (E0) Petrol Exhaust	EXE00[a]	Petrol Vehicle Exhaust - E0 ethanol petrol
ROADE10EV	Roadway Sources - E10 Ethanol Petrol Evap	EVE10[a]	Petrol Vehicle - Evaporative emission - E10 ethanol petrol
ROADE10EX	Roadway Sources - E10 Ethanol Petrol Exhaust	EXE10[a]	Petrol Vehicle Exhaust - E10 ethanol petrol
RUNWAY_LAN	Runway Landing	5565	Aircraft Landing/Takeoff (LTO) - Commercial
RUNWAY_TAK	Runway Takeoff	5565	Aircraft Landing/Takeoff (LTO) - Commercial
TAXIPATH	Taxipath	5565	Aircraft Landing/Takeoff (LTO) - Commercial
STAT_001	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_002	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_003	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_004	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_005	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_006	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_007	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_008	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_009	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_010	Boiler	0003	External Combustion Boiler - Natural Gas

STAT_011	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_012	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_013	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_014	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_015	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_016	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_017	Engine testing	5565	Aircraft Landing/Takeoff (LTO) - Commercial
STAT_018	Fuel_D_Ac_Main	0297	Fixed Roof Tank - Crude Oil Refinery
STAT_019	Fuel_D_ARRF	0297	Fixed Roof Tank - Crude Oil Refinery
STAT_020	Fuel_D_Fuel_Farm	0297	Fixed Roof Tank - Crude Oil Refinery
STAT_021	Fuel_D_Refueler	0297	Fixed Roof Tank - Crude Oil Refinery
STAT_022	Fuel_JF_ARRF	0100	Fixed Roof Tank - Commercial Jet Fuel (Jet A)
STAT_023	Fuel_JF_Fuel_Farm	0100	Fixed Roof Tank - Commercial Jet Fuel (Jet A)
STAT_024	Fuel_P_Ac_Main	1190	Gasoline Marketed - Summer Blend - 1984
STAT_025	Fuel_P_Fuel_Farm	1190	Gasoline Marketed - Summer Blend - 1984
STAT_026	Fuel_P_Refueler	1190	Gasoline Marketed - Summer Blend - 1984
STAT_027	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_028	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_029	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_030	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_031	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_032	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_033	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_034	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_035	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_036	Paint and solvent	1003	Surface Coating/Painting: Solvent Base

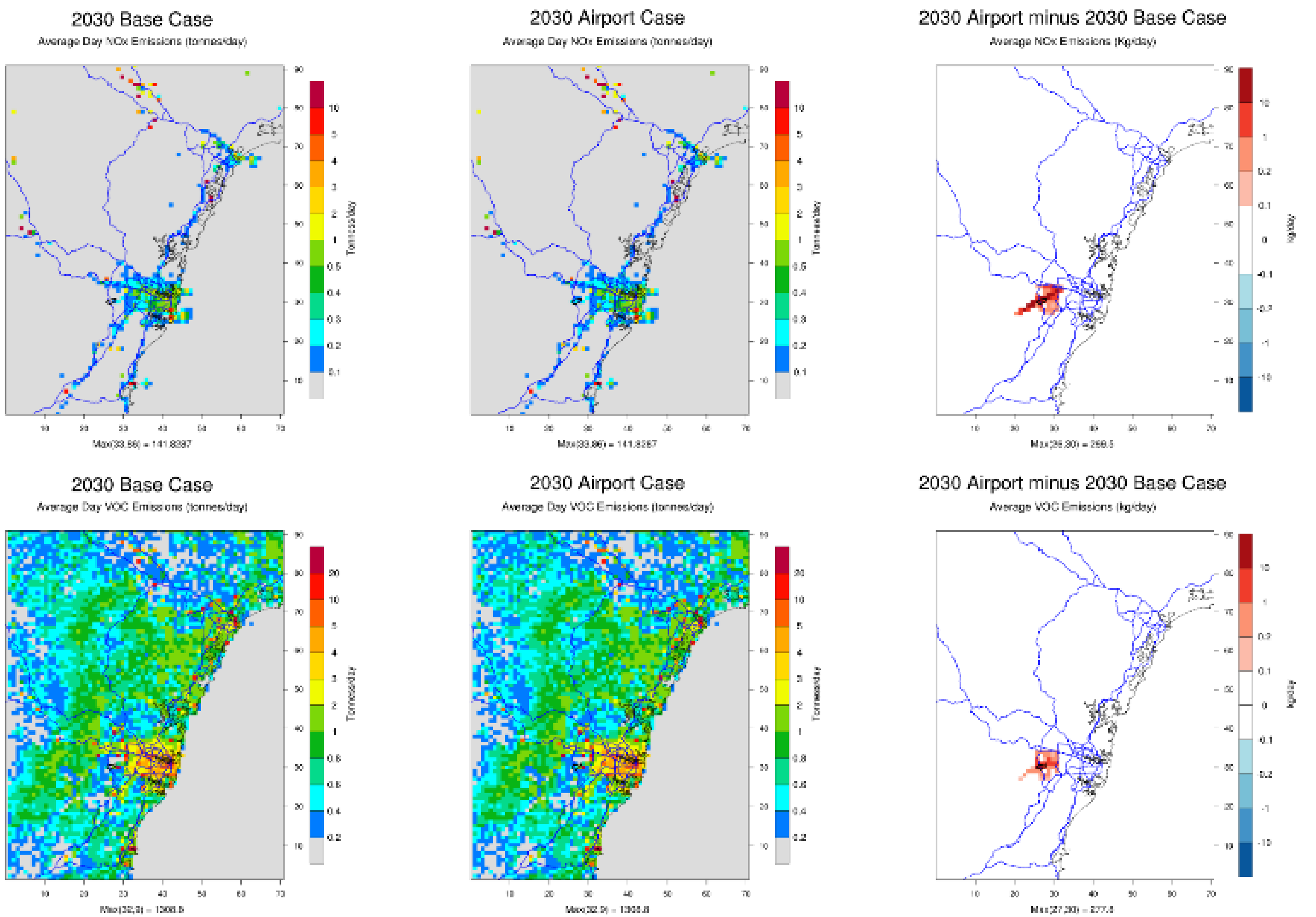
a) On-road mobile profiles are derived from the technical report "Air Emissions Inventory for the Greater Metropolitan Region in New South Wales, 2008 Calendar Year, On-Road Mobile Emissions: Results" http://www.epa.nsw.gov.au/resources/air/120256AEITR7OnRoadMobile.pdf

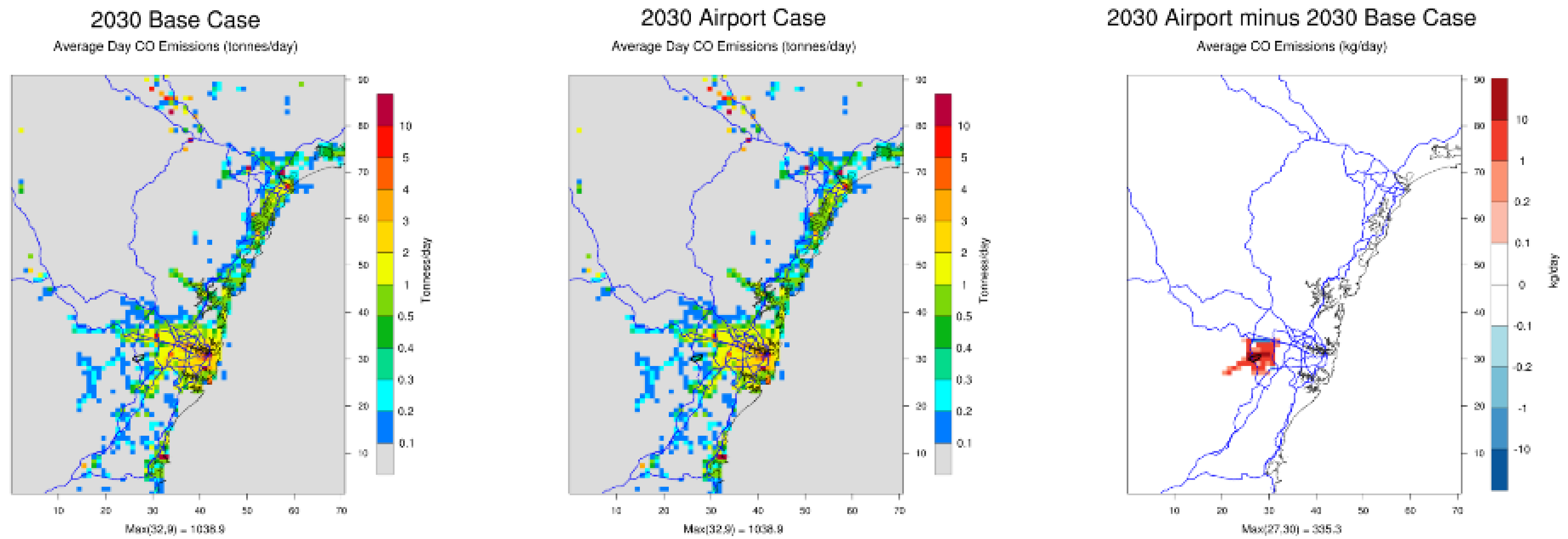
VOC speciation profiles for CB4 chemical mechanism (in moles CB4 species per gram TOG)

Profiles	ALD2	ETH	ETOH	FORM	ISOP	MEOH	NVOL	OLE	PAR	TOL	UNK	UNR	XYL
0003	-	-	-	0.0027	-	-	-	-	0.0202	0.0002	-	0.0385	-
0009	-	0.0102	-	-	-	-	-	0.0091	0.0147	-	-	0.0180	-
0100	-	-	-	-	-	-	-	-	0.0704	-	-	-	-
0122	-	0.0031	-	-	-	-	-	0.0001	0.0020	-	-	0.0560	-
0297	-	-	-	-	-	-	-	-	0.0535	0.0002	-	0.0141	-
1003	0.0000	-	-	-	-	-	-	0.0000	0.0313	0.0042	-	0.0017	0.0007
1190	0.0009	0.0000	0.0000	0.0001	0.0000	0.0000	-	0.0003	0.0255	0.0025	-	0.0024	0.0032
5565	0.0035	0.0055	-	0.0047	-	0.0006	-	0.0030	0.0262	0.0002	-	0.0035	0.0003
EVE00	0.0036	-	-	0.0005	0.0000	-	-	0.0005	0.0567	0.0003	-	0.0009	0.0002
EVE10	0.0037	-	0.0007	0.0005	0.0000	-	-	0.0005	0.0555	0.0002	-	0.0008	0.0001
EXE00	0.0009	0.0037	-	0.0007	0.0000	0.0000	0.0000	0.0018	0.0256	0.0012	-	0.0128	0.0012
EXE10	0.0010	0.0037	0.0005	0.0008	0.0000	0.0001	0.0000	0.0018	0.0238	0.0012	-	0.0126	0.0012
EXHDS	0.0017	0.0025	-	0.0035	0.0000	0.0004	0.0003	0.0010	0.0285	0.0003	0.0000	0.0125	0.0007

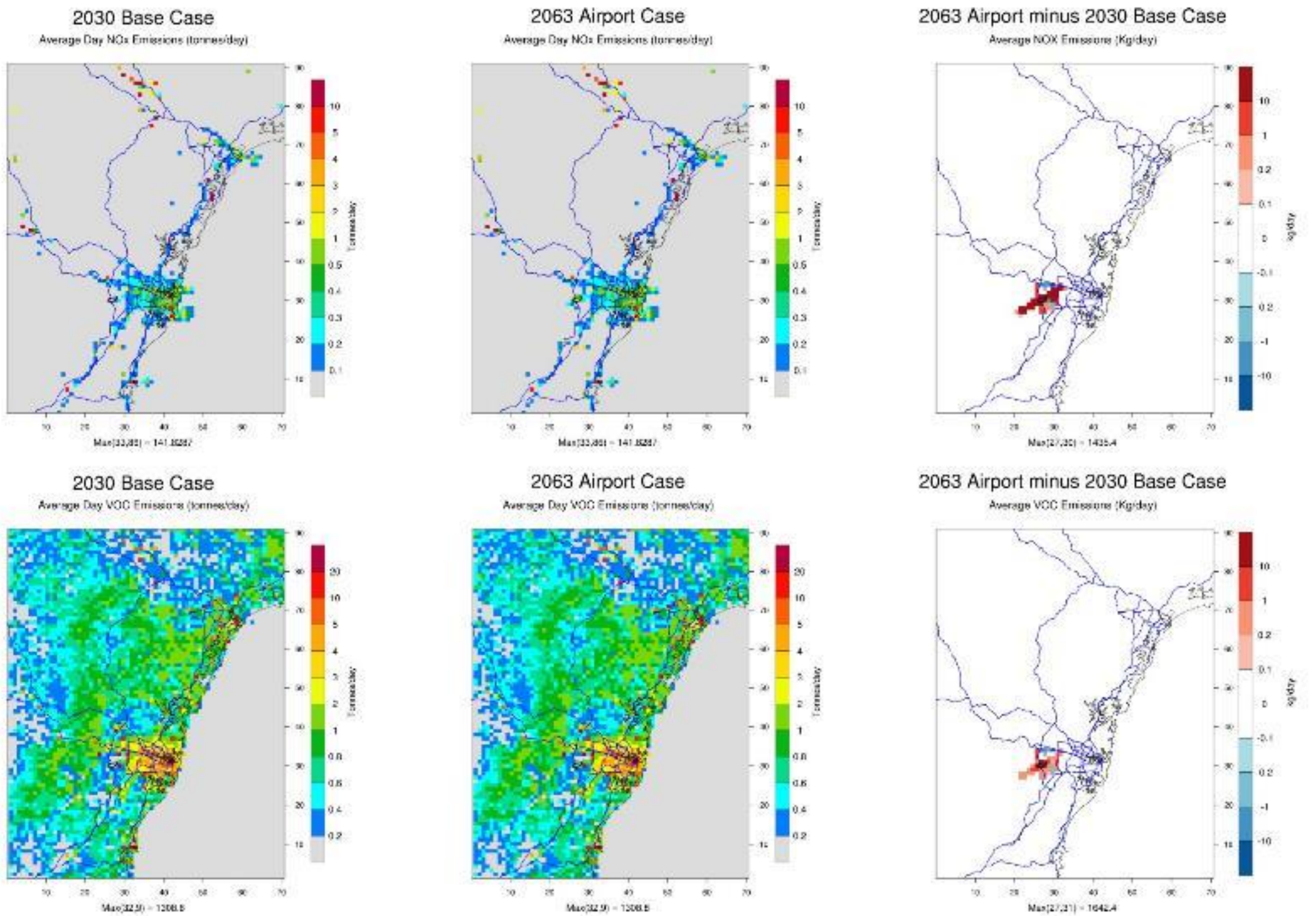
APPENDIX 3
SPATIAL ALLOCATION OF EMISSIONS

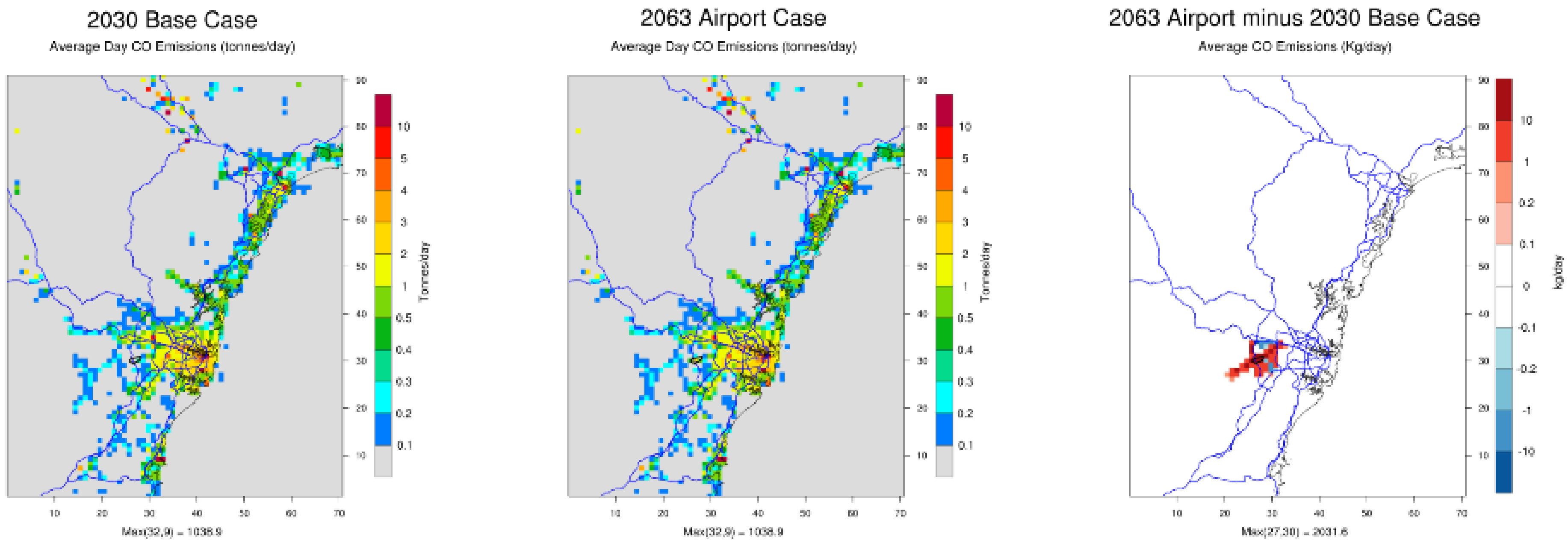
2030


2030 Base Case
Average Day NOx Emissions (tonnes/day)
Max(33,86) = 141.8287
Tonnes/day
2030 Airport Case
Average Day NOx Emissions (tonnes/day)
Max(33,86) = 141.8287
2030 Airport minus 2030 Base Case
Average NOx Emissions (Kg/day)
kg/day
2030 Base Case
Average Day VOC Emissions (tonnes/day)
2030 Airport Case
Average Day VOC Emissions (tonnes/day)
2030 Airport minus 2030 Base Case
Average VOC Emissions (kg/day)


2030 Base Case
Average Day CO Emissions (tonnes/day)
Max(32,9) = 1038.9
Tonnes/day
10
5
4
3
2
1
0.5
0.4
0.3
0.2
0.1
2030 Airport Case
Average Day CO Emissions (tonnes/day)
Max(32,9) = 1038.9
Tonnes/day
2030 Airport minus 2030 Base Case
Average CO Emissions (kg/day)
Max(27,30) = 335.3
kg/day
10
1
0.2
0.1
0
-0.1
-0.2
-1
-10

2063


2030 Base Case
Average Day NOx Emissions (tonnes/day)
2063 Airport Case
Average Day NOx Emissions (tonnes/day)
2063 Airport minus 2030 Base Case
Average NOX Emissions (Kg/day)
2030 Base Case
Average Day VOC Emissions (tonnes/day)
2063 Airport Case
Average Day VOC Emissions (tonnes/day)
2063 Airport minus 2030 Base Case
Average VOC Emissions (Kg/day)


2030 Base Case
Average Day CO Emissions (tonnes/day)
Max(32,9) = 1038.9
Tonnes/day
2063 Airport Case
Average Day CO Emissions (tonnes/day)
Max(32,9) = 1038.9
Tonnes/day
2063 Airport minus 2030 Base Case
Average CO Emissions (Kg/day)
Max(27,30) = 2031.6
kg/day