AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Temperature Forecast Analysis for Winter 2023

February 2024

A report assessing the forecast precision and accuracy of AEMO's operational weather providers in the National Electricity Market from 1 May 2023 to 30 September 2023

Important notice

Purpose

This report has been prepared to:

- Give the weather providers used by AEMO an insight into their comparative temperature forecast performance in the National Electricity Market during the 2023 winter period.
- Give any intending weather providers information to assess the relative performance of their forecasts.
- Facilitate industry discussion and ongoing improvement of weather forecast accuracy.

This report is generally based on information available to AEMO as of 30 September 2023 unless otherwise indicated.

Disclaimer

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Glossary

Term	Description
Dry-bulb temperature	The temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture.
Electricity demand (operational demand)	The sum of scheduled, semi-scheduled, and significant non-scheduled generation connected to the National Electricity Market.
Rolling forecast horizon	A forecast that is always created X hours ahead of the actual observation. For example, for a 4 hour ahead rolling forecast horizon, the observation at 12:00 pm was forecast at 8:00 am, and the observation at 4:00 pm was forecast at 12:00 pm.
Forecast error (°C)	Forecast temperature minus actual temperature.
Mean Absolute Error (MAE)	The calculated average of the absolute (unsigned) forecast error. Mean absolute error is only used in reference to temperature forecast error (°C) in this report.
Accuracy versus precision	Accuracy refers to how close an actual temperature measurement is to the forecast value. Precision is the frequency at which a forecast error is reproduced. Therefore, a set of forecast outcomes could be precise in that its errors fall within a narrow range, and a set of forecast outcomes are both accurate and precise when that small range of errors are close to the actual measurement.

Executive summary

This report examines the hourly temperature forecast performance of AEMO's weather service providers in the National Electricity Market (NEM) from 1 May 2023 to 30 September 2023 (referred to as "winter 2023" in this report). The report studies temperature forecast accuracy and precision at the 1, 4, 24, and 72 hours ahead (HA) rolling forecast horizons. It has been prepared as a resource for weather providers to benchmark their performance, and to facilitate discussion and ongoing improvement of temperature forecast accuracy to support system operation and the broader energy industry.

Key findings from winter 2023 performance analysis of AEMO's three weather forecast providers are:

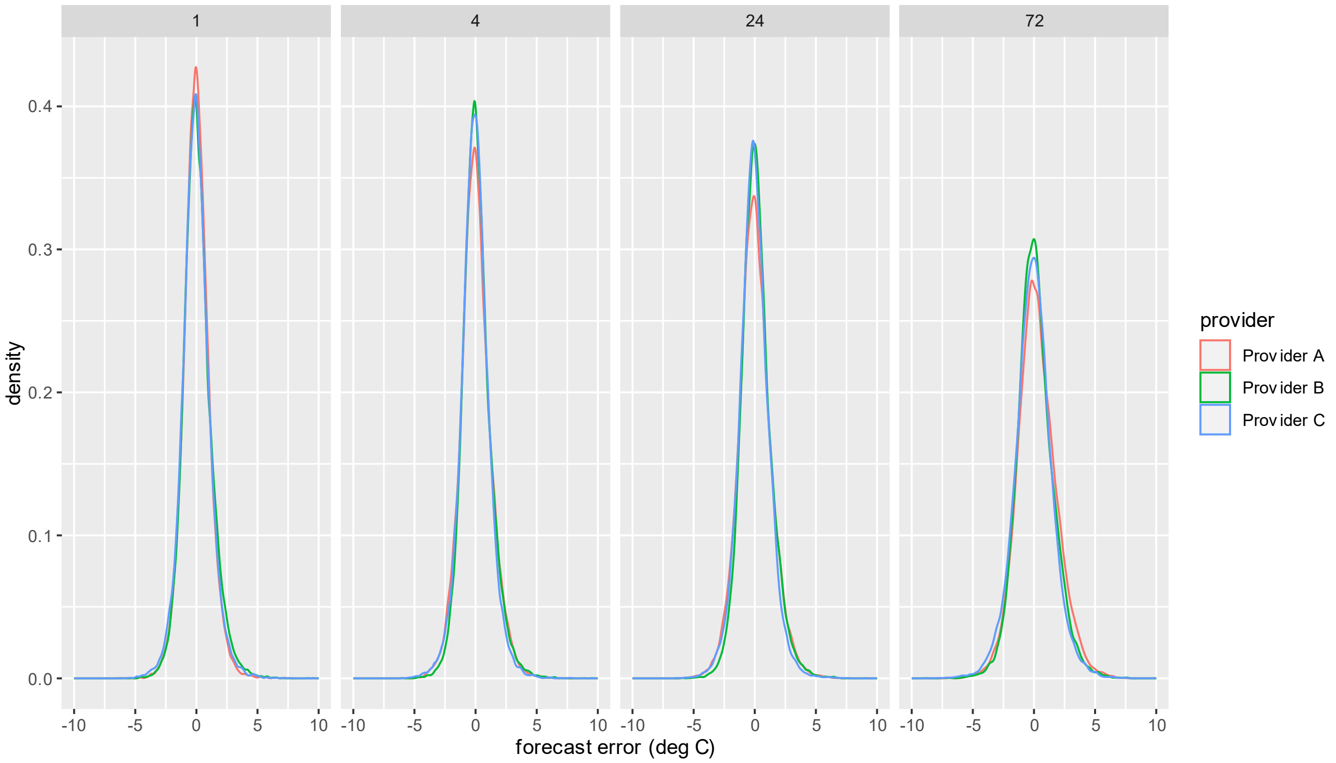
- **Provider A:**
  - Overall accuracy and precision was comparable to winter 2022, however forecasting the bottom 10% of temperatures improved at some weather stations.
  - Performance at the 1 HA forecast horizon was overall the highest among all providers for both accuracy and precision.
  - Performance at the 4, 24 and 72 HA forecast horizons was overall the lowest among all providers, consistent with Winter 2022 performance.
- **Provider B:**
  - Minor reduction in overall precision over all forecast horizons compared to winter 2022.
  - Performance in forecasting the bottom 10% of temperatures was lower for all forecast horizons compared to winter 2022, with an increased tendency to over-forecast these temperatures.
  - Provider B was the highest overall performing provider at the 4 and 72 HA horizon, equal highest with Provider C at 24 HA, and equal second highest at 1 HA (behind Provider A).
- **Provider C:**
  - Performance at 4 to 72 HA remained consistent with winter 2022, however performance reduced at 1 HA for all temperatures and bottom 10% of temperatures.
  - Compared to other providers, Provider C was the equal highest performing provider overall at the 24 HA horizon, a close second at 4 and 72 HA, and equal second at 1 HA (behind Provider A).
  - For the bottom 10% of temperatures, Provider C was the outright highest performing provider at 4, 24 and 72 HA, and the second highest at 1 HA (behind provider A).

AEMO will use this report to aid operational decision-making and draw attention to potential areas of improvement in the weather forecasting industry. This will support existing initiatives between AEMO and the weather forecasting industry, including:

- Redevelopment of AEMO's Projected Assessment of System Adequacy (PASA) to be probabilistic and include weather uncertainty margins in reserve calculations.
- Establishment of new weather observation stations located within renewable energy zones (REZs), near remote variable renewable energy (VRE) generators, and in metropolitan heat islands, to support weather and energy forecasting.

- Accessing a range of probabilistic and ensemble weather forecasts from providers to improve situational awareness and better represent extreme weather risk and operation envelope of demand forecasts.
- Onboarding a fourth provider which utilises AI-powered models with higher spatial and temporal resolution than conventional models to forecast wind speed, irradiance, and temperature for energy forecasts.

Figure 1 Winter 2023 performance across all major weather stations and temperatures



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Figures

1 Introduction

This report examines the hourly temperature forecast performance of AEMO's three weather service providers in the National Electricity Market (NEM) from 1 May 2023 to 30 September 2023[1] (referred to as "winter 2023" in this report).

It aims to highlight the differences in forecasting performance between winter 2022 and 2023, while also drawing new performance insights from the Winter 2023 period. It is part of a series of biannual *Temperature Forecast Analysis* reports available on the AEMO website for summer and winter periods since 2018[2].

This report has been prepared as a resource for existing and intending weather service providers to benchmark their forecast performance, and to facilitate discussion and ongoing improvement of weather forecast performance to support power system operation in the NEM and the broader energy industry. It includes a case study discussing the impact of warmer seasonal trends on minimum operational demand outcomes in winter and spring in South Australia, Victoria, Queensland, and New South Wales.

The providers in this report have been anonymised as Provider A, B, and C (consistent with previous reports) and their temperature forecast accuracy and precision analysed at the 1, 4, 24, and 72 hours ahead (HA) rolling forecast horizons.

The weather stations analysed in this report are Adelaide West Terrace (WT) (South Australia), Archerfield Airport (AP) (Queensland), Bankstown AP (New South Wales), Hobart AP (Tasmania), Melbourne AP (Victoria), Melbourne Olympic Park (OP) (Victoria), Penrith Lakes (New South Wales) and Sydney AP (New South Wales). These are the main weather stations used by the NEM Demand Forecasting System (DFS) and as such they have the largest influence on demand forecasts for their respective NEM regions.

Within the DFS, the New South Wales, Victoria and South Australia regions are each forecast as a single area. The Queensland region forecast is an aggregate of forecasts for the Northern, Central and Southern areas. The Tasmania region forecast is an aggregate of the Northern and Southern areas.

[1] All analysis refers to time in Australian Eastern Standard Time (AEST).

[2] Previous reports available at https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/load-forecasting-in-pre-dispatch-and-stpasa.

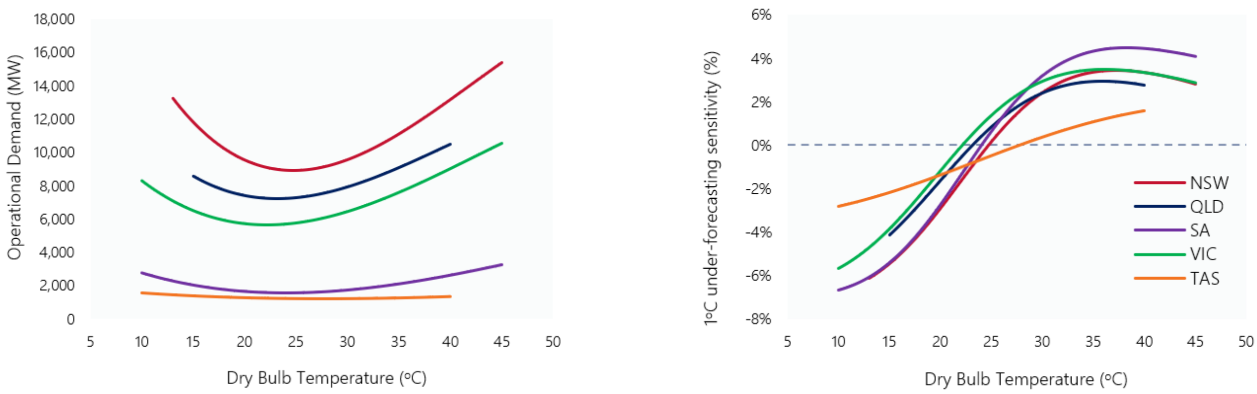
1.1 Sensitivity of electricity demand to temperature

Figure 2 shows the absolute and proportional change in operational demand with reference to temperature for each NEM region, to provide context to the results in this report[3].

The performance of a temperature forecast must be understood with reference to its operational impact on electricity demand. The performance of temperature forecasts is most critical for operational demand forecasting when demand is high or extremely low, generation reserves are low, or when a small change in temperature results in a large change in demand. These conditions are often encountered on hot summer and cold winter days, meaning it is important for weather providers to produce accurate and precise temperature forecasts on these days.

Electricity demand has different temperature sensitivity in each NEM region, due to factors such as climate and the mix of residential, commercial, and industrial load. In addition, the same demand forecast error will have different operational impacts for different regions. Since each region has limited local generation and interconnector capacity, percentage changes in demand must be understood in conjunction with absolute demand changes.

Figure 2 Weekday maximum daily operational demand against maximum dry bulb temperature (left) and the percentage change in operational demand for a 1°C under-forecasting error (right) for each NEM region



1.2 Weather conditions in winter 2023

During winter 2023, national mean temperatures were 1.53˚C above the long-term average, with daytime temperatures above average for parts of the NEM, and the national mean minimum temperature was 1.21°C above average. Daytime temperatures were very much above average across much of Queensland, New South Wales, Tasmania, most of Victoria and parts of Western Australia. Southern and eastern Queensland and northern and eastern New South Wales experienced their warmest winter maximum temperatures on record[4].

Winter rainfall was 4.2% below the long-term average for Australia. Some regions – including Gascoyne and Southwest Land Division (in Western Australia), the Darling Down and Granite Belt (in southeast Queensland), and the New South Wales Coast extending into Victoria's Gippsland and Central Districts – observed winters in their driest 10% of years since 1900.

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[3] This analysis shows the relationship of maximum daily dry bulb temperature and maximum daily operational demand on weekdays between 1 January 2018 and 31 March 2023. The temperature readings were taken from the primary weather station for demand forecasting in each region (New South Wales – Bankstown AP, Queensland – Archerfield AP, Victoria – Melbourne OP, South Australia – Adelaide WT, Tasmania – Hobart AP).

[4] Australia in Winter 2023, Bureau of Meteorology, at http://www.bom.gov.au/clim_data/IDCKGC2AR0/202308.summary.shtml

Winter rainfall was above average in southern Western Australia, western Queensland, and parts of northern and eastern South Australia, extending into western New South Wales and northwest Victoria.

Both minimum and maximum temperatures were above average for winter 2023 for parts of the NEM, with some NEM regions reaching new winter maximum temperature anomaly records. Queensland had a record maximum temperature anomaly of 2.44˚C above average, New South Wales was 2.30˚C above average, and South Australia was 1.42˚C above average. Several weather stations in western and southern Tasmania, southern and north-eastern Victoria, the border between Queensland and New South Wales, and South Australia recorded their warmest winter temperatures on record.

When combined with sunny days, the warmer than average winter period drove record-breaking winter minimum demand levels for New South Wales, Victoria, Queensland, and the NEM:

- New South Wales reached a new winter minimum operational demand record of 4,821 megawatts (MW) on Sunday 20 August 2023.
- Queensland reached a new winter minimum operational demand record of 3,459 MW on Saturday 19 August 2023.
- Victoria reached a new winter minimum operational demand record of 2,916 MW on Sunday 27 August 2023.
- The NEM reached a new winter minimum operational demand record of 13,339 MW on Sunday 27 August 2023.

This trend continued into Spring 2023, which resulted in many new all-time minimum records being set in October. This is explored further in the case study in Section 3 of this report.

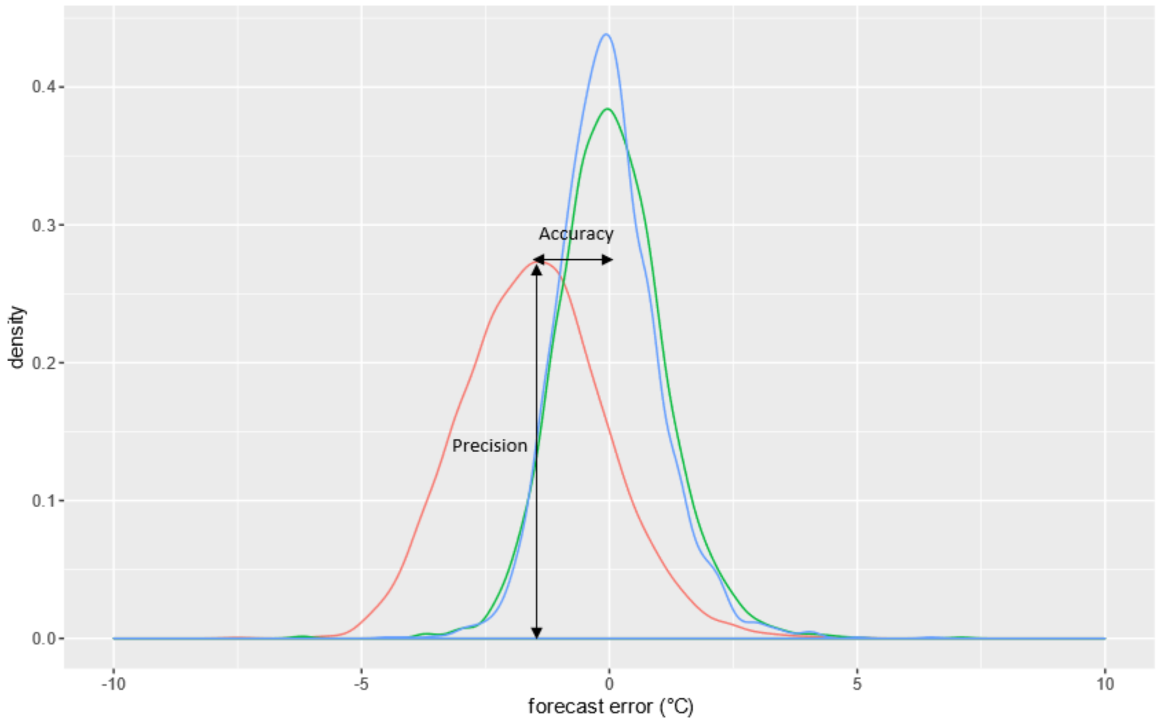
2 Winter forecast performance

This section contains a selection of temperature forecasting performance insights for winter 2023 in the NEM. Results supporting major insights are included in this section, with additional results in the appendices. This report studies temperature forecast performance at the 1, 4, 24, and 72 HA rolling forecast horizons.

Many of the results in this section and in Appendix A1 are displayed as error density plots like Figure 3 below. These figures can be interpreted as follows:

- The **x-axis shows forecast error**. Positive values indicate over-forecasting (the forecast temperature exceeded the actual temperature), and negative values indicate under-forecasting (the forecast temperature was lower than the actual temperature).
- The **y-axis shows error density**. This reflects the relative rate of a forecast error occurring. For each forecast error, the error density will be between 0 and 1, and the area under each curve equals 1.
- The **height of the error density peak captures the level of forecast precision**. The higher the peak, the greater the forecast precision and the smaller the expected deviation from the level of error. In Figure 3, the forecast distribution (blue) has the highest precision, and the forecast distribution (red) has the lowest precision.
- The **position of the peak captures the forecast accuracy** with respect to a forecast error of zero. The further the peak is from zero error, the lower the accuracy, and the larger the tendency for over- or under-forecasting on average. In Figure 3, the forecast distribution in red is less accurate than the forecast distributions in green and blue.

Figure 3 Accuracy and precision in the error density plot



In addition, Appendix A2 contains intraday mean absolute error (MAE) profiles for major weather stations, where forecasts are provided for each hour of the day and for each provider. Appendix A3 contains the net forecast bias profiles, which show the net number of days where each hourly interval was either negative (actuals greater than forecast) or positive (actuals less than forecast) assessed over the coldest 10% of days. The net forecast bias and MAE do not explicitly feature in the main report.

2.1 Overall performance

Winter 2023 performance insights

Figure 4 and Figure 5 below show the performance comparison of winter 2022 and winter 2023 periods across all studied weather stations for Providers A, B, and C.

Key insights include:

- **Provider A** did not exhibit any overall changes in forecast performance but did show improvement at some weather stations for the bottom 10% of temperatures compared to winter 2022. Compared to other providers, Provider A performed marginally lower overall in winter 2023 in terms of precision across the 4, 24 and 72 HA rolling forecast horizons, but performed best at the 1 HA horizon overall.
- **Provider B** had a slight reduction in performance overall, with a general decrease in forecast precision at most weather stations compared to winter 2022. Compared to other providers, Provider B was the overall highest performing provider at the 4 and 72 HA horizon, equal highest with Provider C at 24 HA, and equal second highest at 1 HA (behind Provider A).
- **Provider C** forecast performance at 4 to 72 HA remained consistent with winter 2022, however reduced at 1 HA for all temperatures and bottom 10% of temperatures. Compared to other providers, Provider C was the equal highest performing provider overall at the 24 HA horizon, a close second at 4 and 72 HA, and equal second at 1 HA (behind Provider A).

Figure 4 Winter 2022 and 2023 performance comparison across major weather stations, all temperatures

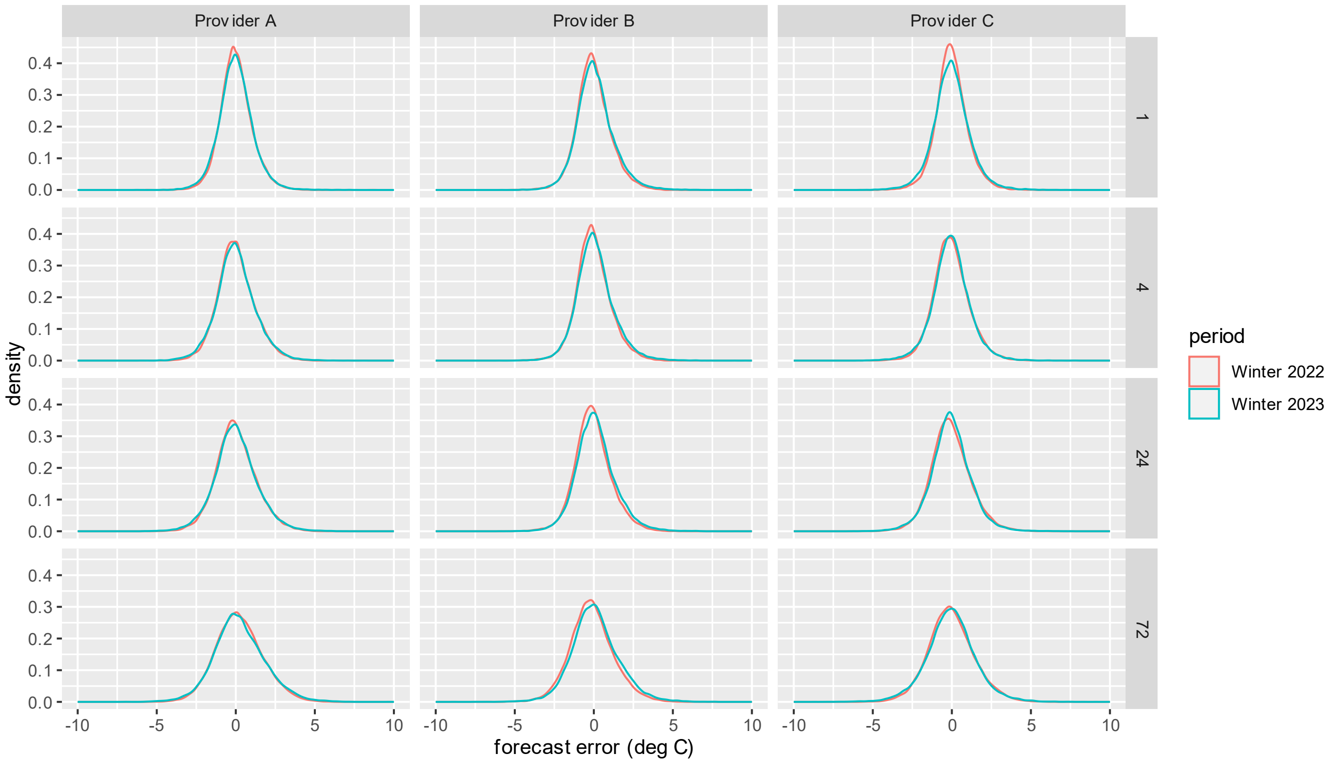


Figure 5 Winter 2022 and 2023 performance comparison across major weather stations, bottom 10% of temperatures

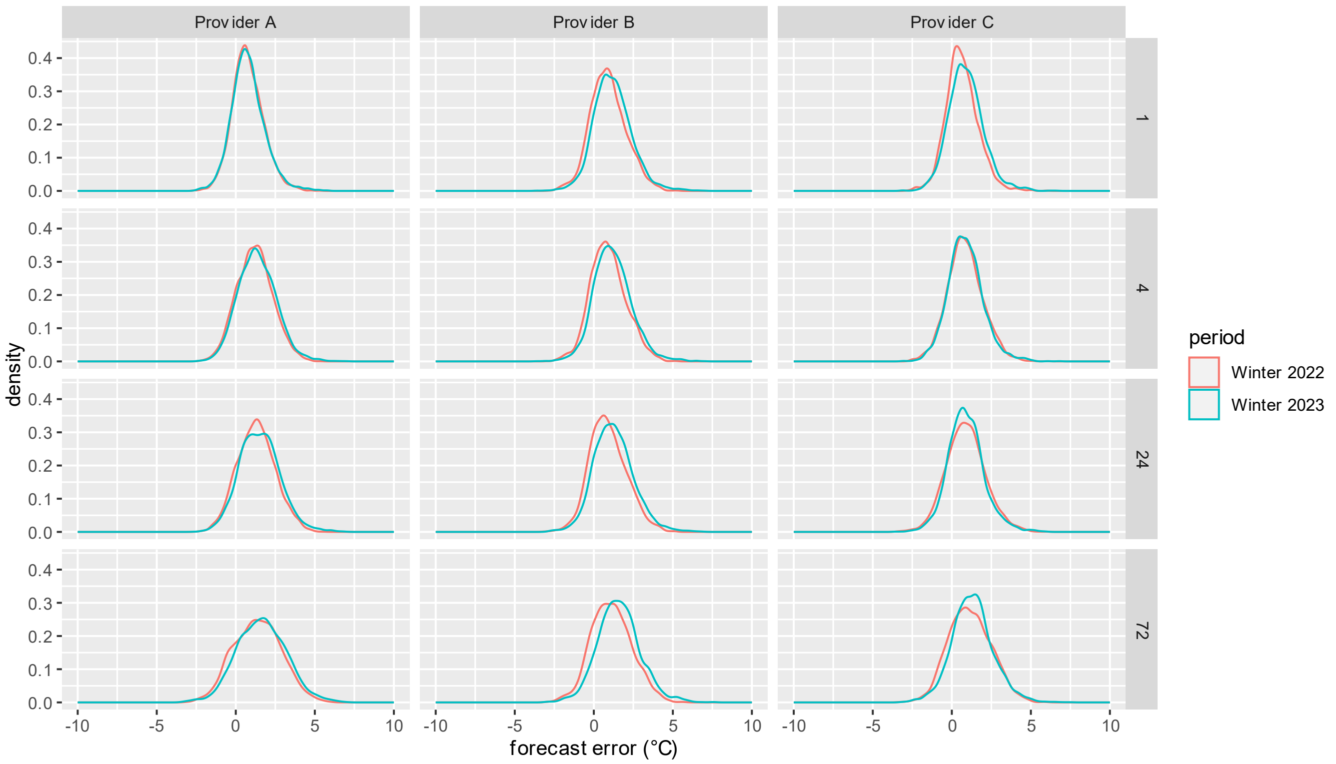
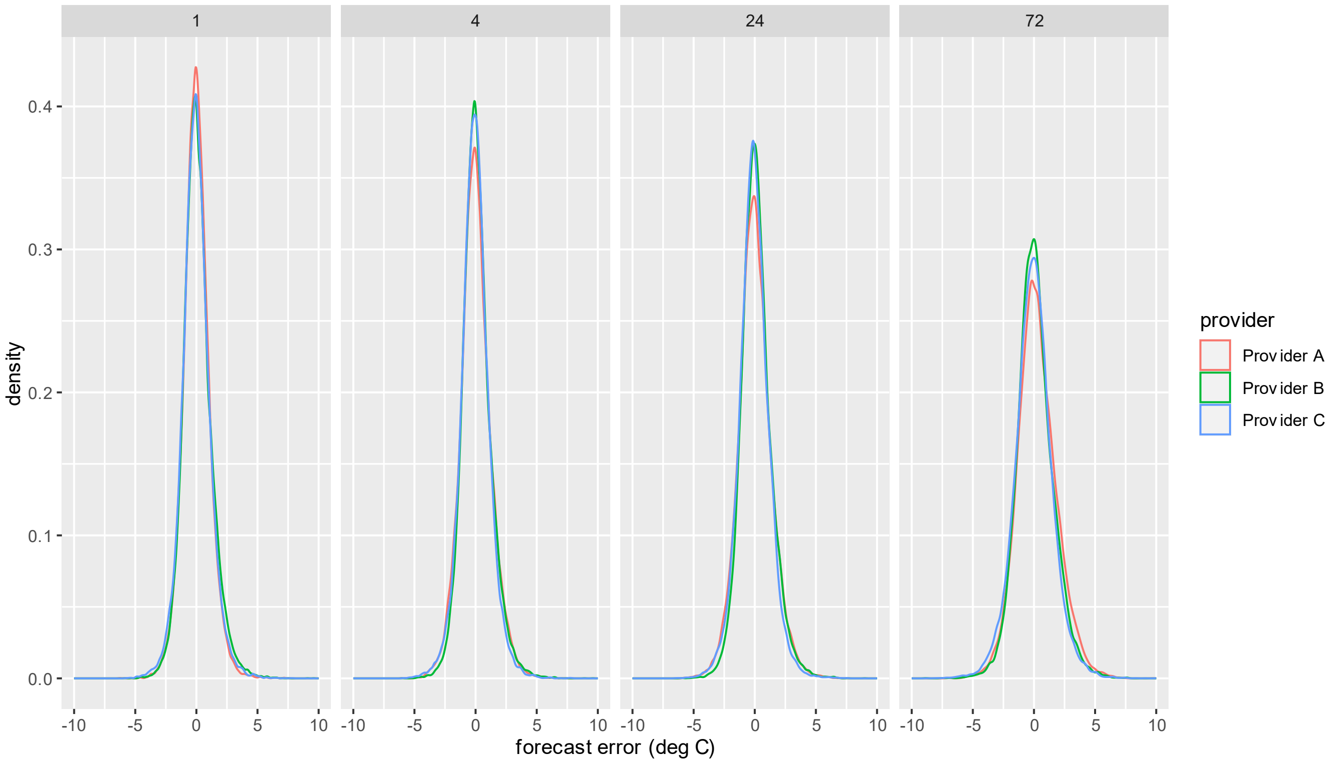


Figure 6 Winter temperatures 2023 performance comparison across major weather stations, all providers, all temperatures



2.2 Provider A forecast performance

Provider A did not exhibit any overall changes in forecast performance but did show improvement at some stations for the bottom 10% of temperatures compared to winter 2022

While overall performance remained consistent with winter 2022, Provider A saw a slight decrease in performance at Adelaide WT and Hobart AP, and a slight increase in performance at Penrith for the 4 to 72 HA horizons (Figure 7).

When examining performance of the bottom 10% of temperatures, Provider A demonstrated a general forecast improvement at Sydney AP and Adelaide WT, and an increase in accuracy (less over-forecasting) at Penrith. Provider A saw a performance decrease at Bankstown AP and Melbourne AP, and a decrease in accuracy at Hobart AP (more over-forecasting), particularly at the 4 and 24 HA horizons.

Compared to other providers, Provider A performed marginally lower overall in winter 2023 in terms of precision across the 4, 24 and 72 HA rolling forecast horizons, but performed best at the 1 HA horizon overall and for the bottom 10% of temperatures, as shown in Figure 8. This was observed across all stations at the 4, 24 and 72 HA forecast horizons, except for Archerfield AP (72 HA) and the two Melbourne stations where provider performance was similar. Provider A also showed the greatest forecast improvement of all providers when moving from 72 HA to 1 HA forecast horizons.

The intraday MAE profiles in A2 show lower performance in accuracy during the middle of day and evening at the 4, 24, and 72 HA horizons at Adelaide WT and Sydney AP, and 72 HA horizon at Bankstown AP and Melbourne AP.

Figure 7 Major weather stations, Provider A, all winter temperatures 2022 and 2023, 24 HA

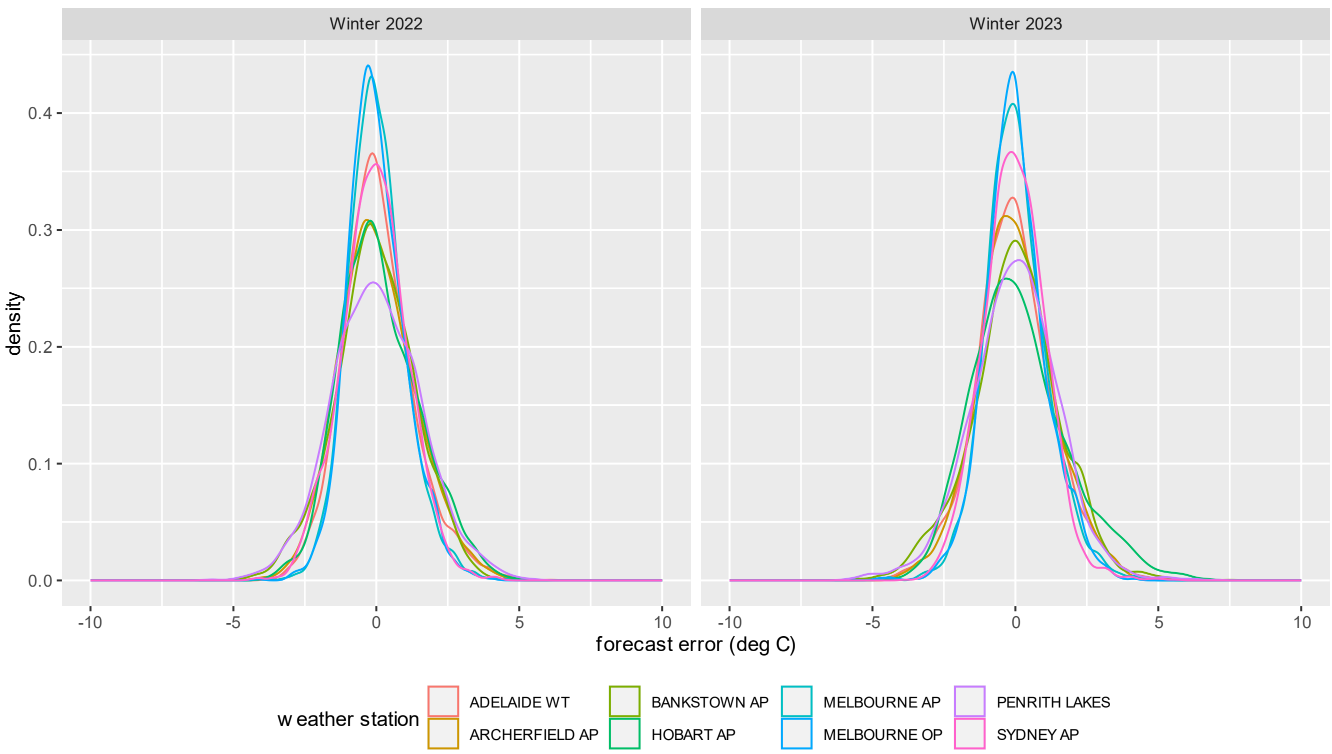
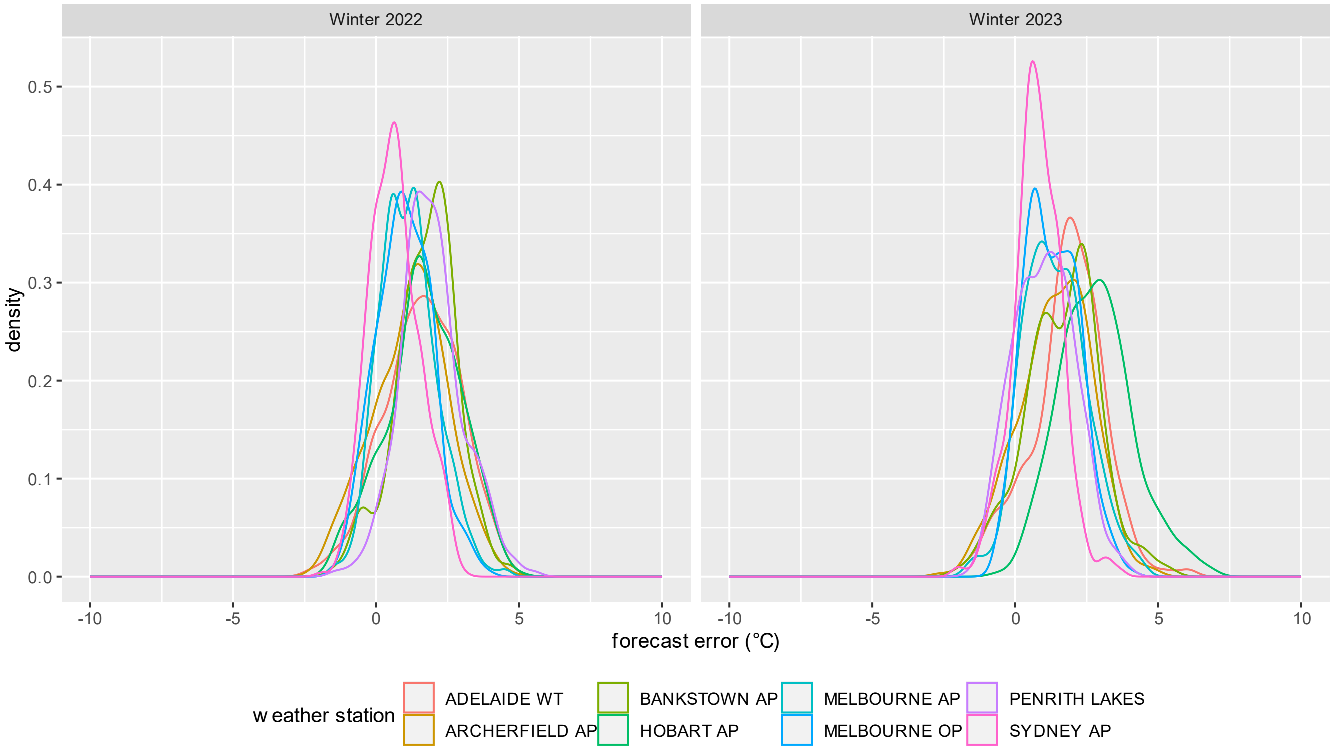


Figure 8 Major weather stations, Provider A, bottom 10% winter temperatures 2022 and 2023, 24 HA



2.3 Provider B forecast performance

Provider B had a slight reduction in performance overall, with a general decrease in forecast precision at most weather stations compared to winter 2022, but remained highest or equal highest provider in winter 2023

Provider B exhibited a slight reduction in forecast precision at most weather stations across all studied forecast horizons compared to winter 2022, except for Sydney AP where precision improved. Accuracy remained generally comparable to winter 2022 levels, except for Penrith which demonstrated an improved forecast accuracy across all forecast horizons in winter 2023 (Figure 9).

For the bottom 10% of temperatures, Provider B exhibited a slight decrease in forecast precision and accuracy, particularly at the 24 HA horizon, with notable reduction in accuracy (increased over-forecasting) at Archerfield and Hobart AP for all horizons, and Bankstown AP at 24 and 74 HA. While accuracy decreased, Provider B did demonstrate increased precision at Archerfield and Penrith at all horizons, and Sydney AP at 72 HA (Figure 10).

Compared to other providers, Provider B was the overall highest performing provider at the 4 and 72 HA horizon, equal highest with Provider C at 24 HA, and equal second highest at 1 HA (behind Provider A). Relative to other providers, Provider B performed particularly well at Hobart AP and Adelaide WT at 4, 24 and 72 HA. For the bottom 10% of temperatures, Provider B was generally the second highest performing provider, with the highest relative precision at Archerfield.

The intraday MAE profiles in Appendix A2 show Provider B was the highest performer for almost all forecast horizons at Adelaide WT and Archerfield AP, and improved at Bankstown AP at all horizons compared to winter 2022.

Figure 9 Major weather stations, Provider B, all winter temperatures 2022 and 2023, 24 HA

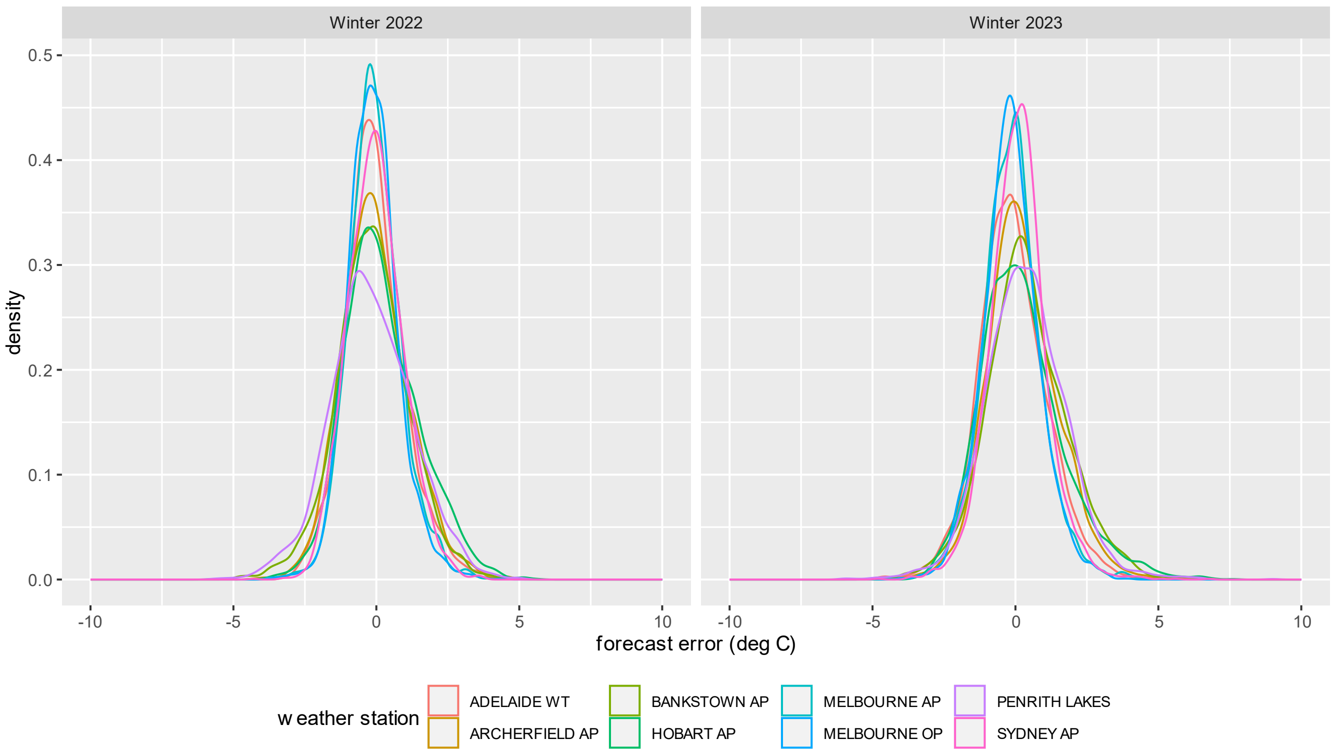
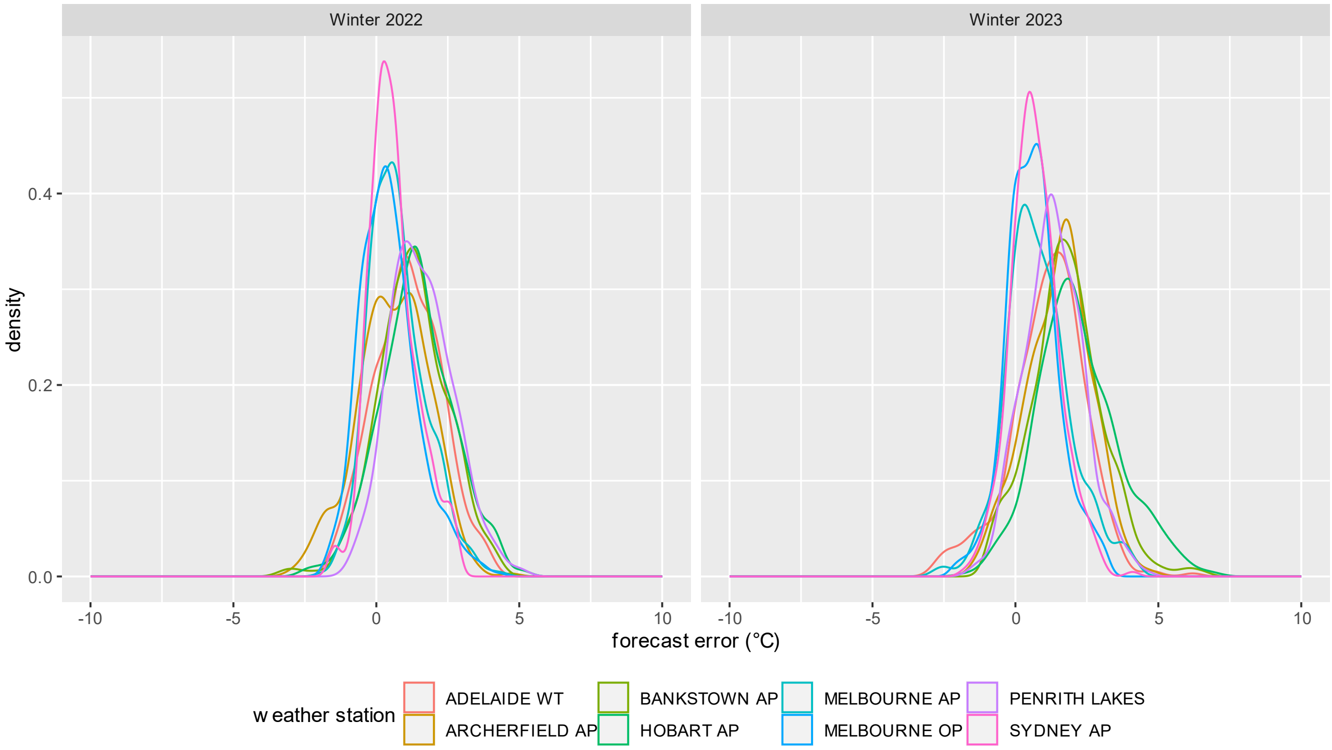


Figure 10 Major weather stations, Provider B, top 10% winter temperatures 2022 and 2023, 24 HA



2.4 Provider C forecast performance

Provider C forecast performance at 4 to 72 HA remained consistent with winter 2022, however reduced at 1 HA for all temperatures and bottom 10% of temperatures

Overall, Provider C performance remained relatively consistent with winter 2022 at the 4, 24 and 72 HA horizon, and decreased slightly in precision at the 1 HA horizon for all temperatures. At 4, 24 and 72 HA, Provider C either improved or maintained performance at all weather stations, except for Hobart AP and Melbourne AP where performance decreased. Conversely, performance decreased at all weather stations at the 1 HA forecast horizon except for Sydney AP, where it remained comparable to winter 2022.

A similar trend was observed for the bottom 10% of temperatures, with improvements in accuracy and precision at the 24 and 72 HA horizon, and a general decrease in performance at 1 HA compared to winter 2022. Provider C significantly improved at Penrith and Sydney AP at the 24 HA forecast horizon (Figure 12), while performance decreased at all weather stations at 1 HA, except for Adelaide WT and Penrith where precision increased.

Compared to other providers, Provider C was the equal highest performing provider overall at the 24 HA horizon, a close second at 4 and 72 HA, and equal second at 1 HA (behind Provider A) and was notably the highest performing provider at Penrith. For the bottom 10% of temperatures, Provider C was the outright highest performing provider at 4, 24 and 72 HA, and the second highest at 1 HA (behind provider A).

Provider C had one of best performances across all providers during evening peaks for the major weather stations shown in the MAE profiles in Appendix A2.

Figure 11 Major weather stations, Provider C, all winter temperatures 2022 and 2023, 24 HA

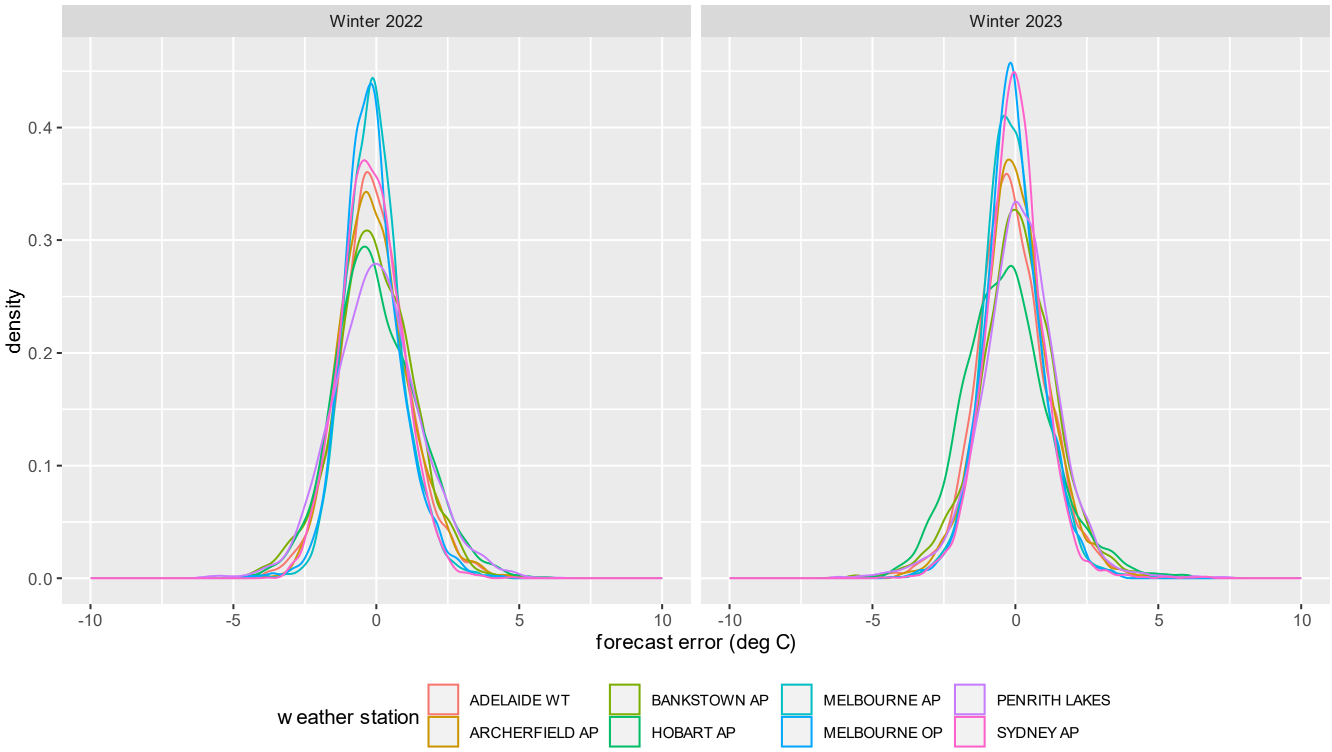
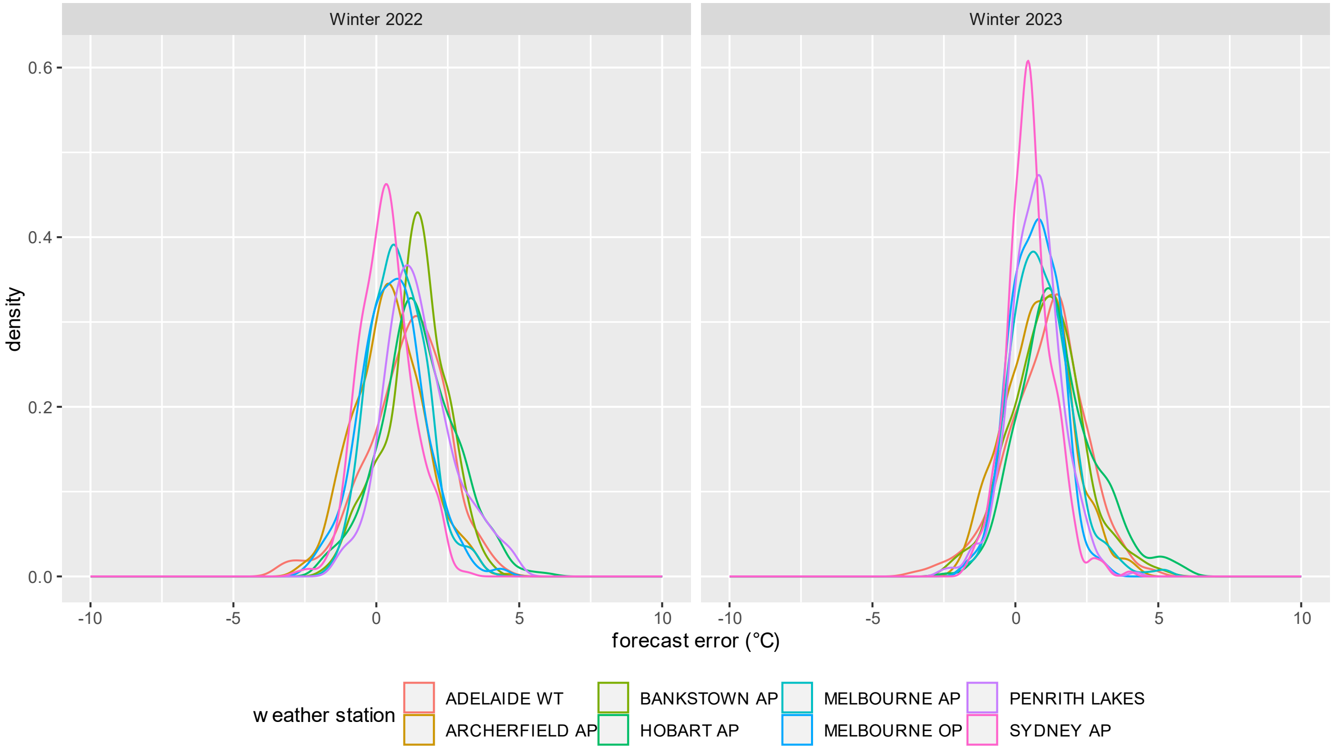


Figure 12 Winter temperatures 2022 and 2023 performance comparison across major weather stations, top 10% temperatures



3 Case study: warmer seasons and record low demands

Warmer temperatures in winter and spring drove minimum demands in the NEM

This case study presents the noticeable effects of warmer than average temperatures in winter and subsequent conditions in spring on minimum operational demand outcomes in the NEM. The warmer winter conditions and associated minimum operational demand records discussed in Section 1.2 of this report were a precursor to new all-time minimum operational demand records in spring 2023. The forecasts and outcomes of these all-time records will be the focus of this case study.

For the purpose of this case study:

- Tasmania has been excluded, as this region did not record any seasonal records during the winter and spring period.
- The temperature average noted is based on historical data, more specifically 1961–1990 temperature data.

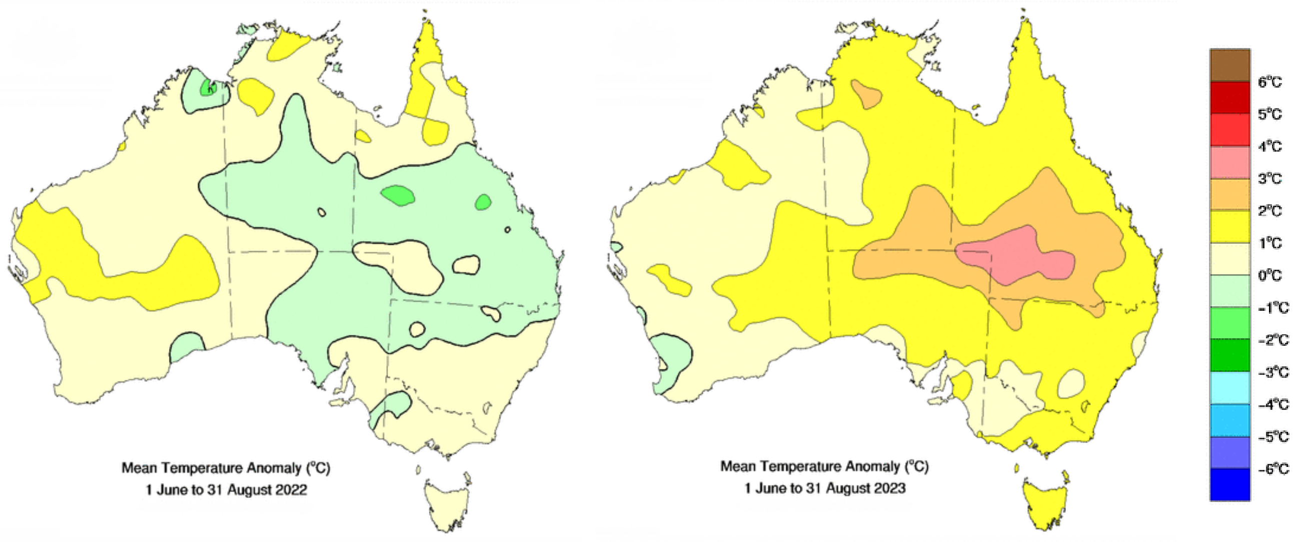
Winter 2023 temperatures

The mean temperatures observed for eastern Australia were above average in winter 2023, with New South Wales and Queensland recording their warmest mean temperature on record and Victoria recording its second-highest winter mean temperature on record[5].

- The mean temperature for Queensland in winter 2023 was 2.32°C higher than average. The highest recorded mean temperature for Queensland before winter 2023 was 1.99°C higher than average in 1973.
- The mean temperature for New South Wales in winter 2023 was 1.72°C higher than average. The highest recorded mean temperature for New South Wales before winter 2023 was 1.58°C higher than average in 2009.
- The mean temperature for Victoria in winter 2023 was 1.12°C higher than average, which is the second highest on record. The previous highest recorded mean temperature for Victoria was 1.15°C higher than average in 2013.
- The mean temperature for South Australia in winter 2023 was 1.75°C higher than average, which is the second-highest on record. The highest recorded mean temperature for South Australia before winter 2023 was 1.78°C higher than average in 2009.
- Winter 2023 was also warmer than winter 2022 by an average of 1.17°C across Australia (Figure 13), proving to be a driver of the record minimum demands in winter.
- This trend continued into spring 2023, increasing the likelihood of extreme minimum demands occurring when sunny days coincided with weekends and/or public holidays.

[5] Australia in Winter 2023, Bureau of Meteorology, at http://www.bom.gov.au/clim_data/IDCKGC2AR0/202308.summary.shtml.

Figure 13 Mean temperature anomalies for winter 2022 (left) and winter 2023 (right)



Temperature forecast and outcomes for all-time minimum demands

On Sunday 1 October 2023, the weather conditions in Queensland and South Australia were relatively mild to warm, and the skies were mostly clear. These conditions were conducive for record daytime minimum operational demand:

- Southeast Queensland observed daytime temperatures in the mid-20s with Archerfield AP (Figure 14), Coolangatta and Amberley recording maximum temperatures of 26.5°C, 24.7°C and 28.4°C respectively.
- South Australia observed cooler than forecast daytime temperatures, with a difference of 2°C at Adelaide West Terrace (Figure 15) which reached a maximum temperature of 19.1°C.

On Sunday 29 October 2023, a high-pressure system dominated most of the NEM, bringing warm, settled, and clear conditions conducive to extremely low daytime minimum operational demand, particularly in Victoria and New South Wales:

- Sydney AP (Figure 16), Bankstown, and Penrith in New South Wales recorded maximum temperatures of 27.1°C, 25.2°C, and 29.4°C respectively.
- Victoria observed cooler daytime temperatures than forecast, with a difference of 3°C at Melbourne AP and Melbourne OP, which reached maximum temperatures of 22.2°C and 20.2°C respectively (Figure 17).

For Melbourne AP and Adelaide WT, daytime temperatures were over-forecast for all rolling forecast horizons. With all providers exhibiting this behaviour during the middle of the day, while the morning and afternoon temperatures were forecast within reasonable error standards.

The performance of the providers in the 1, 4, and 24 HA rolling forecast horizon in New South Wales and Queensland exhibited very high accuracy and precision, while the providers performed reasonably well at the extended 72 HA rolling forecast horizon.

Figure 14 Forecast temperatures at various horizons against actual temperature observations for each provider at Archerfield AP on 1 October 2023

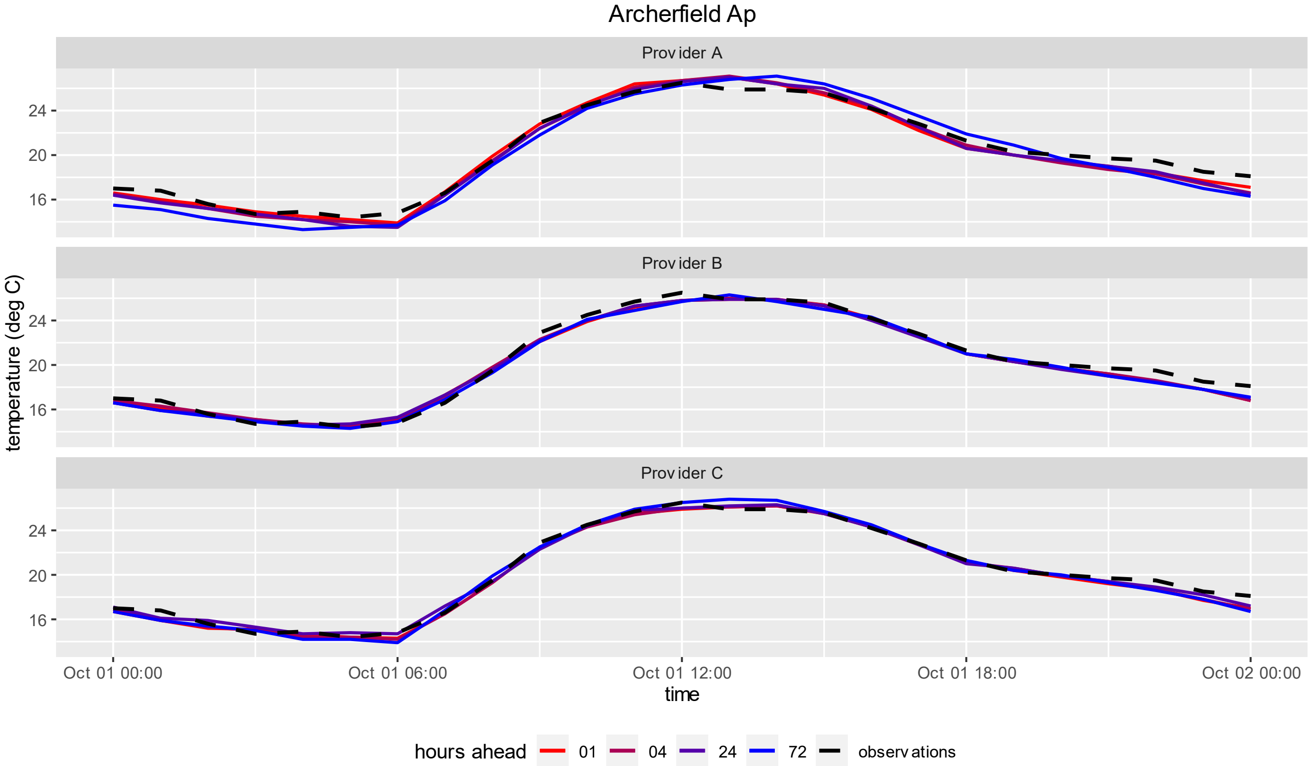


Figure 15 Forecast temperatures at various horizons against actual temperature observations for each provider at Adelaide WT on 1 October 2023

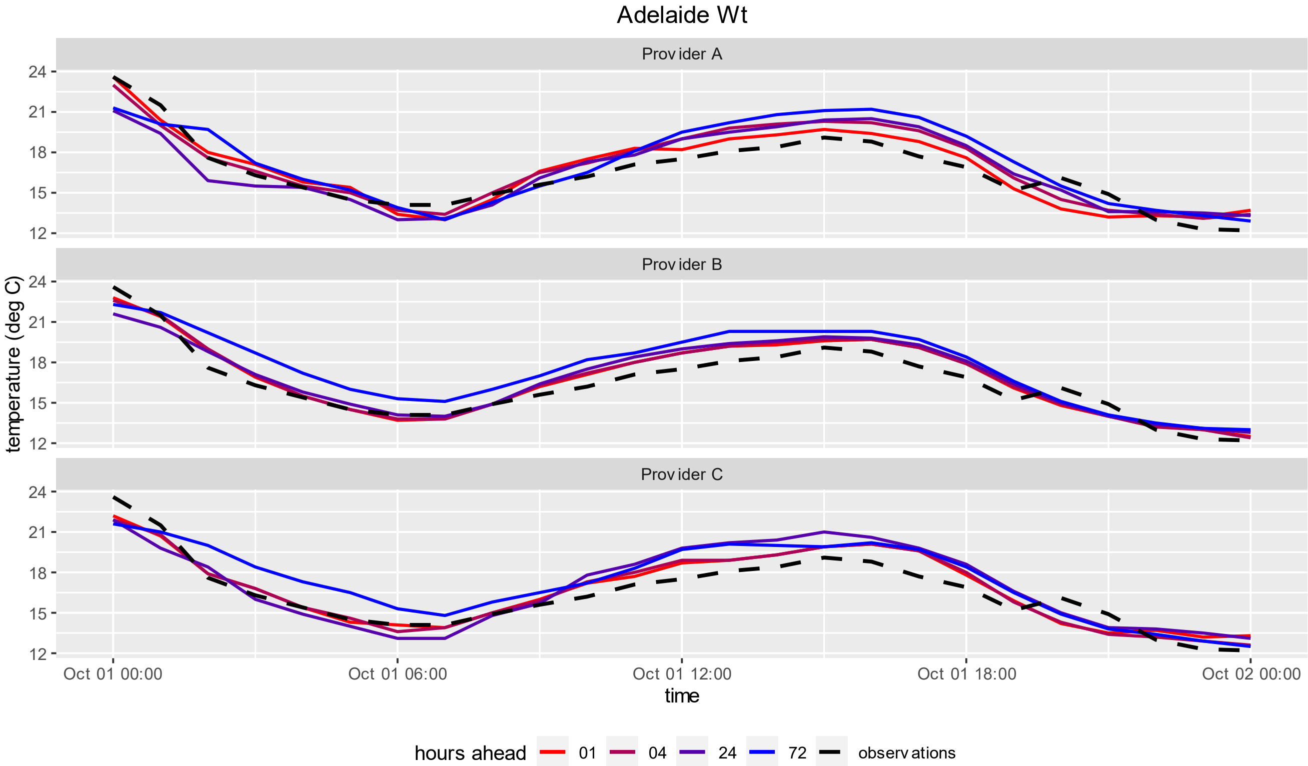


Figure 16 Forecast temperatures at various horizons against actual temperature observations for each provider at Sydney AP on 29 October 2023

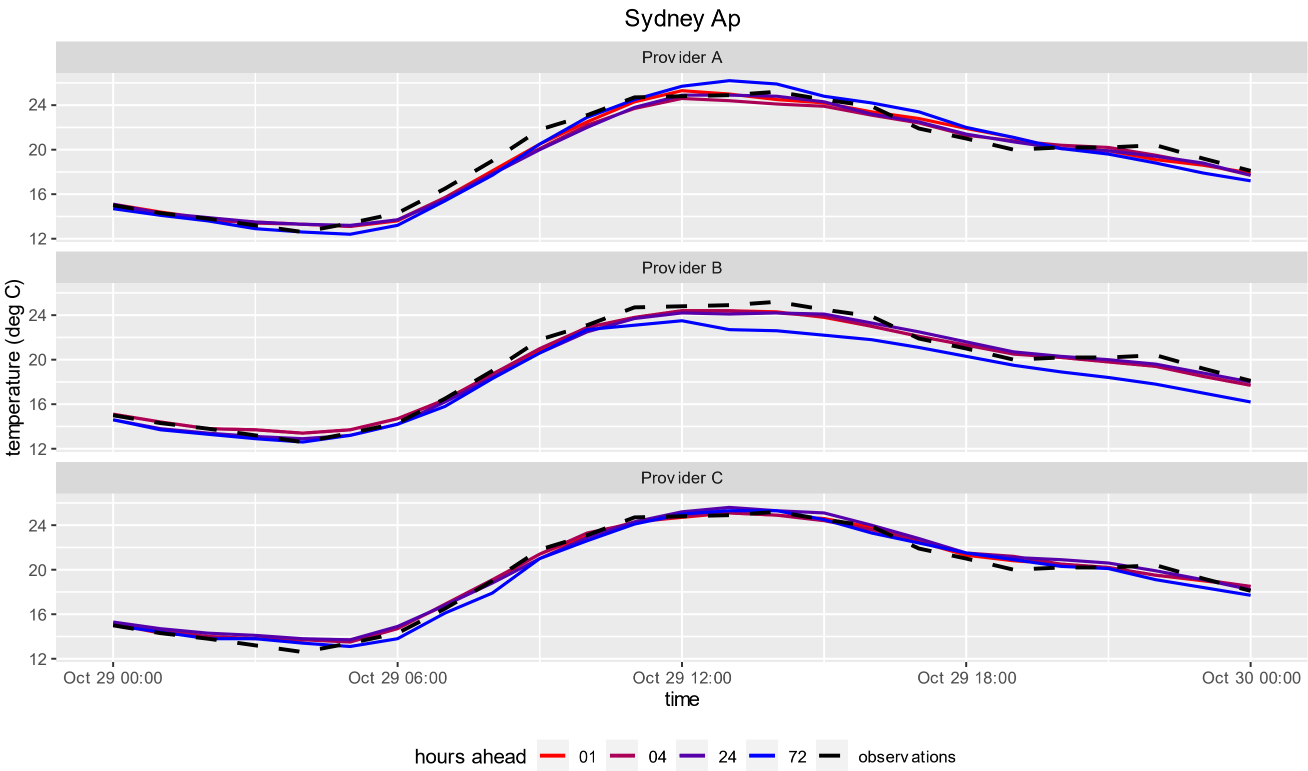
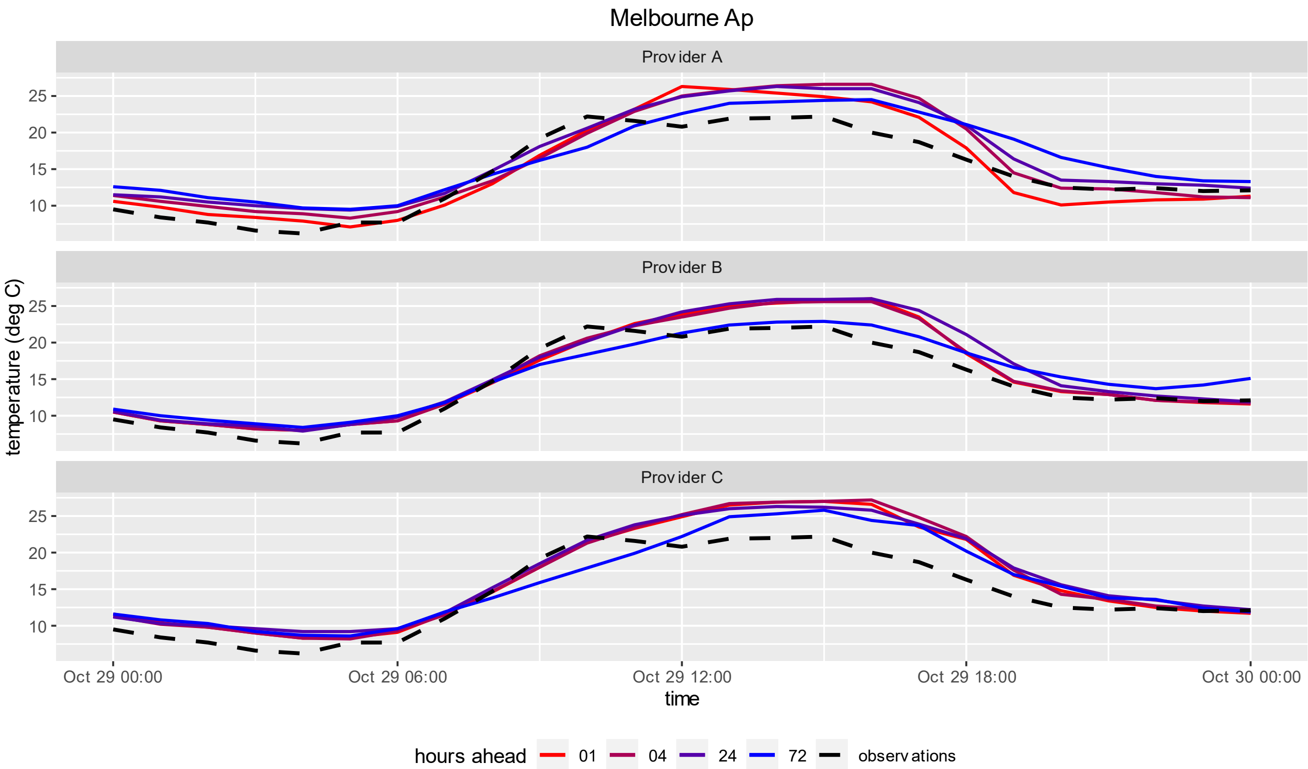


Figure 17 Forecast temperatures at various horizons against actual temperature observations for each provider at Melbourne AP on 29 October 2023



Demand forecast and outcomes

The trend of warmer than average temperatures in 2023 and new winter minimum operational demand records continued into spring 2023, where all mainland NEM regions observed new all-time minimum operational demand records in October 2023 (the actual demand profiles against day-ahead forecasts are shown in Figure 18):

- Queensland reached a new all-time operational demand record of 3,131 MW on Sunday 1 October 2023.
- South Australia reached a new all-time operational demand record of 5 MW on Sunday 1 October 2023.
- New South Wales reached a new all-time operational demand record of 3,719 MW on Sunday 29 October 2023.
- Victoria reached a new all-time operational demand record of 1,915 MW on Sunday 29 October 2023[6].
- The NEM reached a new all-time operational demand record of 11,009 MW on Sunday 29 October 2023.

On Sunday 1 October 2023, the performance of the Queensland demand forecast model was reasonable, however there were forecast deviations which can be attributed to model error (defined as the inherent deviation not captured by the demand forecast model). The forecast deviations can be mainly explained by behavioural impacts, as the weather observed on this day was closely aligned with the weather forecast across the major weather stations in Queensland.

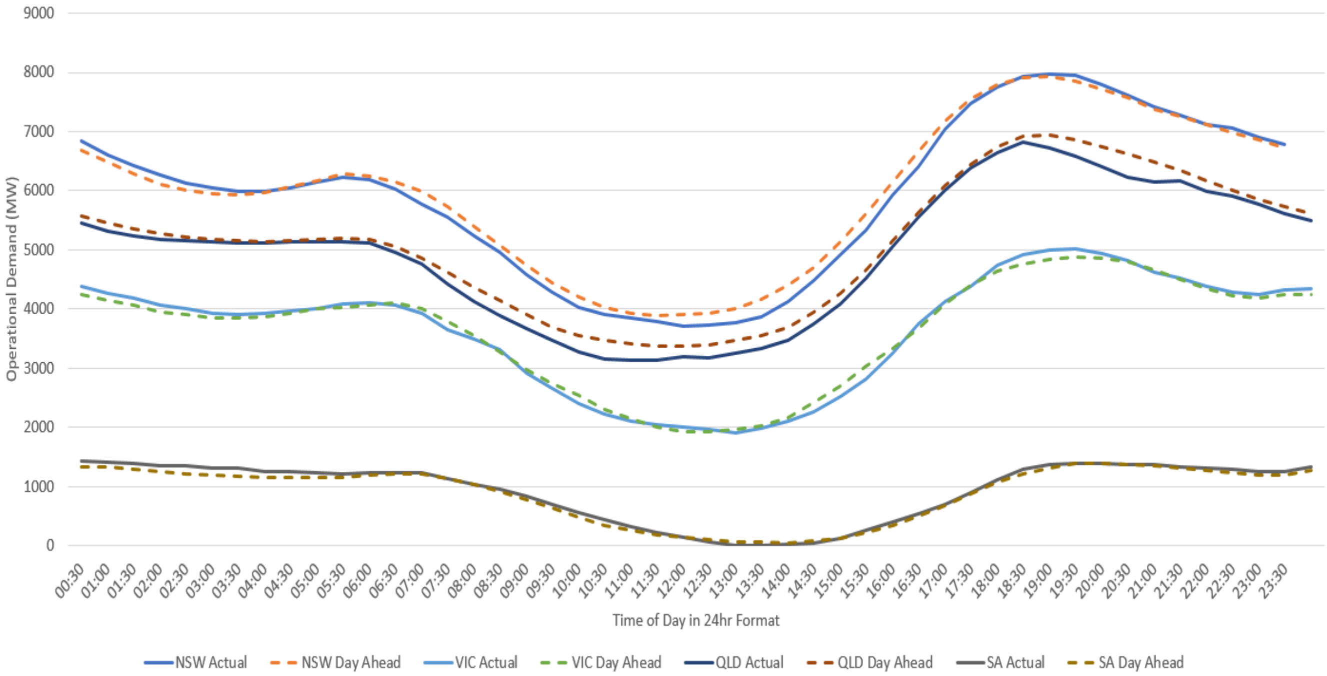
On Sunday 1 October 2023, the South Australia demand forecast models also performed reasonably well in forecasting a record minimum operational demand, with a difference of 53 MW between the forecast and observed demand. There were small forecast deviations due to generally settled conditions and cooler daytime temperatures across the region which were conducive to lower levels of actual demand.

On Sunday 29 October 2023, the demand forecast models for New South Wales performed reasonably well in forecasting record minimum operational demand. It was observed that there was a difference of around 200 MW between the forecast and observed demand.

The performance of the model for Victoria on this day was more accurate, with a difference of around 50 MW between the forecast and observed demand (Figure 18).

[6] As at the time of publication, Victoria and South Australia have set new all-time operational demand records of 1,564 MW and -26 MW respectively, both on Sunday 31 December 2023. These will be discussed in the *Temperature Forecast Analysis for Summer 2023-24* report to be published later this year.

Figure 18 Operational demand forecast vs actual demand for Victoria and New South Wales on 29 October 2023 and Queensland and South Australia on 1 October 2023



4 Conclusions

The results and insights presented in this report supplement the findings of previous *Temperature Forecast Analysis* reports and will continue to aid operational forecasting and decision-making at AEMO. This report is to be shared with current and potential weather service providers to draw attention to areas of improvement and help in baselining performance. AEMO is continuing to work with the weather forecasting industry on developing weather forecast products tailored for the energy industry as well as addressing the key challenges identified in this report.

The key findings of this report are:

- **Provider A** did not exhibit any overall changes in forecast performance but did show improvement at some weather stations for the bottom 10% of temperatures compared to winter 2022. Compared to other providers, Provider A performed marginally lower overall in winter 2023 in terms of precision across the 4, 24 and 72 HA rolling forecast horizons, but performed best at the 1 HA horizon overall.
- **Provider B** had a slight reduction in performance overall, with a general decrease in forecast precision at most weather stations compared to winter 2022. Compared to other providers, Provider B was the overall highest performing provider at the 4 and 72 HA horizon, equal highest with Provider C at 24 HA, and equal second highest at 1 HA (behind Provider A).
- **Provider C** forecast performance at 4 to 72 HA remained consistent with winter 2022, however reduced at 1 HA for all temperatures and bottom 10% of temperatures. Compared to other providers, Provider C was the equal highest performing provider overall at the 24 HA horizon, a close second at 4 and 72 HA, and equal second at 1 HA (behind Provider A).

In 2024, AEMO is continuing to work with the weather forecasting industry to ensure weather forecast tools are developed for the purposes of energy forecasting. Initiatives include:

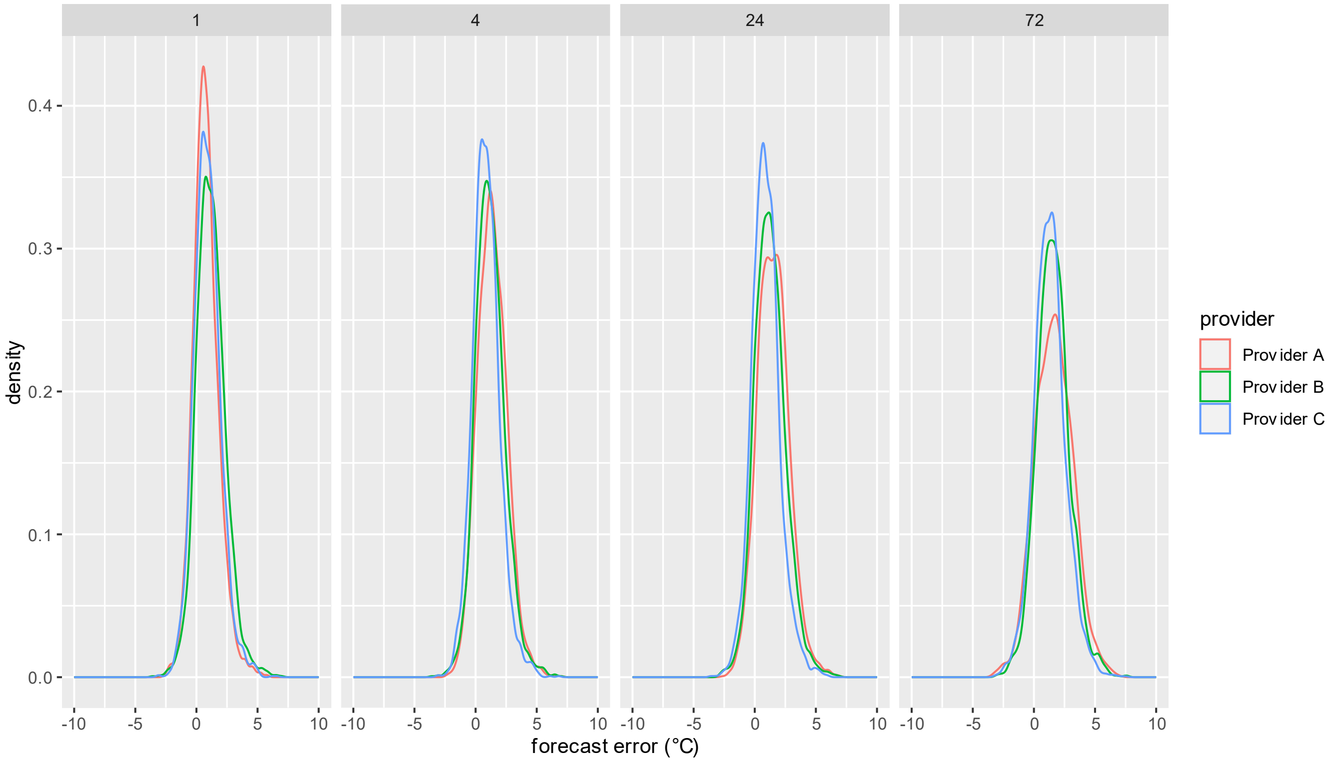
- Redevelopment of AEMO's Projected Assessment of System Adequacy (PASA) to be probabilistic and include weather uncertainty margins in reserve calculations.
- Establishment of new weather observation stations located within renewable energy zones (REZs), near remote variable renewable energy (VRE) generators, and in metropolitan heat islands to support weather and energy forecasting.
- Accessing a range of probabilistic and ensemble weather forecasts from providers to improve situational awareness and better represent extreme weather risk and operation envelope of demand forecasts.
- Onboarding a fourth provider which utilises AI-powered models with higher spatial and temporal resolution than conventional models to forecast wind speed, irradiance, and temperature for energy forecasts.

The next *Temperature Forecast Analysis* report, focusing on summer 2023-24, is to be published later this year.

A1. Error density plots

A1.1 2023 winter performance

Figure 19 Winter temperatures 2023 performance comparison across all weather stations, top 10% of temperatures



A1.2 Provider comparison by weather station

Figure 20 Adelaide WT, all winter temperatures 2022 and 2023, all time horizons

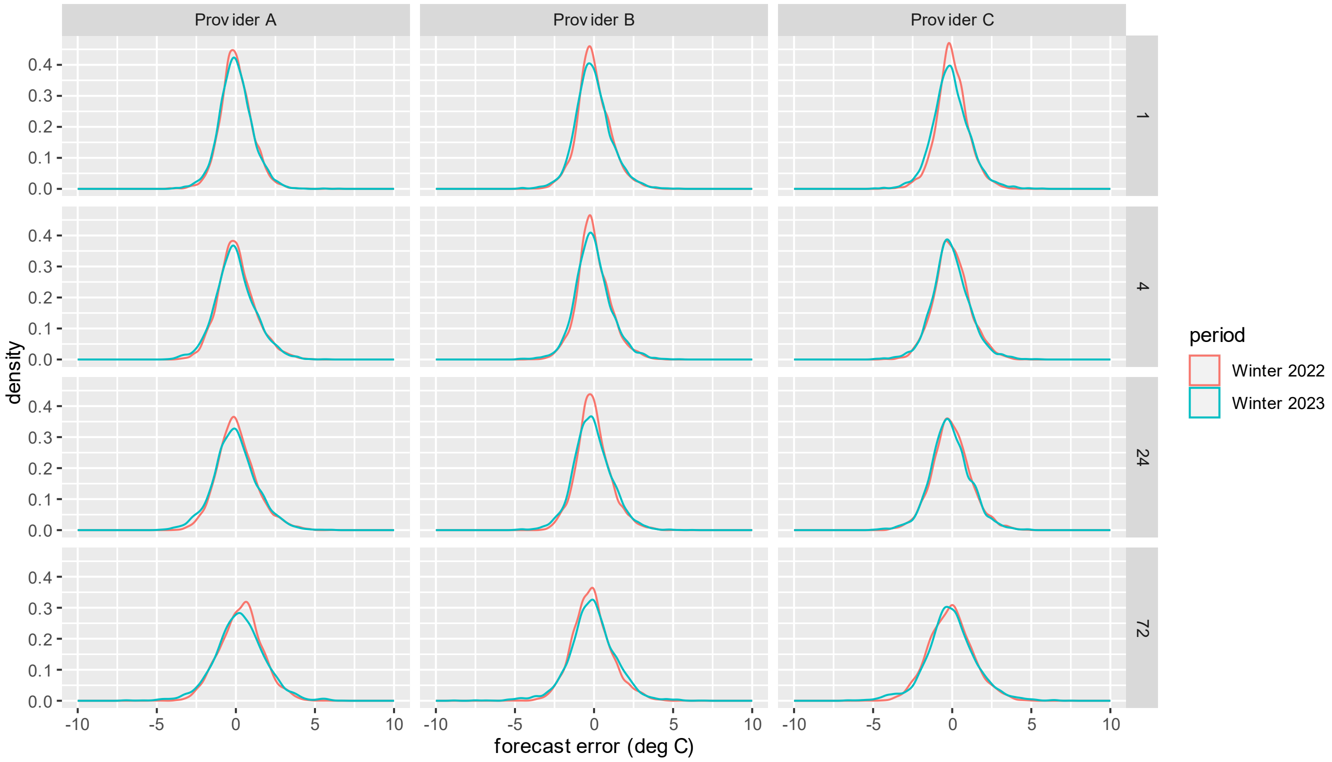


Figure 21 Archerfield AP, all winter temperatures 2022 and 2023, all time horizons

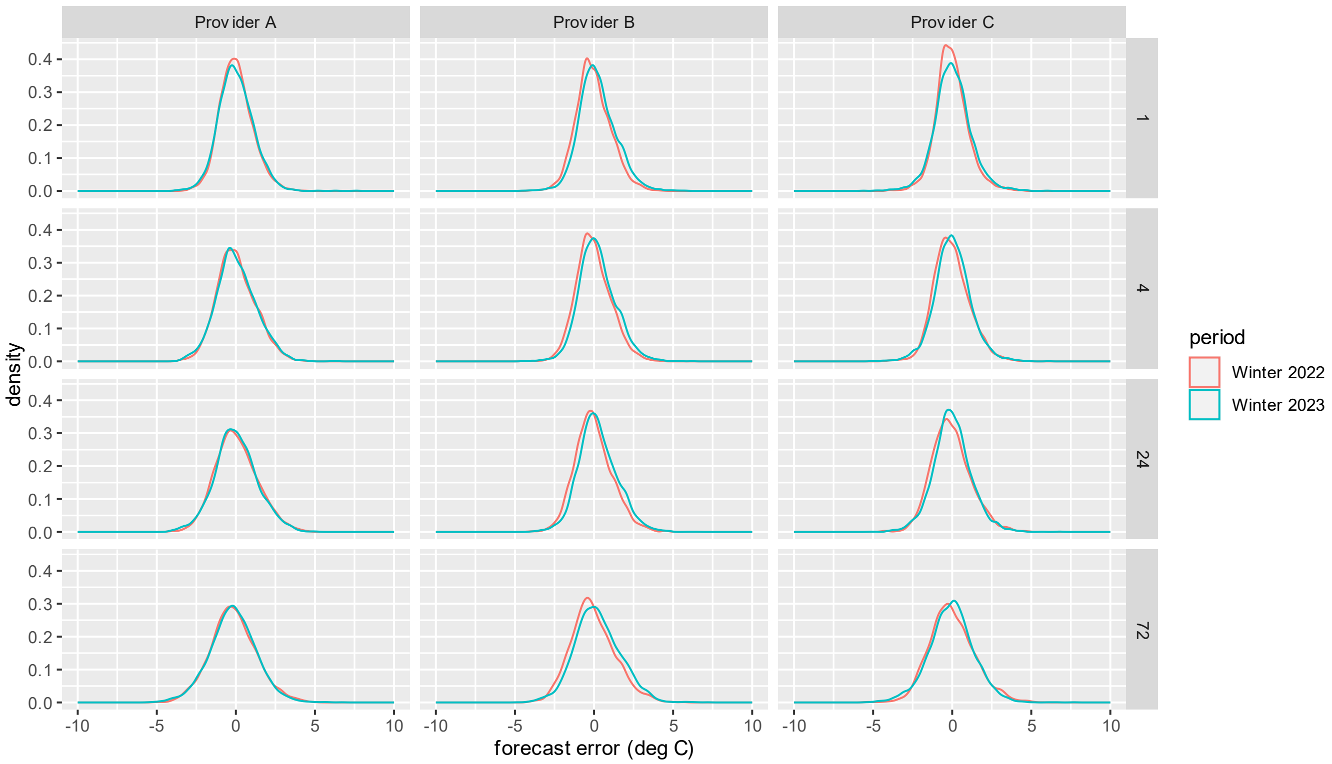


Figure 22 Bankstown AP, all winter temperatures 2022 and 2023, all time horizons

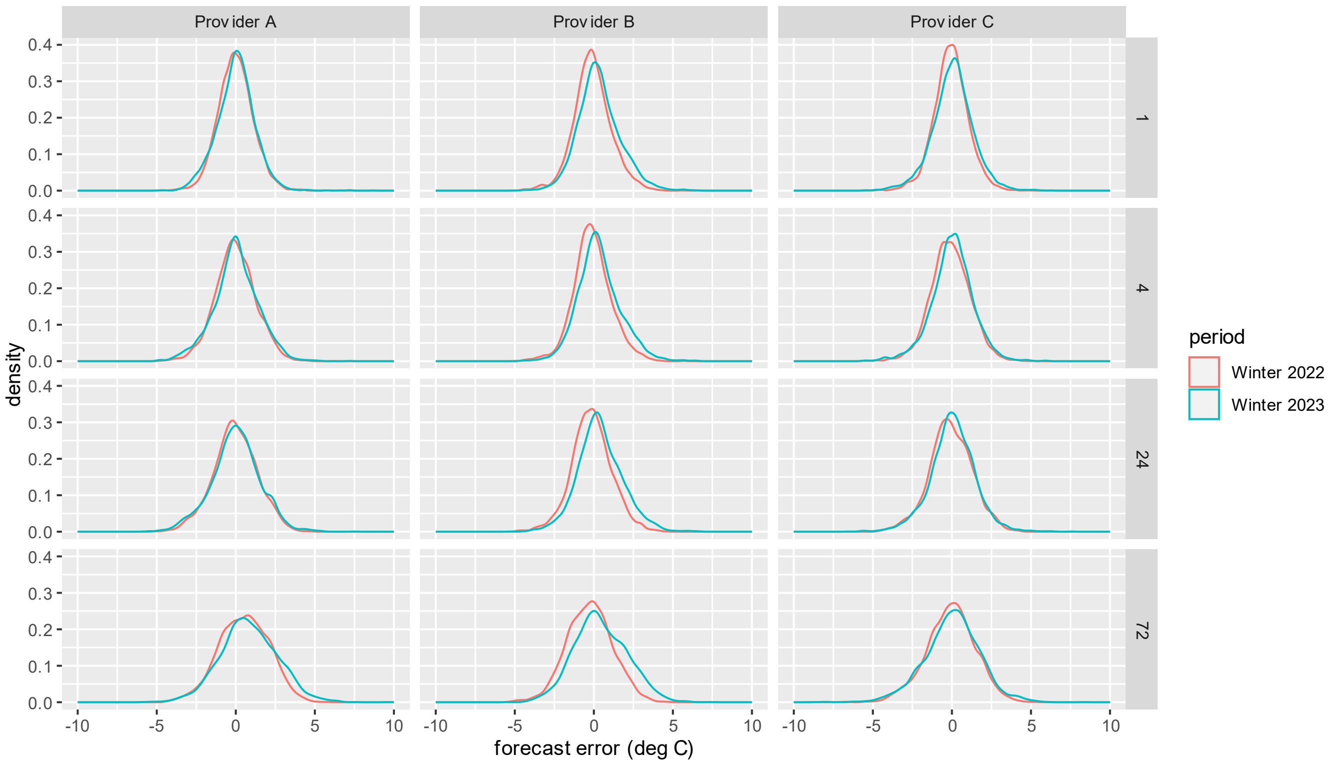


Figure 23 Hobart AP, all winter temperatures 2022 and 2023, all time horizons

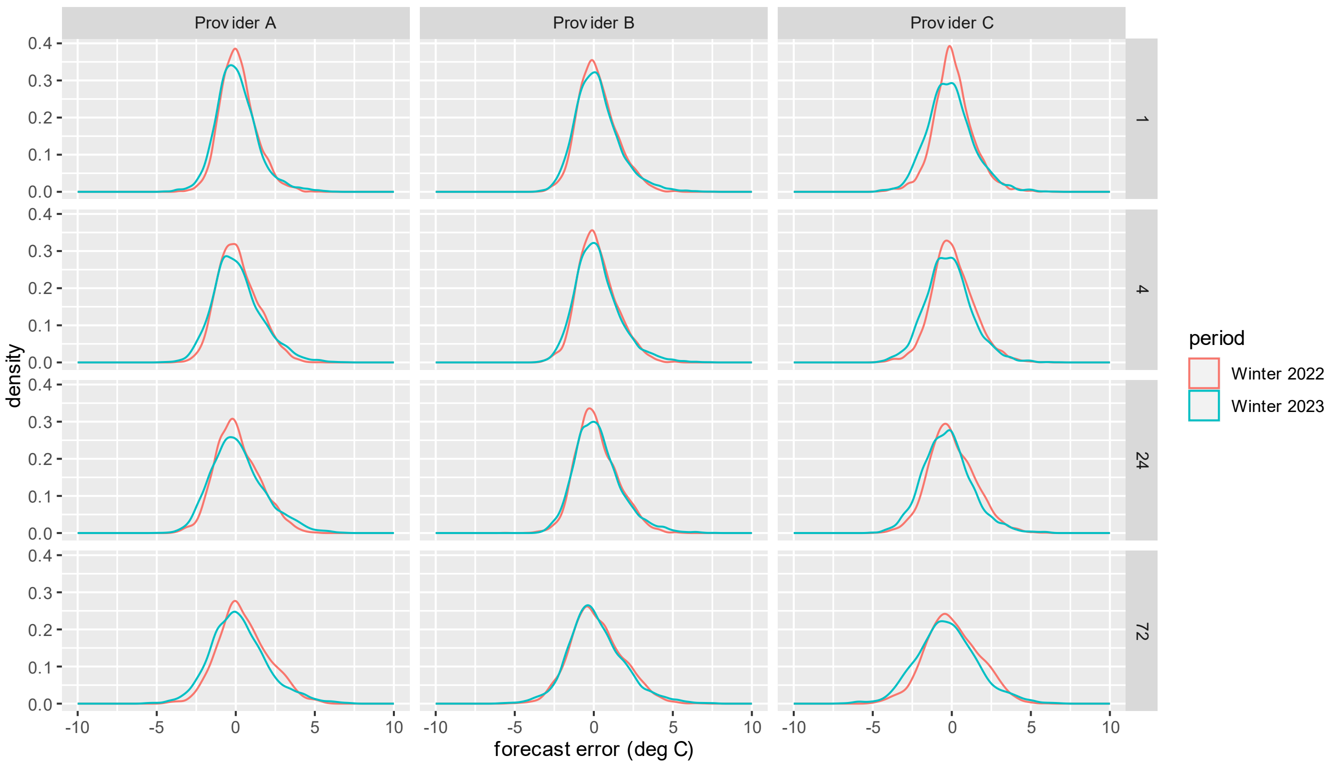


Figure 24 Melbourne AP, all winter temperatures 2022 and 2023, all time horizons

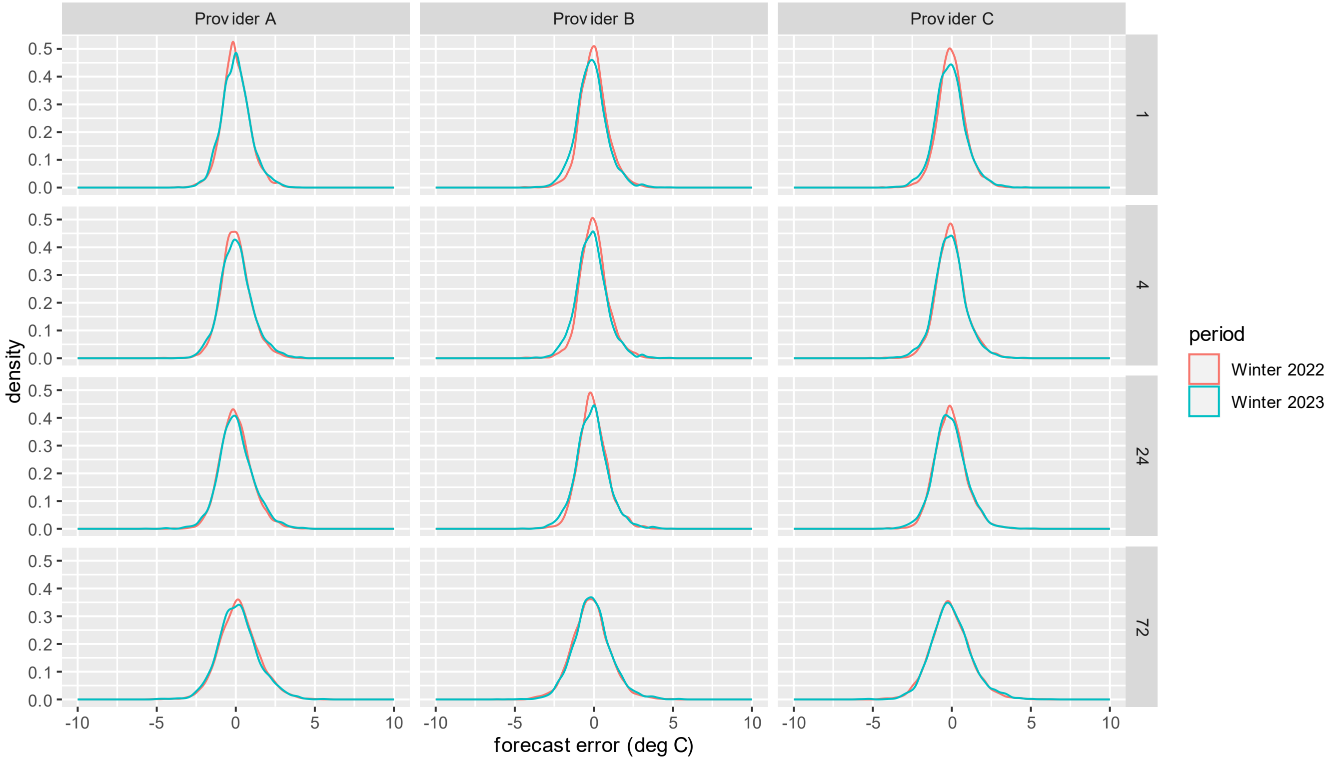


Figure 25 Melbourne OP, all winter temperatures 2022 and 2023, all time horizons

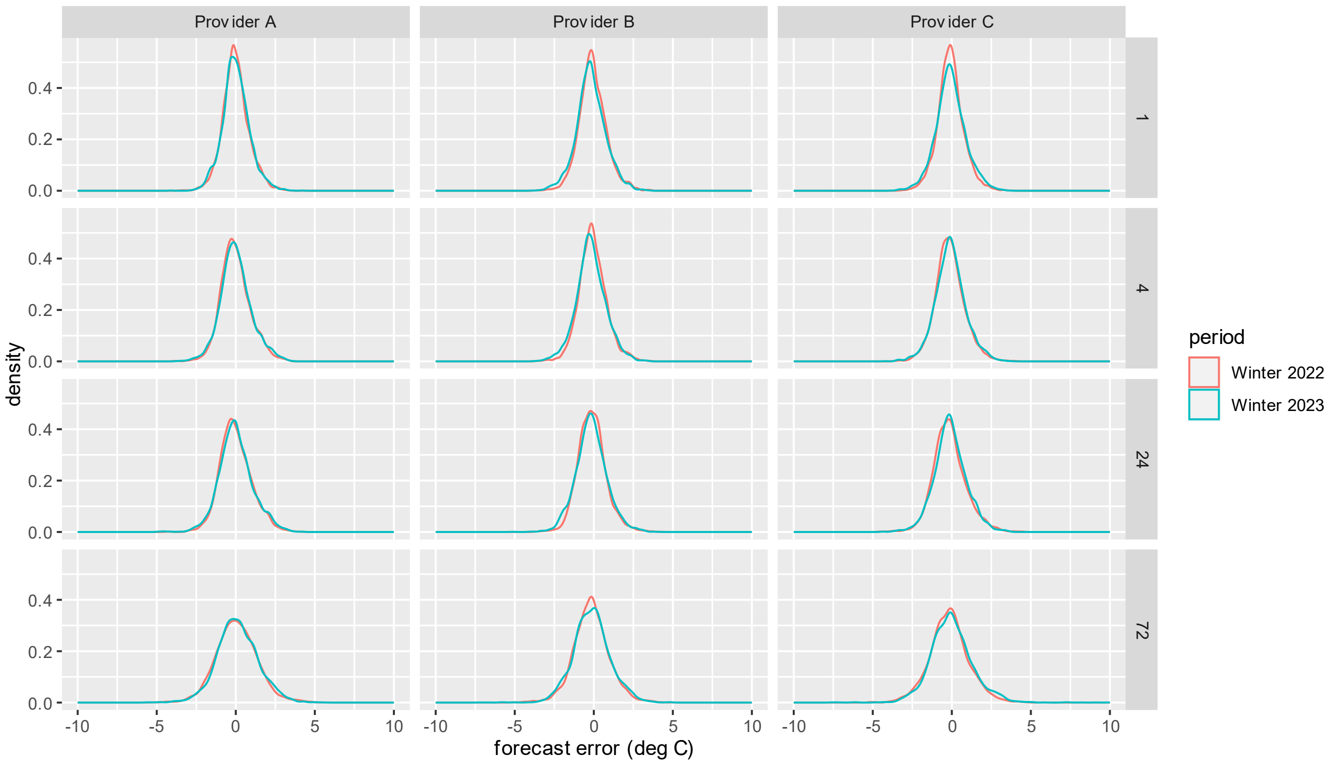


Figure 26 Penrith Lakes, all winter temperatures 2022 and 2023, all time horizons

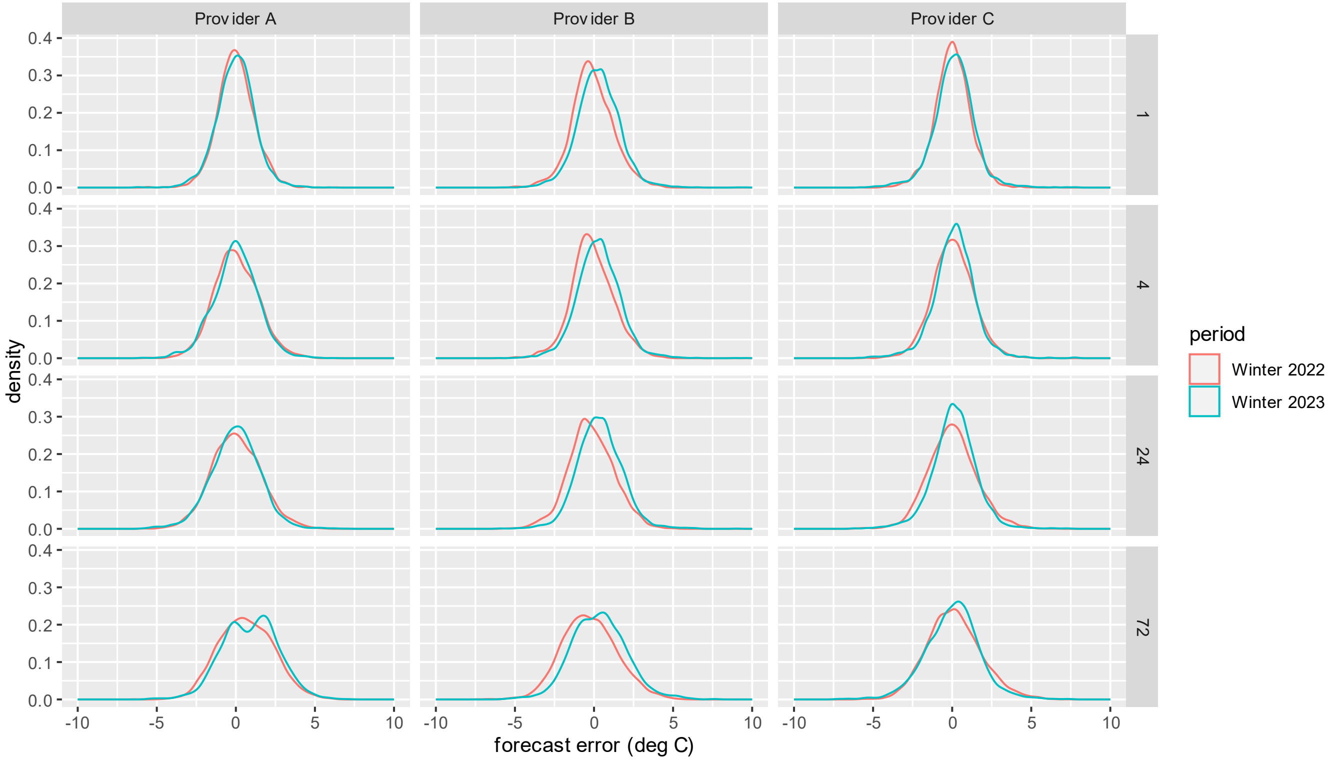
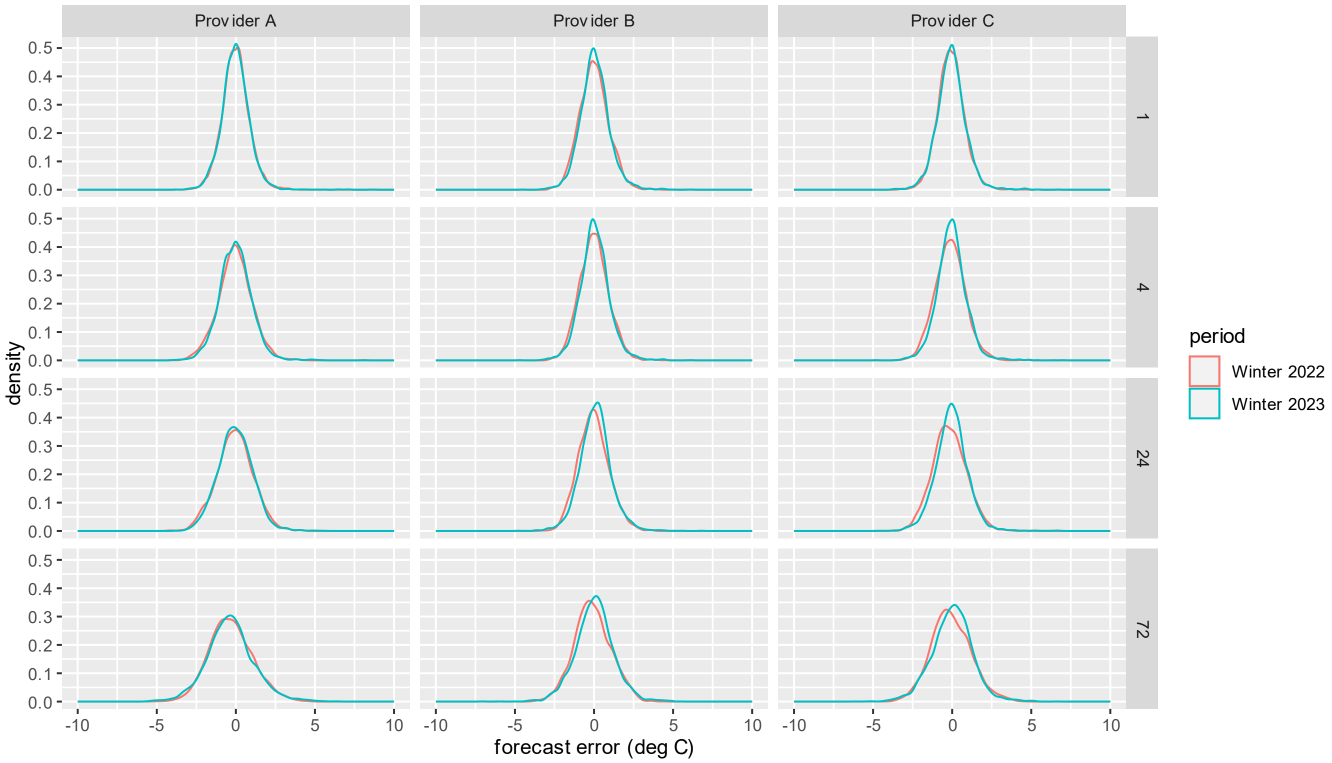


Figure 27 Sydney AP, all winter temperatures 2022 and 2023, all time horizons



A2. Intraday MAE profiles

Figure 28 Adelaide WT, intraday MAE profile, winter temperatures 2022 and 2023, all time horizons, all temperatures

Figure 29 Archerfield AP, intraday MAE profile, winter temperatures 2022 and 2023, all time horizons, all temperatures

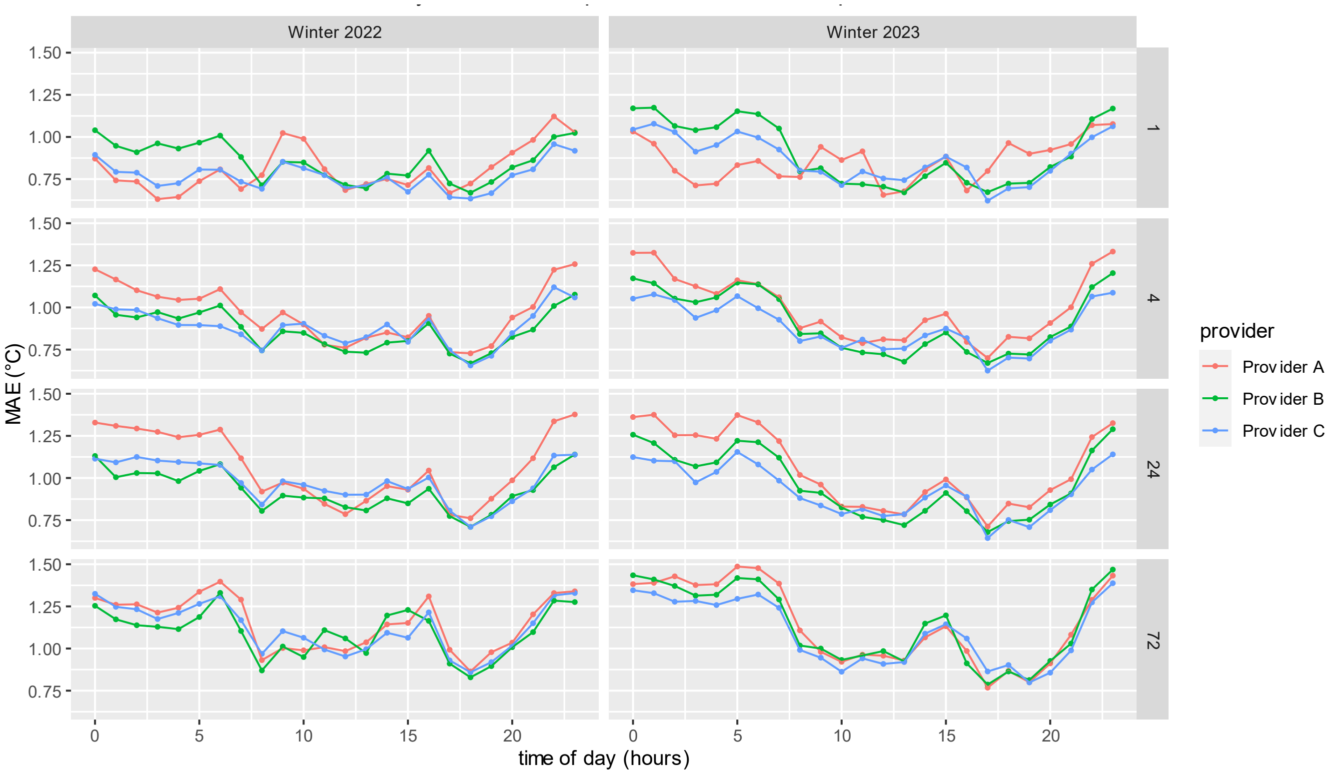


Figure 30 Bankstown AP, intraday MAE profile, winter temperatures 2022 and 2023, all time horizons, all temperatures

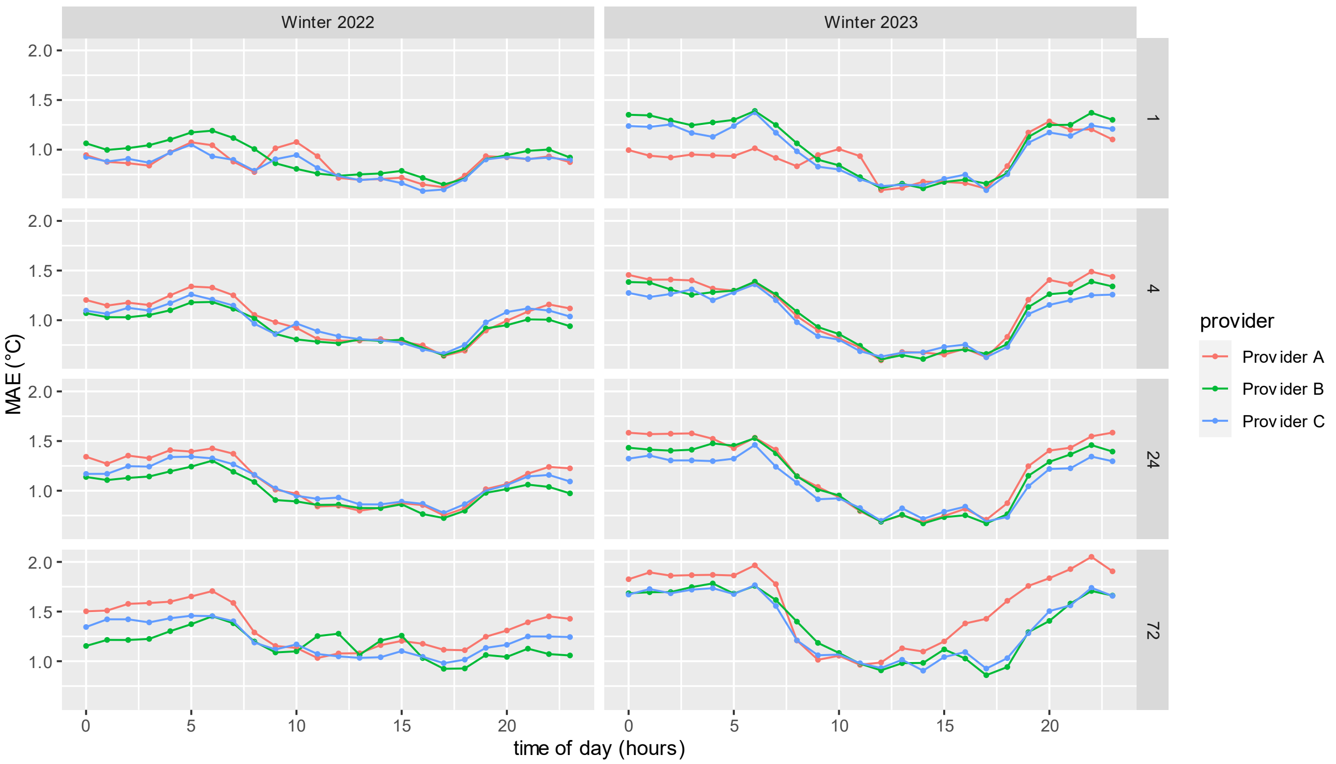


Figure 31 Hobart AP, intraday MAE profile, winter temperatures 2022 and 2023, all time horizons, all temperatures

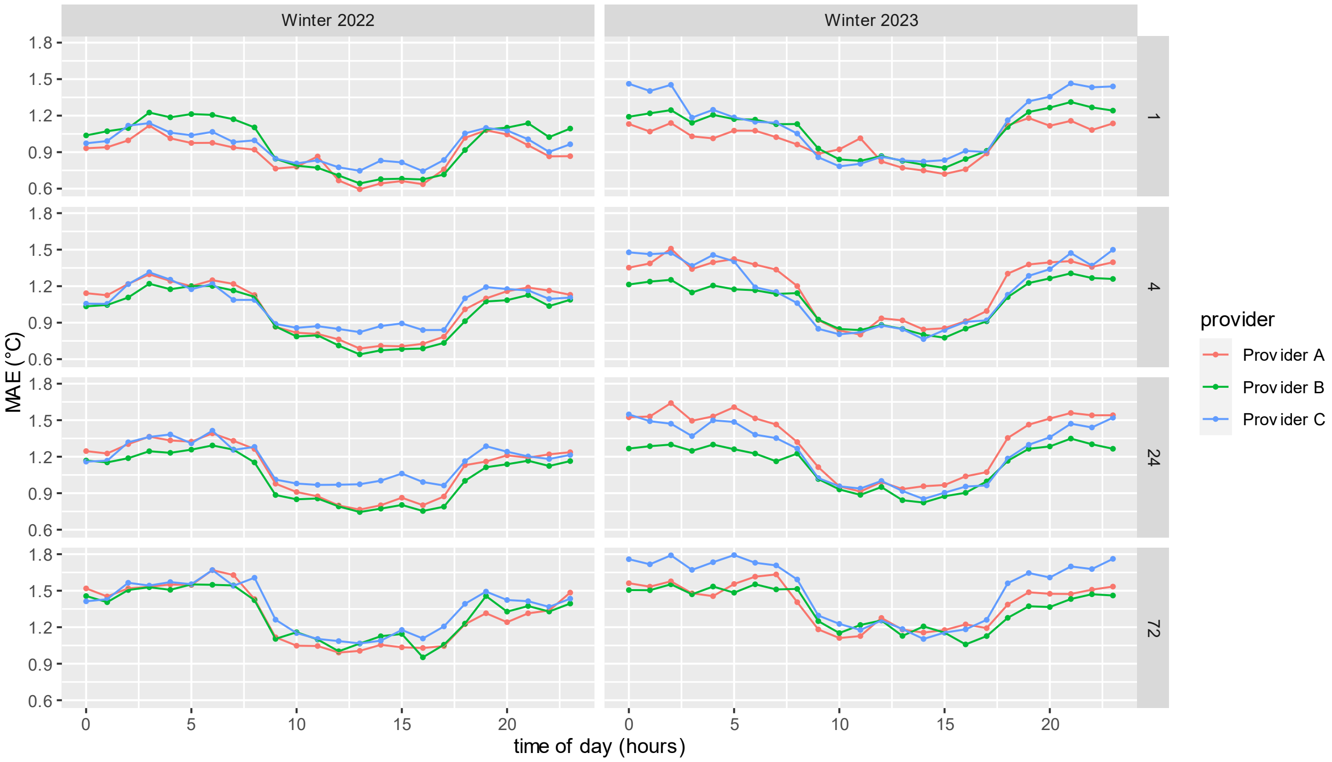


Figure 32 Melbourne OP, intraday MAE profile, winter temperatures 2022 and 2023, all time horizons, all temperatures

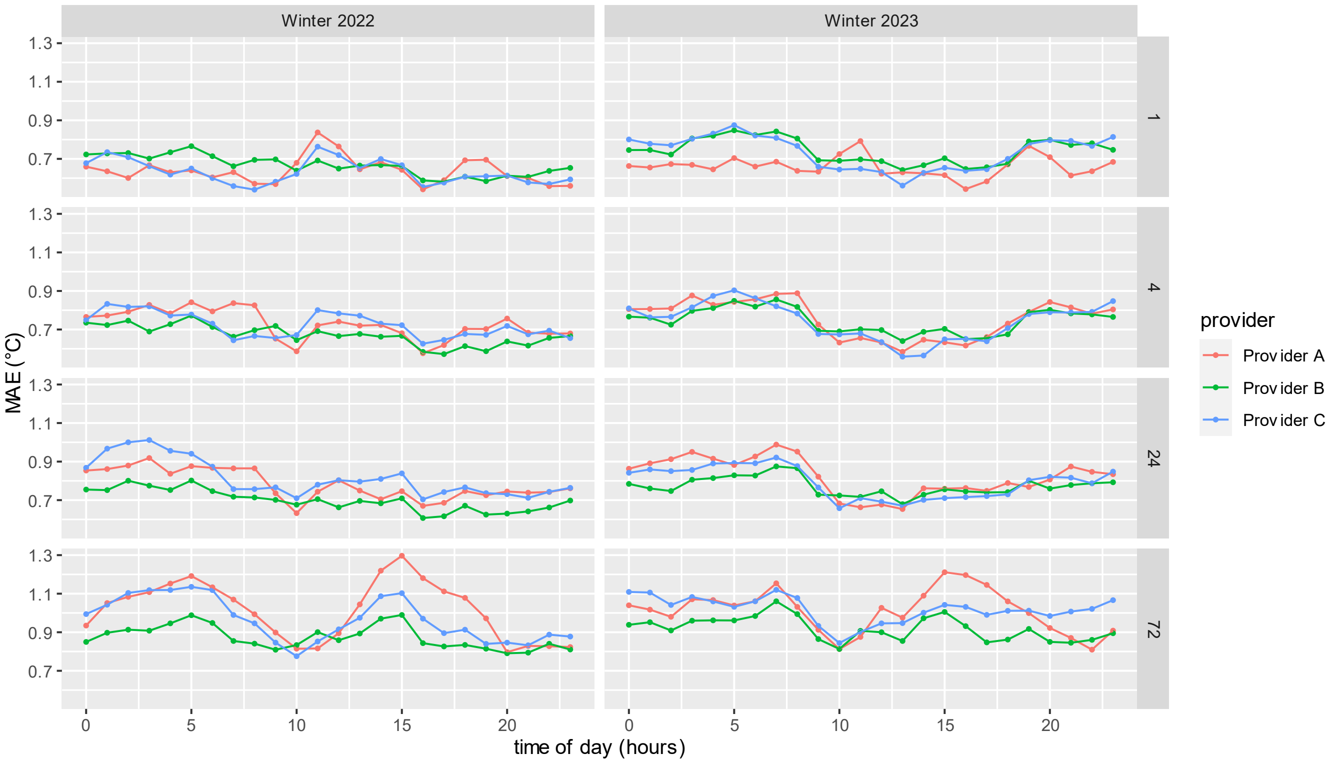


Figure 33 Melbourne AP, intraday MAE profile, winter temperatures 2022 and 2023, all time horizons, all temperatures

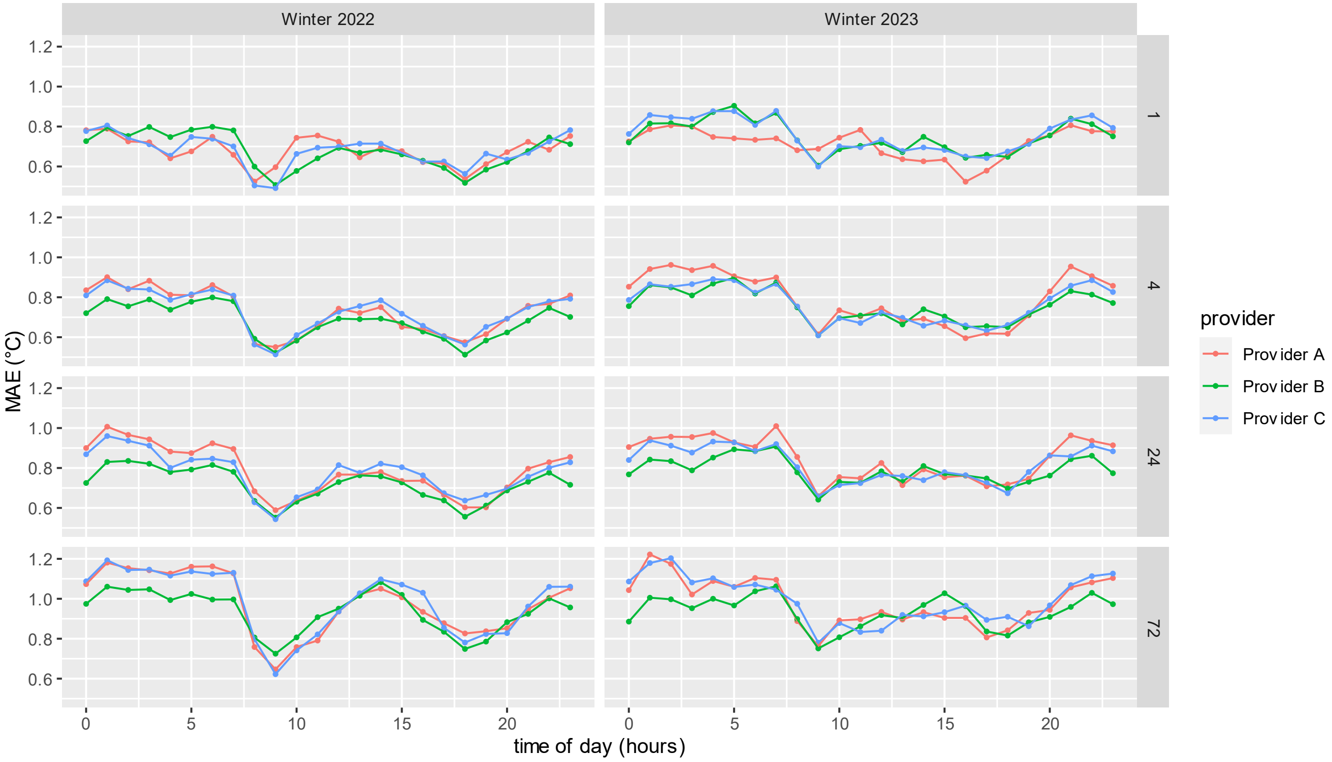


Figure 34 Penrith Lakes, intraday MAE profile, winter temperatures 2022 and 2023, all time horizons, all temperatures

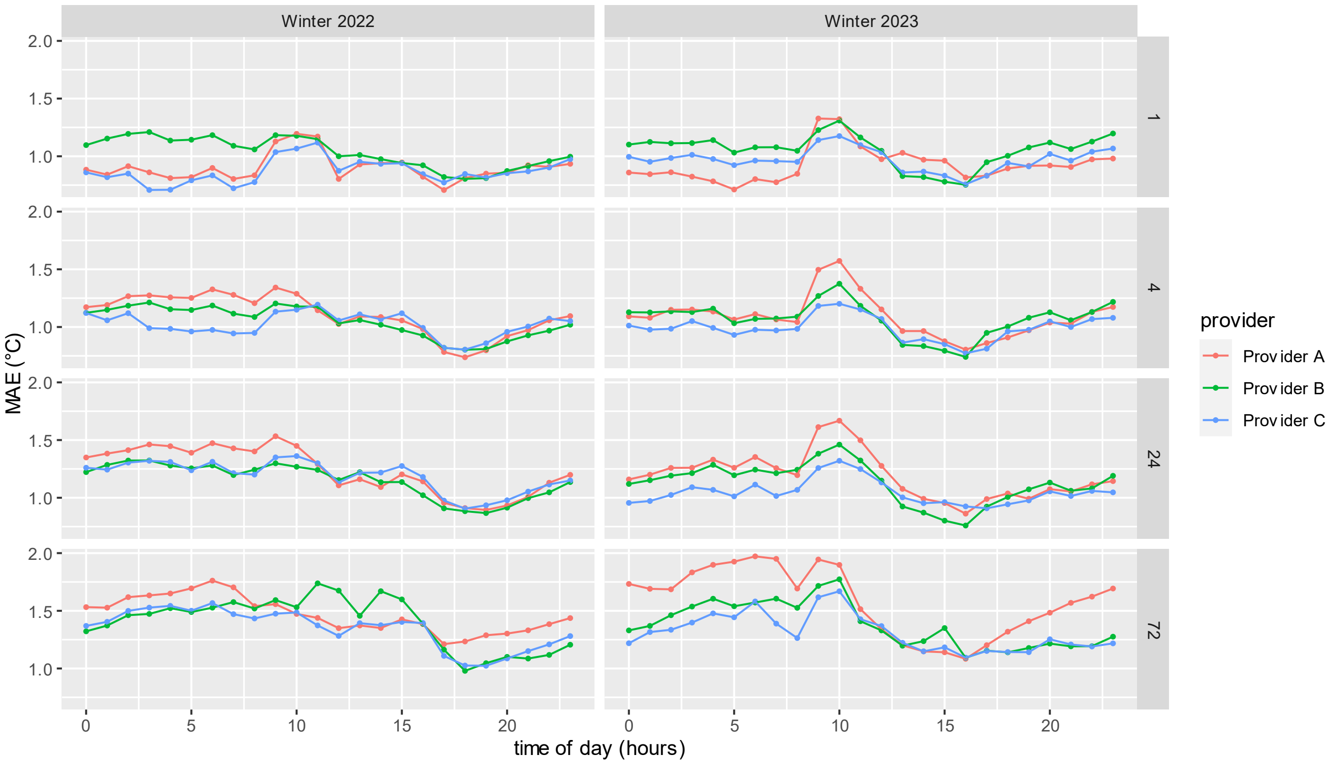
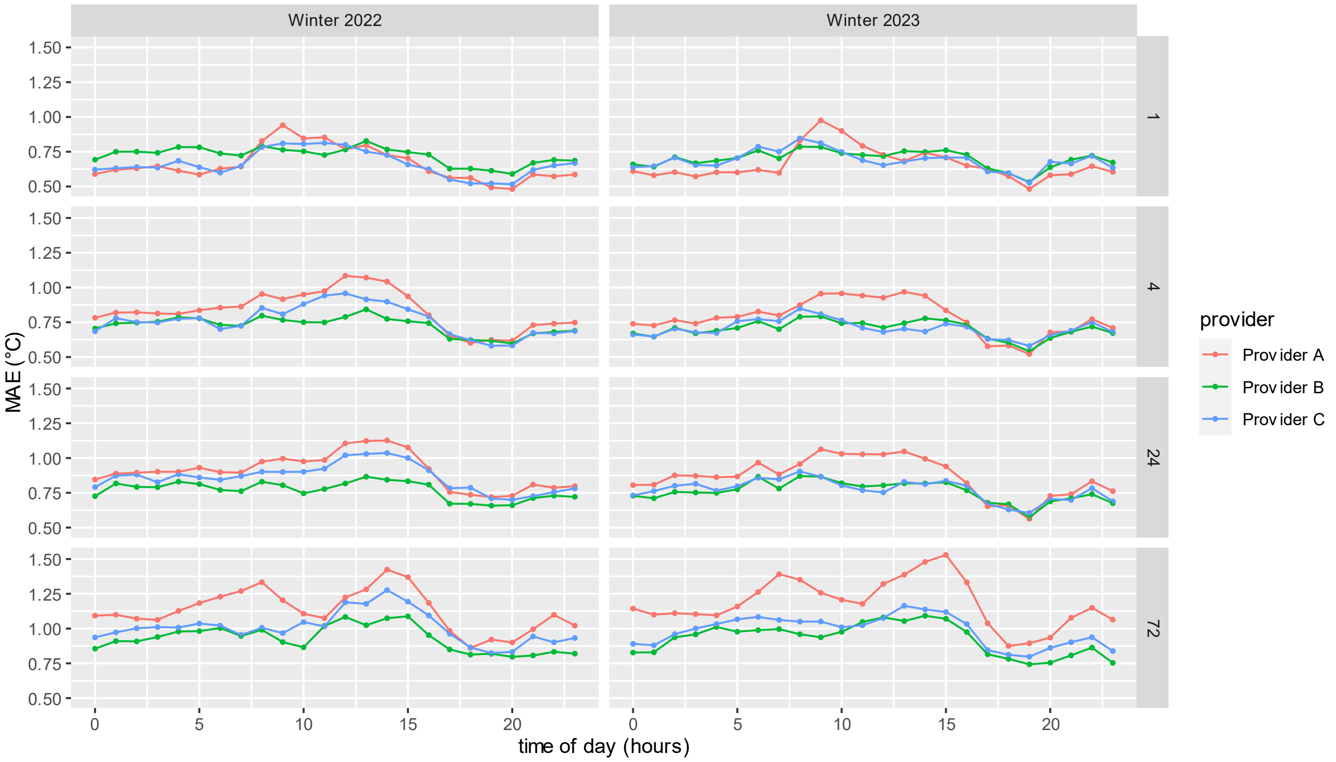


Figure 35 Sydney AP, intraday MAE profile, winter temperatures 2022 and 2023, all time horizons, all temperatures



A3. Net forecast bias profiles

Figure 36 Adelaide WT, net forecast bias profile for the bottom 10% of days

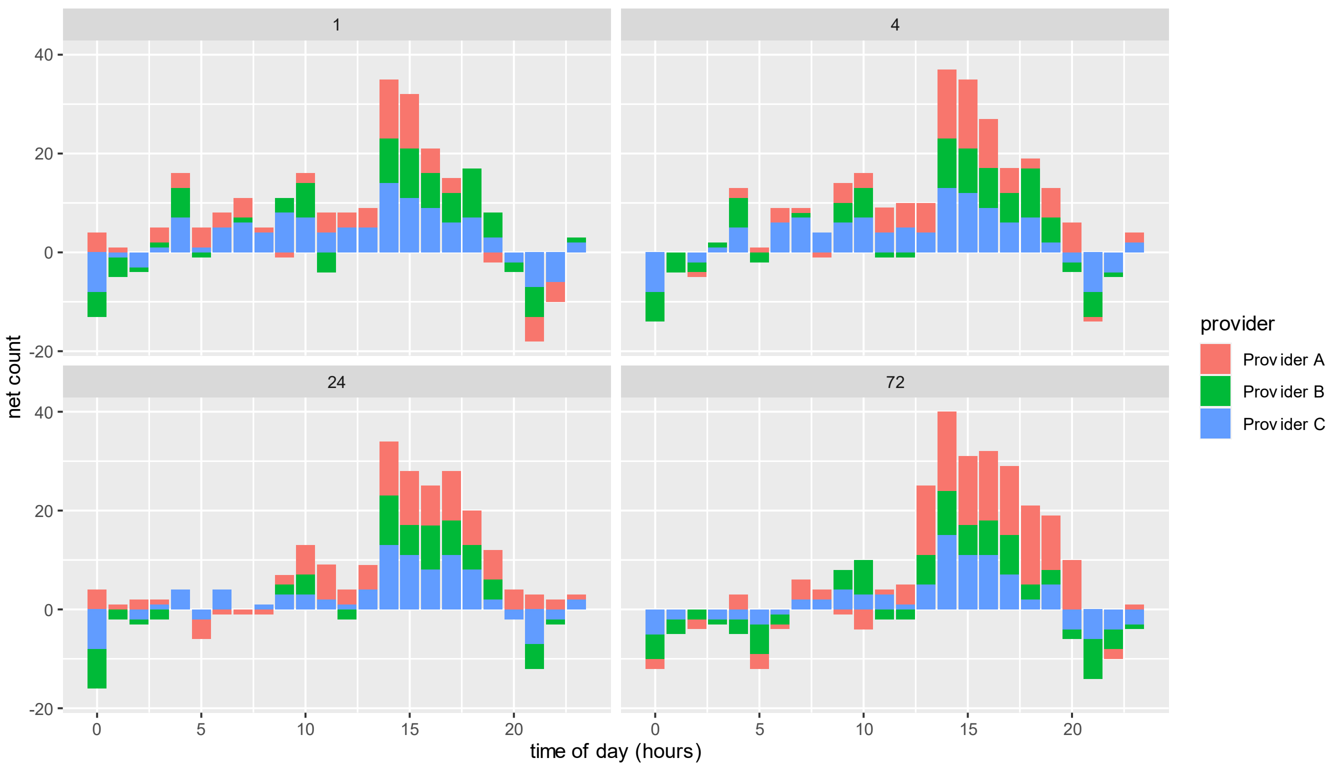


Figure 37 Archerfield AP, net forecast bias profile for the bottom 10% of days

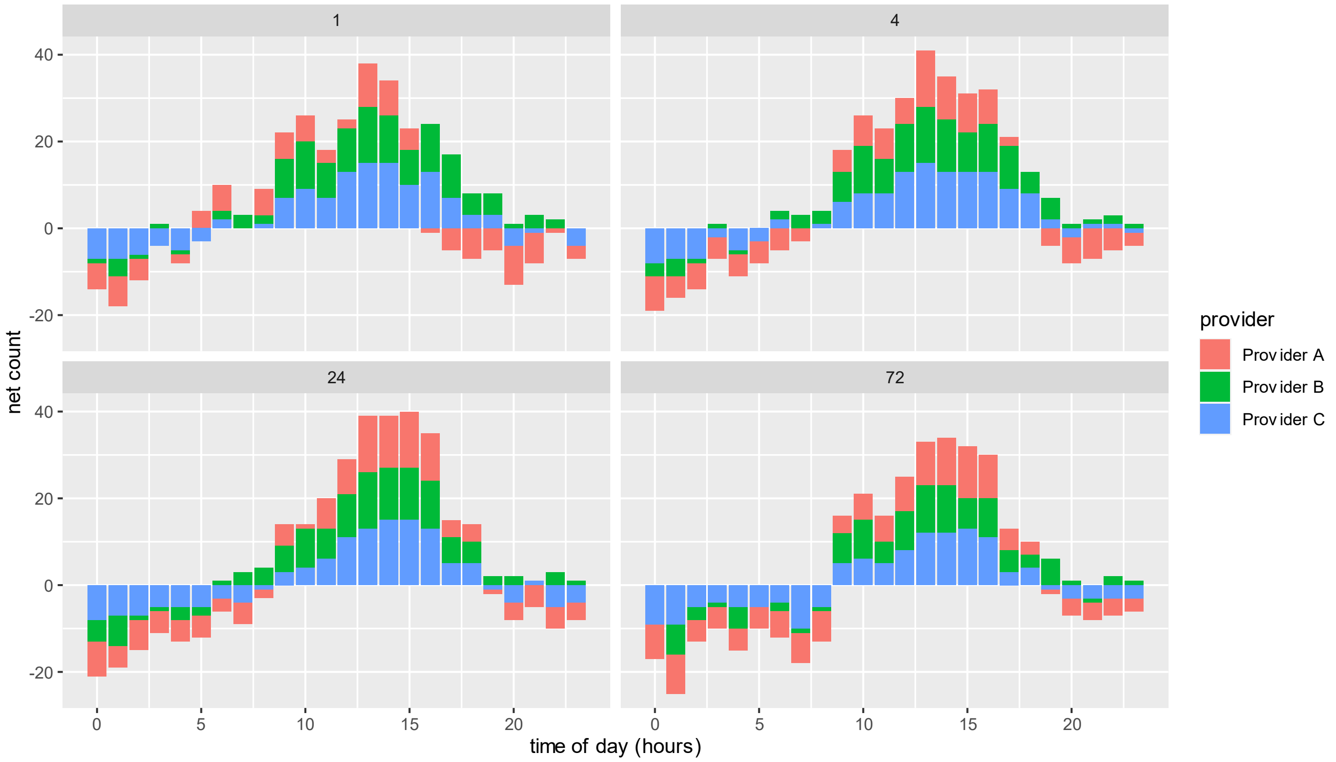


Figure 38 Bankstown AP, net forecast bias profile for the bottom 10% of days

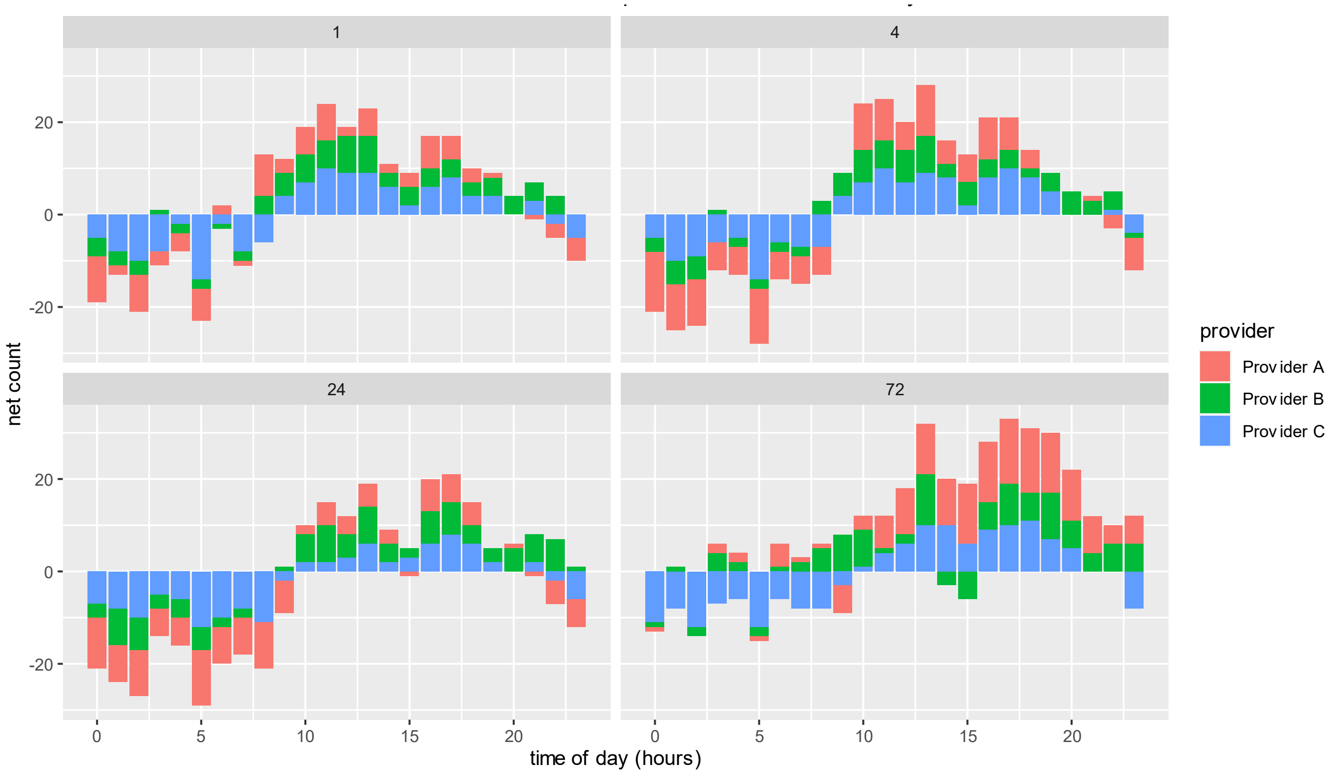


Figure 39 Hobart AP, net forecast bias profile for the 10% of days

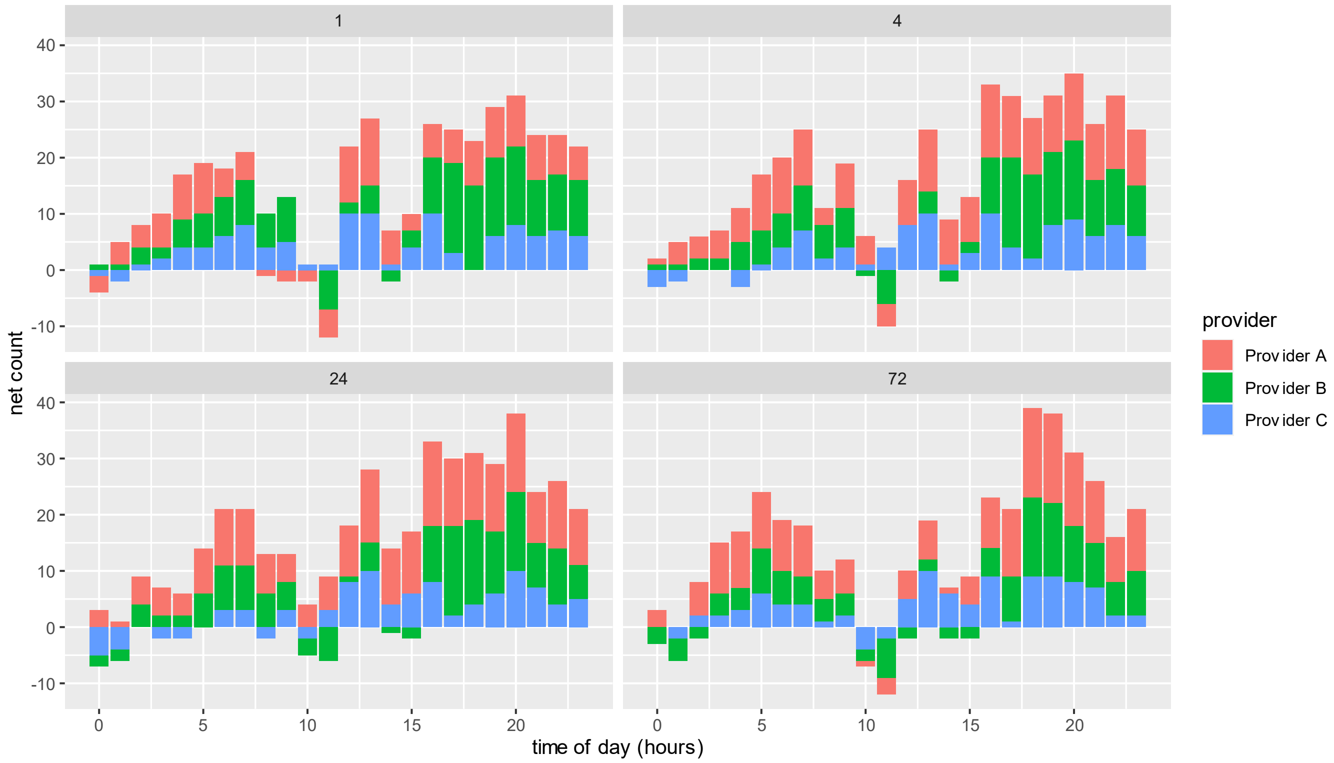


Figure 40 Melbourne AP, net forecast bias profile for the bottom 10% of days

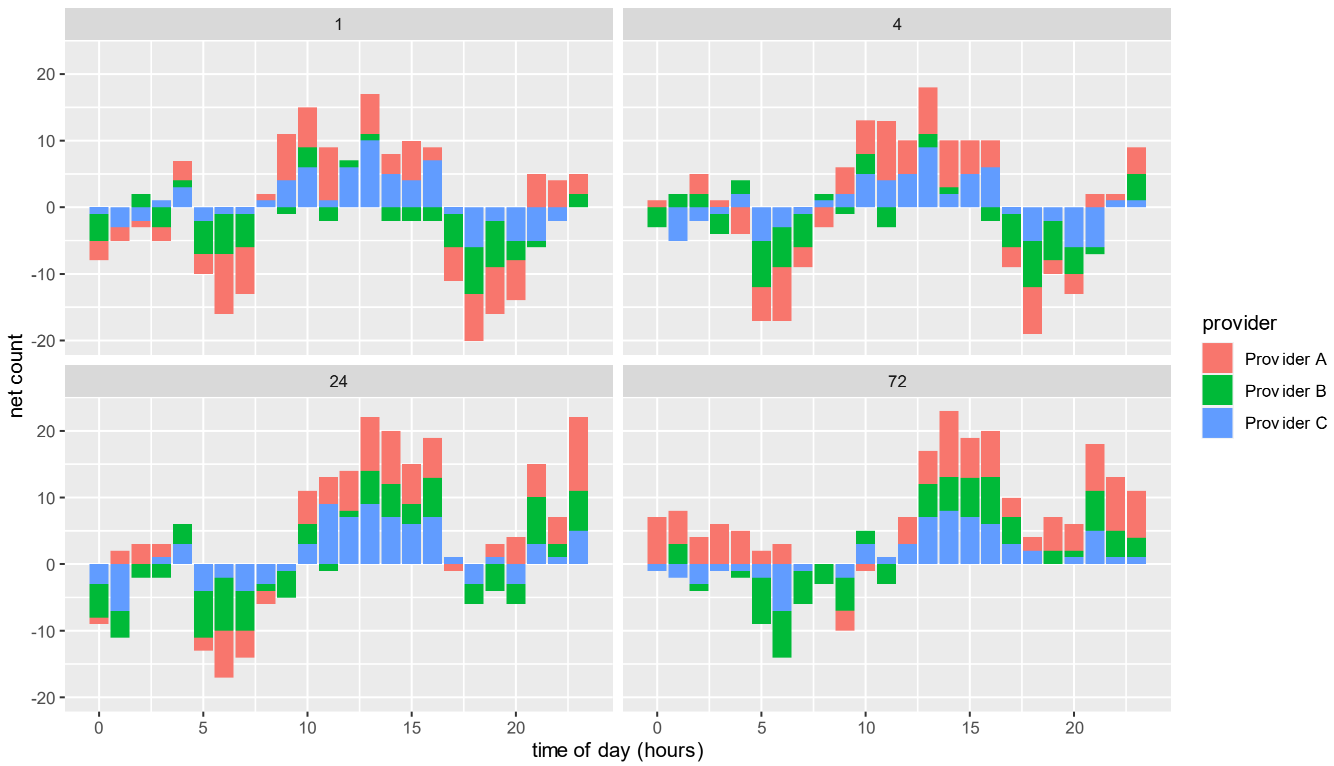


Figure 41 Melbourne OP, net forecast bias profile for the bottom 10% of days

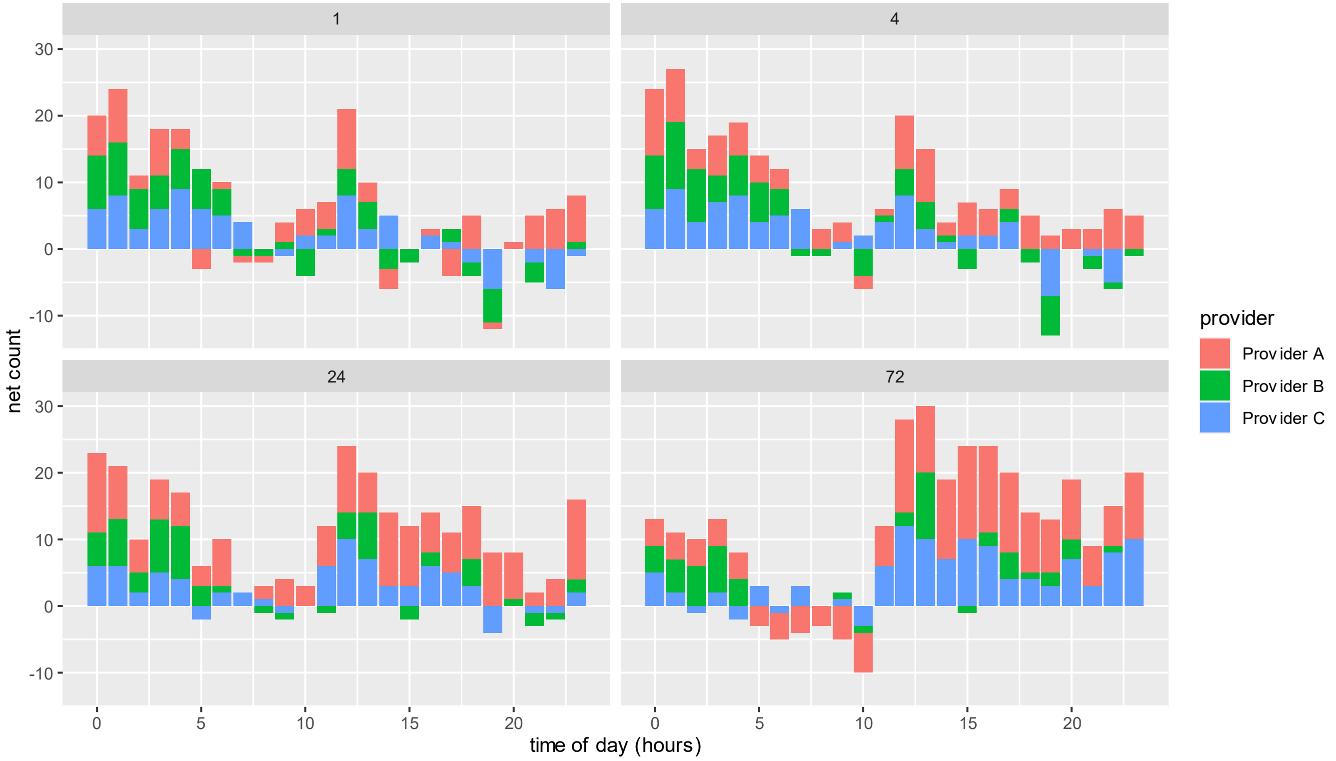


Figure 42 Penrith Lakes, net forecast bias profile for the bottom 10% of days

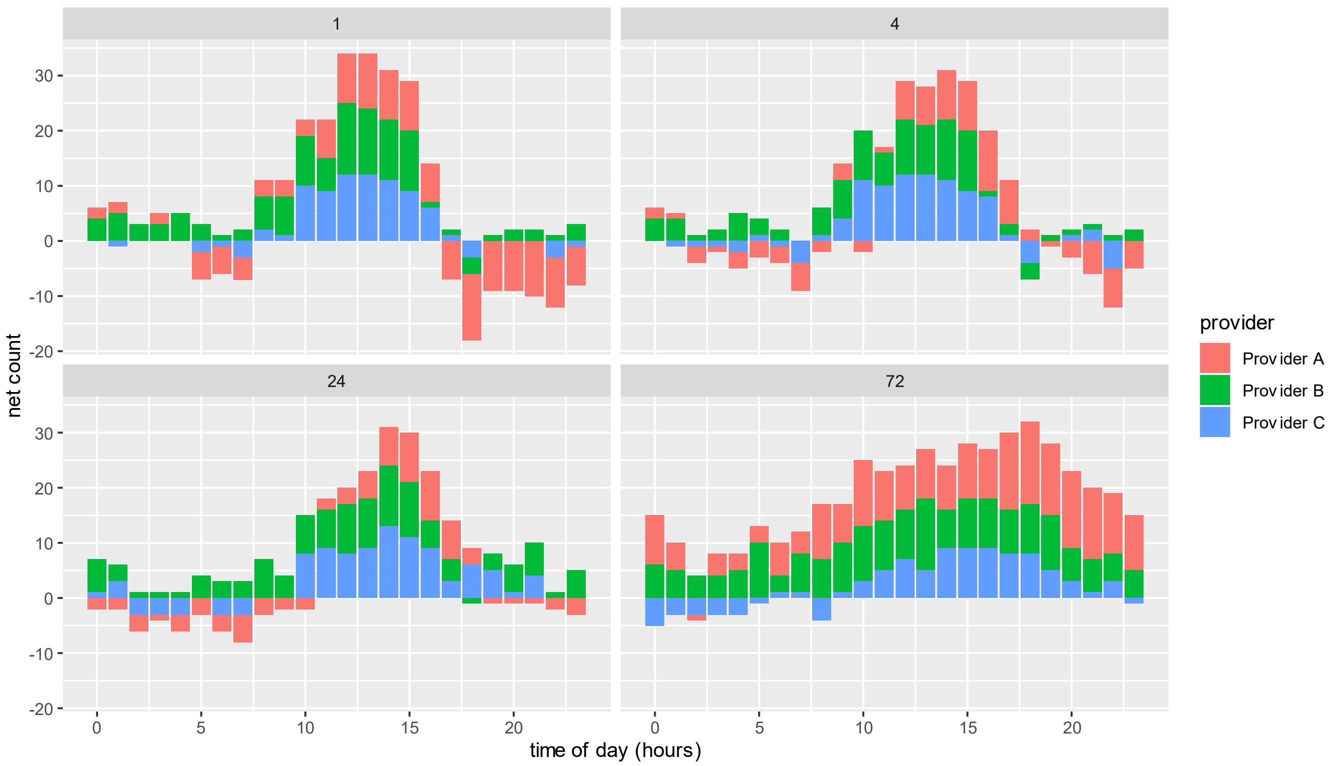


Figure 43 Sydney AP, net forecast bias profile for the bottom 10% of days