Temperature Forecast Analysis for Winter 2021

February 2022

A report assessing the forecast precision and accuracy of AEMO's operational weather providers in the National Electricity Market from 1 May 2021 to 30 September 2021

Important notice

Purpose

This report has been prepared to:

- Give the weather providers used by Operational Forecasting an insight into their comparative temperature forecast performance in the NEM during the 2021 winter period.
- Give any intending weather providers information to assess the relative performance of their forecasts.
- Facilitate discussion and ongoing improvement of temperature forecast accuracy.

Disclaimer

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 paper.
Accuracy vs. precision	Accuracy refers to the closeness of an actual temperature measurement 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

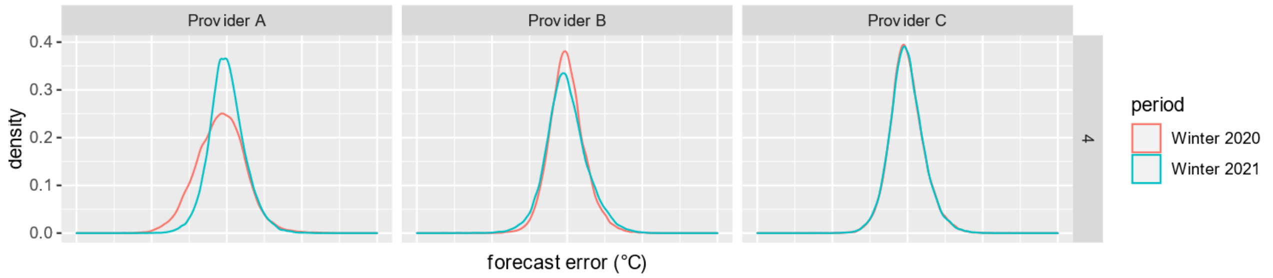
This report examines the temperature forecast performance of AEMO's weather service providers in the National Electricity Market (NEM) from 1 May to 30 September 2021. The report studies temperature forecast accuracy and precision at the 4, 24, and 72 hour ahead (HA) rolling forecast horizons. It has been prepared as a resource for providers to benchmark performance, and to facilitate discussion and ongoing improvement of temperature forecast accuracy to support system operation and the broader energy industry.

In 2021, Australia experienced the warmest winter since 2013 and the fourth warmest on record with near-average rainfall across the country. Cold conditions were experienced on 10 June in New South Wales and in late July in South Australia, with several locations experiencing their coldest winter days on record[1]. On Thursday 22 July, a record winter electricity demand peak of 2,628MW was reached in South Australia with a maximum temperature of 9.1°C at Adelaide West Terrace. In Victoria on Tuesday 20 July, the highest winter peak since June 2011 was recorded at 7,972MW with a maximum temperature of 11.4°C at Melbourne Olympic Park.

Key findings from winter 2021 performance analysis of AEMO's three weather forecast providers are:

- Provider A had the greatest overall improvement for all temperatures linked to a switch to improved forecast feeds in March 2021.
- Provider B forecast performance degraded when compared to winter 2020.
- Provider C had the most accurate and precise performance overall.
- For all providers, Penrith Lakes continues to be challenging to forecast in winter.
- At the lowest 10% of temperatures, all providers showed a tendency to over-forecast across 4, 24, and 72 HA rolling forecast horizons.

Figure 1 4 HA winter performance comparison across major weather stations, all temperatures



This report also analyses a case study of the forecasting performance in New South Wales on 10 June 2021, where extreme cold conditions were experienced. This day showcased the challenges in forecasting extremely low temperatures across all providers. It also highlighted the impact of other types of error on operational demand forecasts on the day, such as model, industrial and rooftop photovoltaic (PV) error.

[1] Bureau of Meteorology, Australia in winter 2021, at http://www.bom.gov.au/climate/current/season/aus/archive/202108.summary.shtml.

AEMO will use the analysis in this report to aid operational decision-making and draw weather providers' attention to potential areas of improvement. AEMO will continue to work with the weather forecasting industry on the key challenges identified in this report. 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.
- The South Australia gridded renewables nowcasting demonstration nearing completion, with promising results on intra-day (0-4 hours ahead) forecasting being demonstrated[2].
- Investigating the direct use of solar irradiance in demand forecasting to capture increased electricity demand due to heat island effects in major metropolitan areas.
- Exploring the utilisation of different weather models in the Australian Wind and Solar Energy Forecasting Systems (AWEFS/ASEFS) to better adapt the weather forecasts for renewable generation forecasting.
- Onboarding of a new weather forecast provider suitable for integration into demand forecast models. A review of the provider arrangements will take place if this assessment is favourable.

[2] See https://arena.gov.au/projects/gridded-renewables-nowcasting-demonstration-over-south-australia/.

Contents

Figures

1 Introduction

This report examines the temperature forecast accuracy of AEMO's three weather service providers in the National Electricity Market (NEM) from 1 May 2021 to 30 September 2021[3]. This report aims to highlight the differences in forecasting performance between winter 2020 and 2021, while also drawing new performance insights from the winter 2021 period. The report is part of a series of biannual *Temperature Forecast Analysis* reports available on the AEMO website for summer and winter periods since 2018[4].

This report has been prepared as a resource for weather service providers to benchmark their forecast performance, and to facilitate discussion and ongoing improvement of temperature forecast accuracy to support system operation and the broader energy industry. It also includes a case study to discuss the impact extreme cold temperatures had on electricity demand in New South Wales on 10 June 2021.

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 weather stations have the largest influence on demand forecasts for their respective NEM regions.

Sensitivity of electricity demand to temperature

The performance of a temperature forecast must be understood with reference to its operational impact on electricity demand. The accuracy of temperature forecasts is most critical for operational demand forecasting when demand is high, 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 providers to produce accurate and precise temperature forecasts on these days.

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[5].

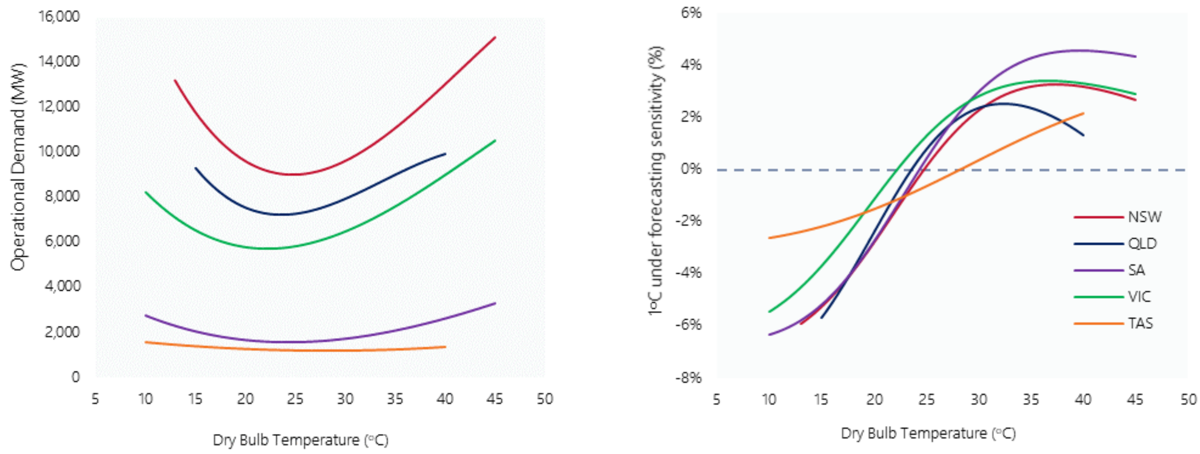
Electricity demand has different temperature sensitivity in each NEM region due to factors such as climate and the mix of residential, commercial, and industrial load. In addition, the same demand forecast error will have different operational impacts for different regions. Since each region has limited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

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

[4] 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.

[5] This analysis shows the relationship of maximum daily dry bulb temperature values with maximum daily operational demand on weekdays between 1 January 2018 and 31 December 2021. The temperature readings were taken from the primary weather station for demand forecasting in each region (New South Wales – Bankstown Airport, Queensland – Archerfield, Victoria – Melbourne Olympic Park, South Australia – Kent Town, Tasmania – Hobart Airport). Adelaide West Terrace was used instead of Kent Town, due to the decommissioning of Kent Town by the Bureau of Meteorology on 31 July 2020.

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

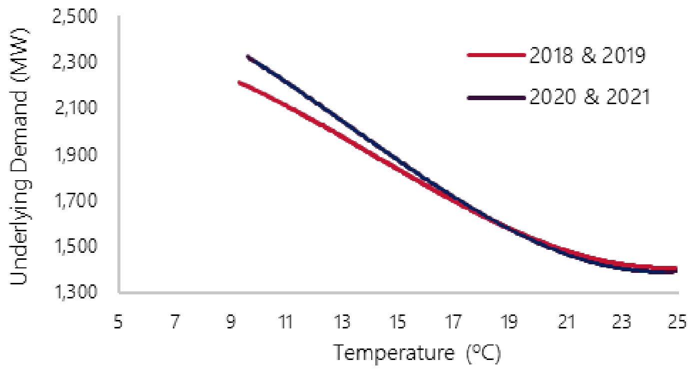


COVID-19 impact on winter demand sensitivity

The shift towards increased working from home arrangements during the COVID-19 pandemic has driven an increase in weather-sensitive residential load across the NEM. The discretionary use of heating and lighting during colder winter months has increased electricity demand above levels seen in similar periods and similar temperatures before the pandemic.

This increase was observed to the greatest extent in South Australia, which although did not experience the sustained lockdowns seen in other regions, it has experienced a large increase in people working from home. At low temperatures during the pandemic (2020 and 2021), evening peak demands in South Australia have been observed to flex to higher levels compared to equivalent months in previous years (2018 and 2019) as discretional heating and lighting in homes increased (see Figure 3).

Figure 3 Temperature sensitivity of South Australian underlying evening peak demand during winter periods



This heightened sensitivity has increased the dependency on accurate and precise temperature forecasts during the winter months, especially at very cold temperatures where above-normal demand was exerted on the power system. With more people than before the pandemic expected to continue working from home for the foreseeable future, this impact poses a risk for future winter periods, and for summer periods with increased residential cooling load.

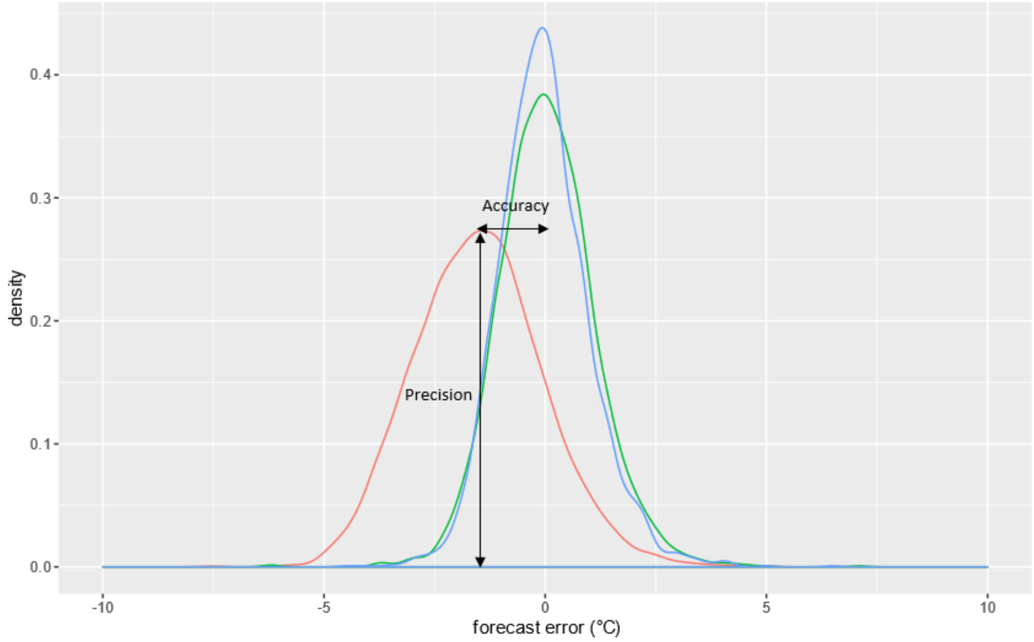
2 Winter forecast performance

This section contains a selection of temperature forecasting performance insights for winter 2021 in the NEM. Results supporting major insights are included in this section, with additional results included in appendices A1 and A2. This report studies temperature forecast performance at the 4, 24, and 72 HA rolling forecast horizons.

Guide to interpreting error density plots

Many of the results in this section and in Appendix A1 are displayed as error density plots like Figure 4 below.

Figure 4 Accuracy and precision in the error density plot



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 4, the forecast distribution in blue has the highest precision and the forecast distribution in 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 4, the forecast distribution in red is less accurate than the forecast distributions in green and blue.

Appendix A2 contains intraday mean absolute error (MAE) profiles for weather stations not explicitly featured in the main report. Forecasts are provided for each hour of the day and for each provider.

2.1 Overall performance

Weather conditions in winter 2021

In 2021, Australia experienced its warmest winter since 2013 and the fourth-warmest on record, with a national mean temperature 1.18°C above average. The mean maximum temperature was 1.27°C above average, with July and August well above average, reaching record highs in the northern tropics and into the top 10% of winter records for inland regions of Queensland. The mean minimum temperature was 1.08°C above average, however was not as widespread as maximum temperatures, with most states and territories experiencing localised areas of below average minimum temperatures.

An intense low off the east coast of New South Wales on 10 June 2021 led to very cold conditions, resulting in coldest winter day records being broken in several locations across central and northern inland parts of the state (see Section 3 for the impact on demand forecasting). Several sites in South Australia had their coldest winter day on record between 17 July and 25 July 2021 during a prolonged period of low temperatures.

In South Australia on Thursday 22 July, a record winter peak electricity demand of 2,628MW was reached with a maximum temperature of 9.1°C at Adelaide West Terrace. In Victoria on Tuesday 20 July, the highest winter peak since June 2011 was recorded at 7,972MW with a maximum temperature of 11.4°C at Melbourne Olympic Park.

Winter 2021 rainfall was near average for an Australian winter. Rainfall was above average in New South Wales, varied across parts of Queensland, and near average in the other NEM states[6].

Overall winter 2021 performance insights

Figure 5 and Figure 6 show the performance comparison of 2020 and 2021 winter periods across all studied weather stations for Providers A, B, and C. Key insights include:

- **Provider A performance had the greatest overall improvement** in both accuracy and precision when considering all temperatures in winter 2021, but with reduced accuracy in performance at the lowest 10% of temperatures compared to its performance in winter 2020.
- **Provider B performance degraded in winter 2021** compared to winter 2020, with the lowest performance for the 4 HA rolling forecast horizon for all temperatures at major weather stations.
- **Provider C continues to demonstrate the most accurate and precise overall performance**. This was observed for all horizons across all temperatures in winter 2021, as well as when considering performance at the lowest 10% of temperatures. Provider C also demonstrated the least change in its overall accuracy and precision of forecasting between winter 2020 and winter 2021.
- **At the lowest 10% of temperatures, all providers showed a tendency to over-forecast** across 4, 24 and 72 HA rolling forecast horizons in winter 2021 (Figure 6). This phenomenon also occurred at the lowest 10% of temperatures in winter 2020 for Provider B and C, where Provider A's tendency to over-forecast these cold temperatures increased in 2021.

[6] Australia in Winter 2021, Bureau of Meteorology, at http://www.bom.gov.au/climate/current/season/aus/archive/202108.summary.shtml.

Figure 5 Winter 2020 and 2021 performance comparison across major weather stations, all temperatures

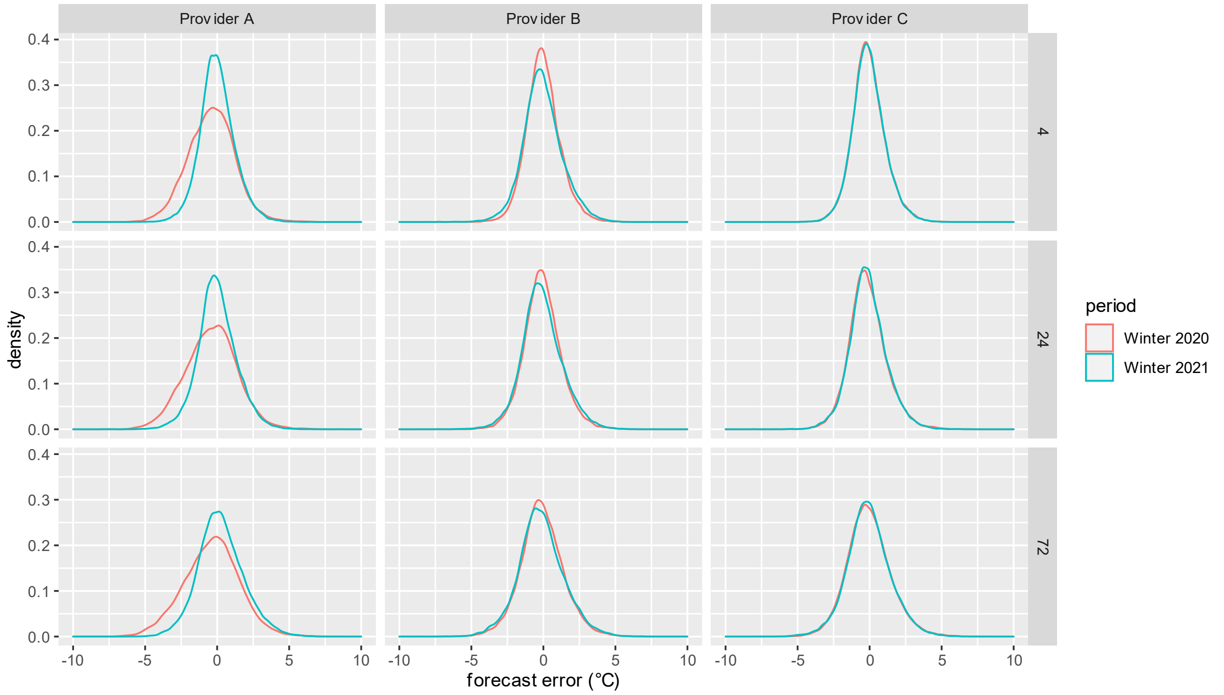
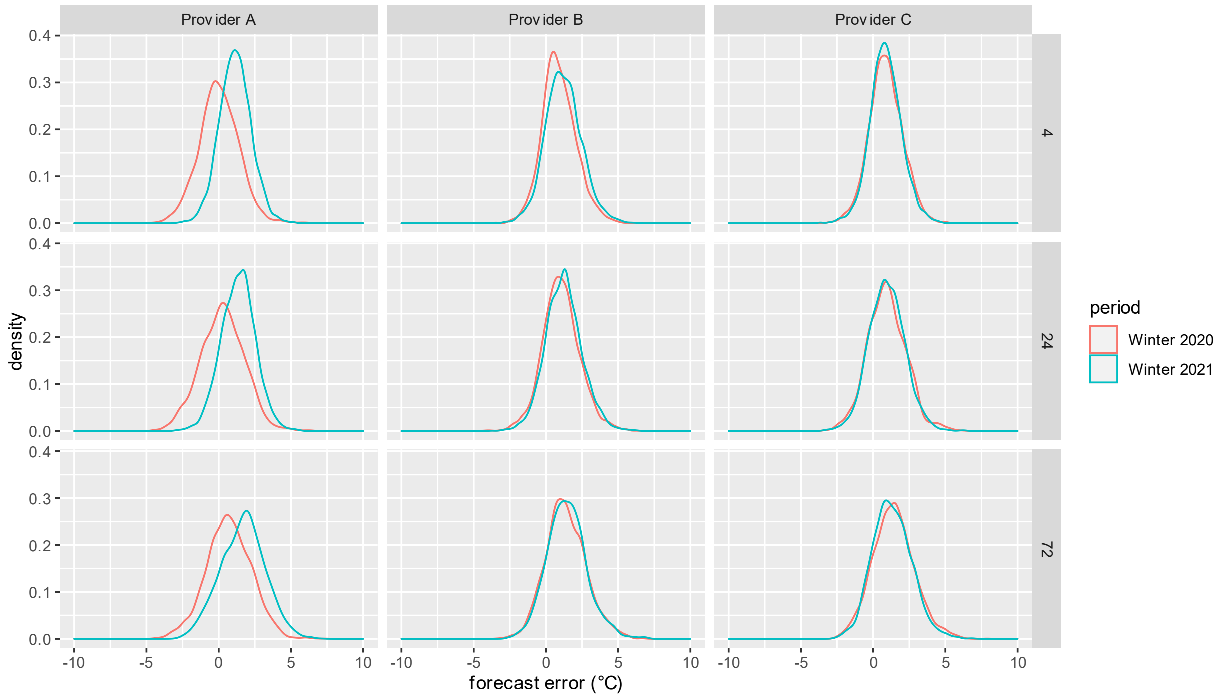


Figure 6 Winter 2020 and 2021 performance comparison across major weather stations, lowest 10% of temperatures



2.2 Provider A forecast performance

Provider A had the greatest improvement for all temperatures, but a degraded accuracy at the lowest 10% of temperatures.

Provider A forecasts significantly improved in both accuracy and precision for winter 2021 when compared to winter 2020, as demonstrated in Figure 5 and shown for all key weather stations for 24 HA forecasts in Figure 7 below. This marked improvement resulted in much more comparable performance to Provider B and C for winter 2021, after relatively worse performance for winter 2020.

While forecast performance improved at most weather stations, the improvement at Hobart AP was most noticeable compared to previous winter and summer analysis where the tendency to under-forecast was corrected. This correction, along with the general increase in performance, was related to Provider A's switch to improved feeds, with a change in the way forecast data is assimilated, in March 2021.

Although overall performance improved, the accuracy of Provider A degraded from winter 2020 when forecasting the lowest 10% of temperatures. This degraded performance was observed at most major weather stations, as shown in Figure 8. In this figure, the position of the peak shifted to the right for winter 2021, indicating an increased tendency to over-forecast, while the error density peak increased indicating an increased precision in over-forecasting. It should be noted that while the tendency to over-forecast at low temperatures was observed for all providers, Provider A is unique in demonstrating an increased over-forecasting tendency between winter 2020 and winter 2021.

Figure 7 Major weather stations, Provider A, all winter temperatures 2020 and 2021, 24 HA

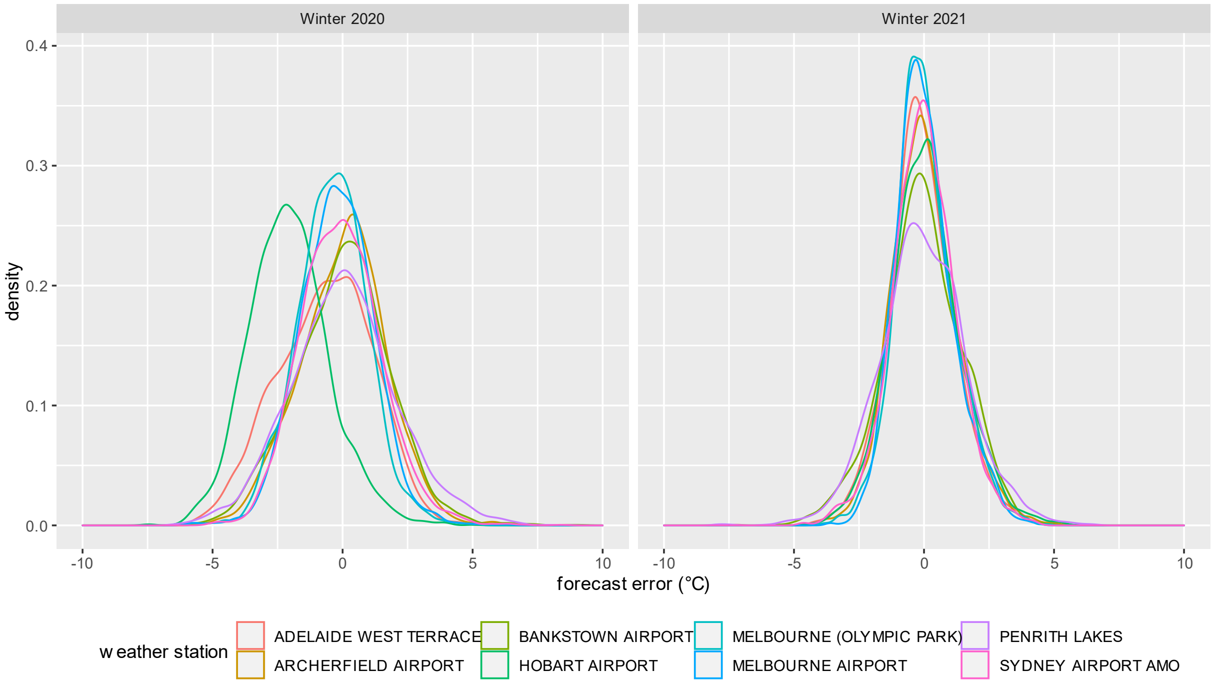
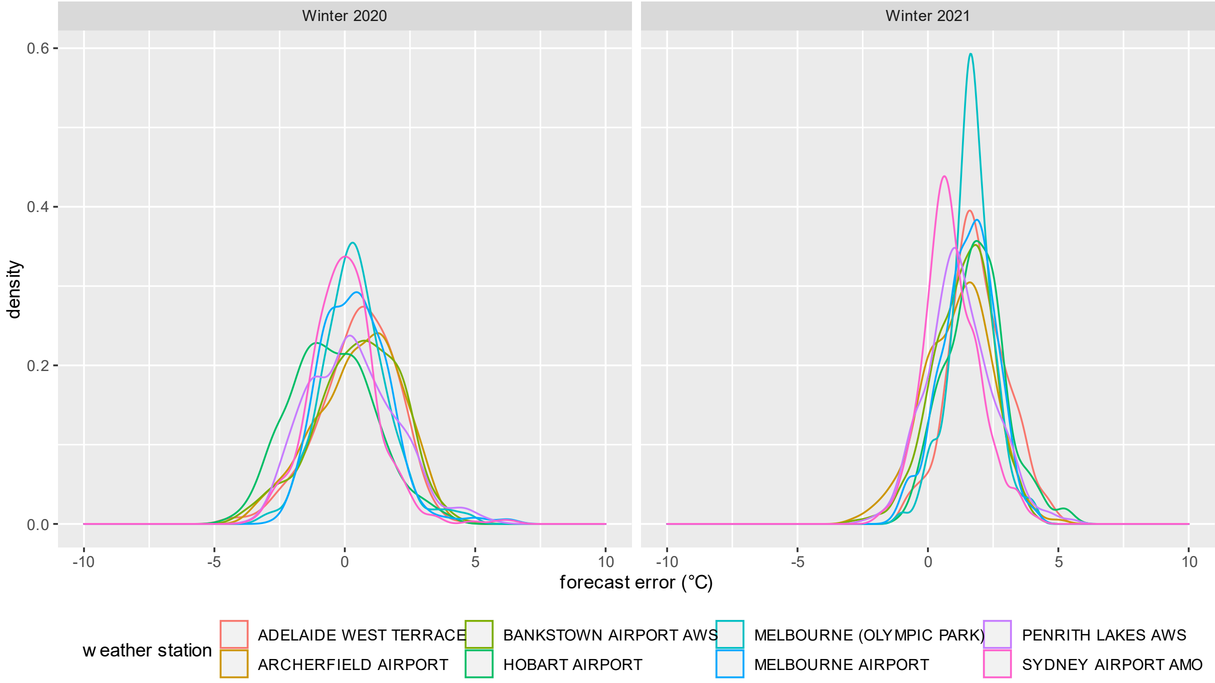


Figure 8 Major weather stations, Provider A, lowest 10% winter temperatures 2020 and 2021, 24 HA



2.3 Provider B forecast performance

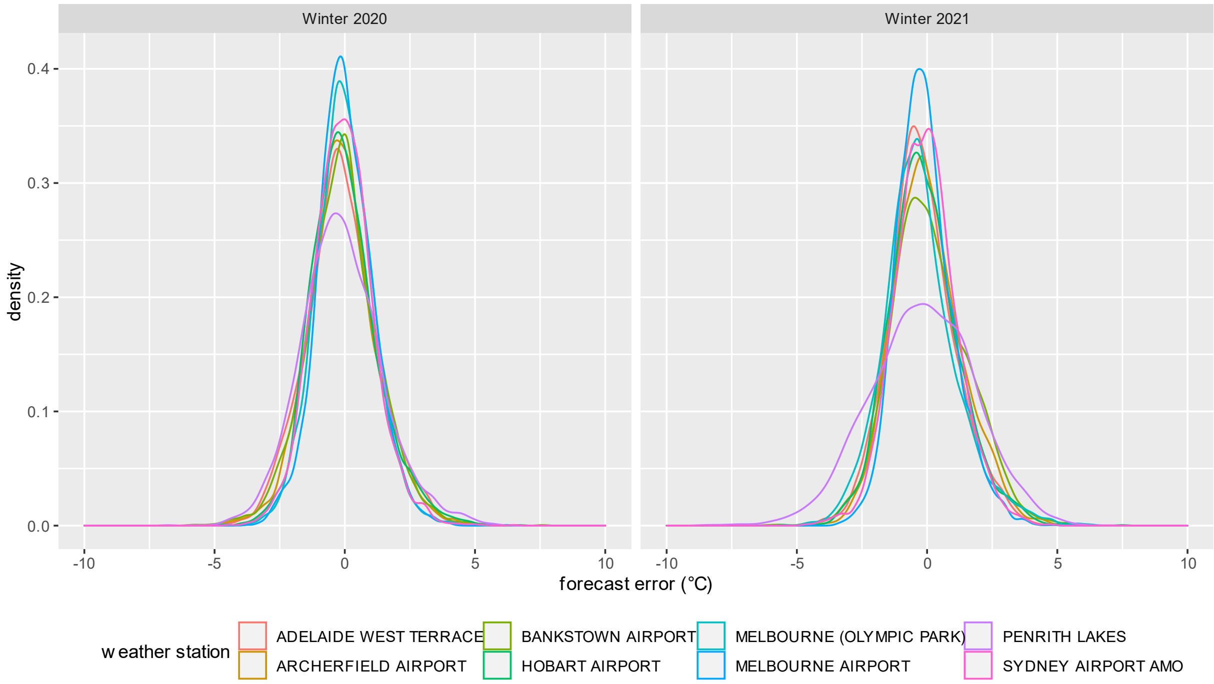
Provider B forecast performance degraded when compared to winter 2020.

Overall, Provider B had less precise forecasts in winter 2021 compared to winter 2020 (Figure 9), with an increased tendency to over-forecast at the lowest 10% of temperatures (as observed by all providers).

When forecasting the lowest 10% of temperatures, performance further degraded with increased over-forecasting tendencies at several weather stations, particularly Melbourne OP and Bankstown, yet improved performance at Adelaide WT as shown for 24 HA forecast performance in Appendix 1.2 (Figure 21).

The material degradation in Provider B performance, particularly at major weather stations in New South Wales and Victoria, required corrective action during winter 2021. To minimise the impact of the erroneous feeds, the weighting of Provider B in demand forecast models was suppressed indefinitely. Following winter 2021, AEMO have onboarded a new provider which is currently being assessed for use in demand forecast models, a review of the provider arrangements will take place if this assessment is favourable.

Figure 9 Major weather stations, Provider B, all winter temperatures 2020 and 2021, 24 HA



2.4 Provider C forecast performance

Provider C had the most accurate and precise performance overall.

Provider C performed best overall in winter 2021 in terms of accuracy and precision across 4, 24 and 72 HA rolling forecast horizons, as seen in Figure 5 and Figure 6. Provider C also demonstrated the least change in its overall accuracy and precision of forecasting between winter 2020 and 2021, with consistent 24 HA performance at major weather stations and improvement to precision at Melbourne AP (Figure 10).

It should be noted however, that Provider C also showed a tendency to over-forecast during the lowest 10% of temperatures. Provider C showed improved 24 HA precision compared to winter 2020 at Bankstown, Sydney AP and Hobart AP. Melbourne OP and Sydney AP 24 HA forecasts were less precise than winter 2020 for the lowest 10% of temperatures, with a tendency at Sydney AP to slightly under-forecast (see Appendix A1.2 Figure 20 for comparison at 24 HA rolling forecast horizon). However, when forecast performance at lowest 10% temperatures is compared to the other provider performance at Sydney AP, Provider C continues to perform best at the 4 HA horizon. Its performance at the 24 and 72 HA horizons was comparable with Provider A and B (Figure 11).

Following winter 2021, Provider C implemented updated model feeds which are expected to improve both near-term and day-ahead hourly temperature forecasts. The impact on performance will be assessed in the upcoming summer 2021-22 temperature forecast analysis report.

Figure 10 Major weather stations, Provider C, winter temperatures 2020 and 2021, 24 HA

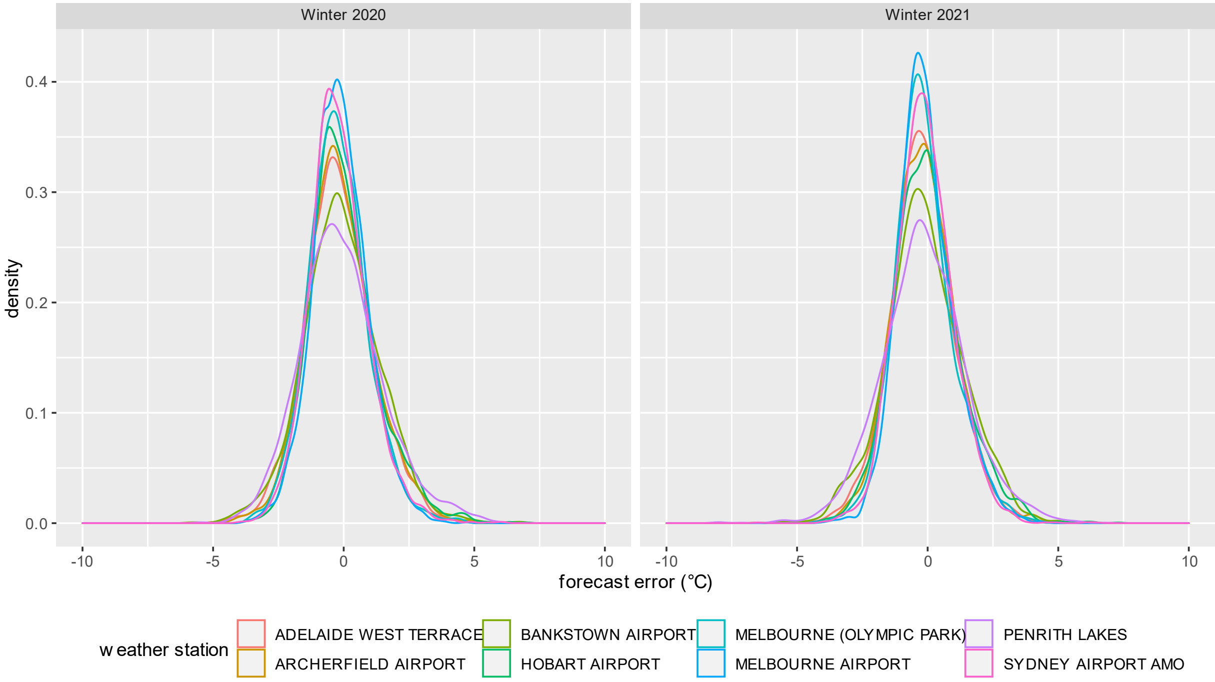
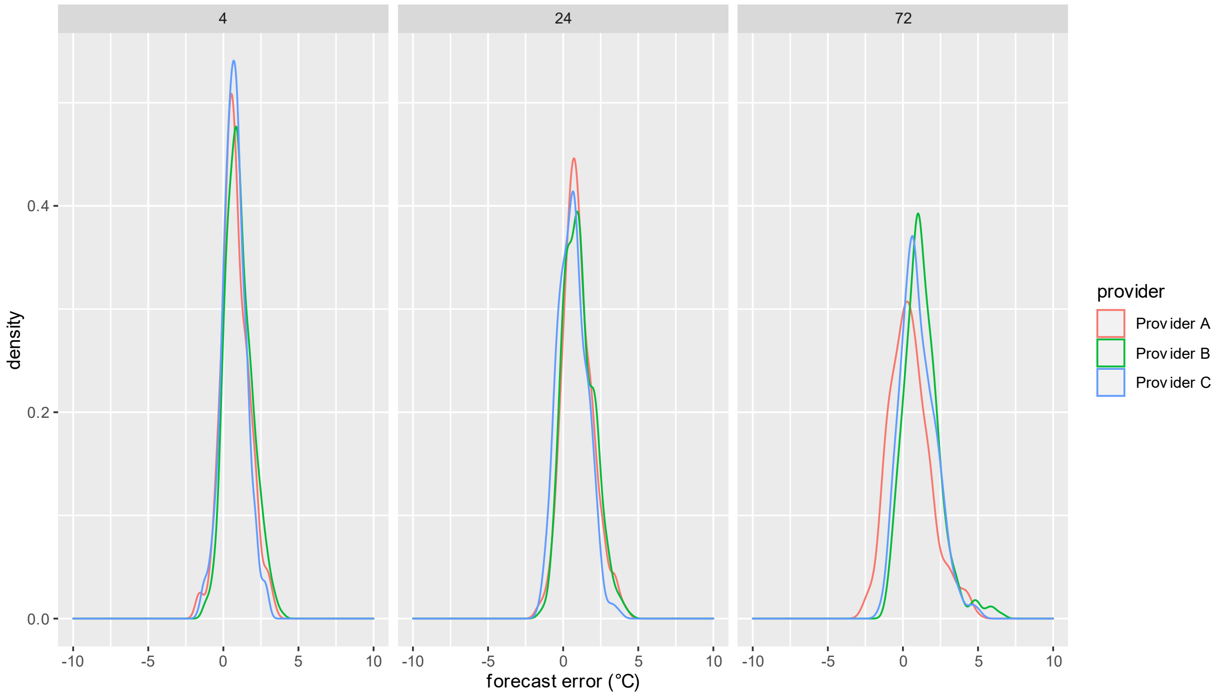


Figure 11 Winter 2020 and 2021 performance comparison at Sydney Airport, lowest 10% of temperatures

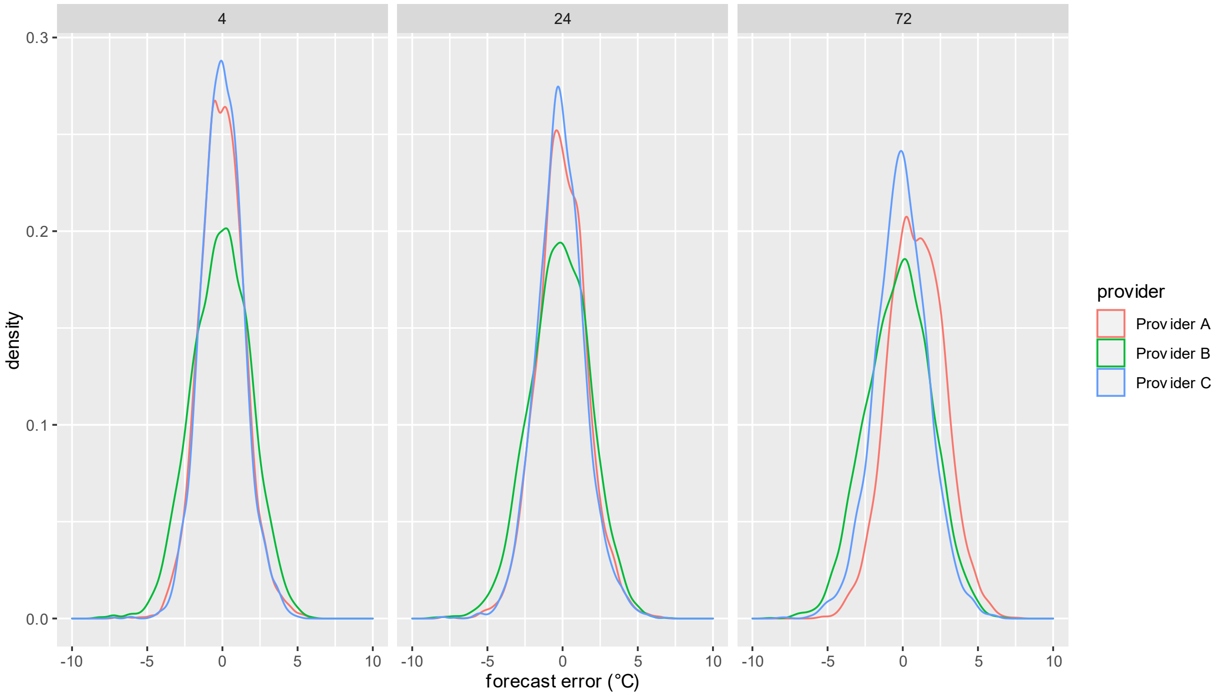


2.5 Penrith Lakes continues to be challenging to forecast in winter

In the *Temperature Forecast Analysis for Winter 2020* report, Penrith Lakes was identified as being one of the most challenging weather stations to forecast of all weather stations, with each provider having under- and over-forecasting errors at this station[7]. In winter 2021, forecasting remained challenging at Penrith Lakes. When comparing performance at Penrith Lakes between providers in winter 2021, Provider C continued to show the greatest overall performance, while Provider B had the overall lowest performance, particularly for the 4 HA forecasts (Figure 12).

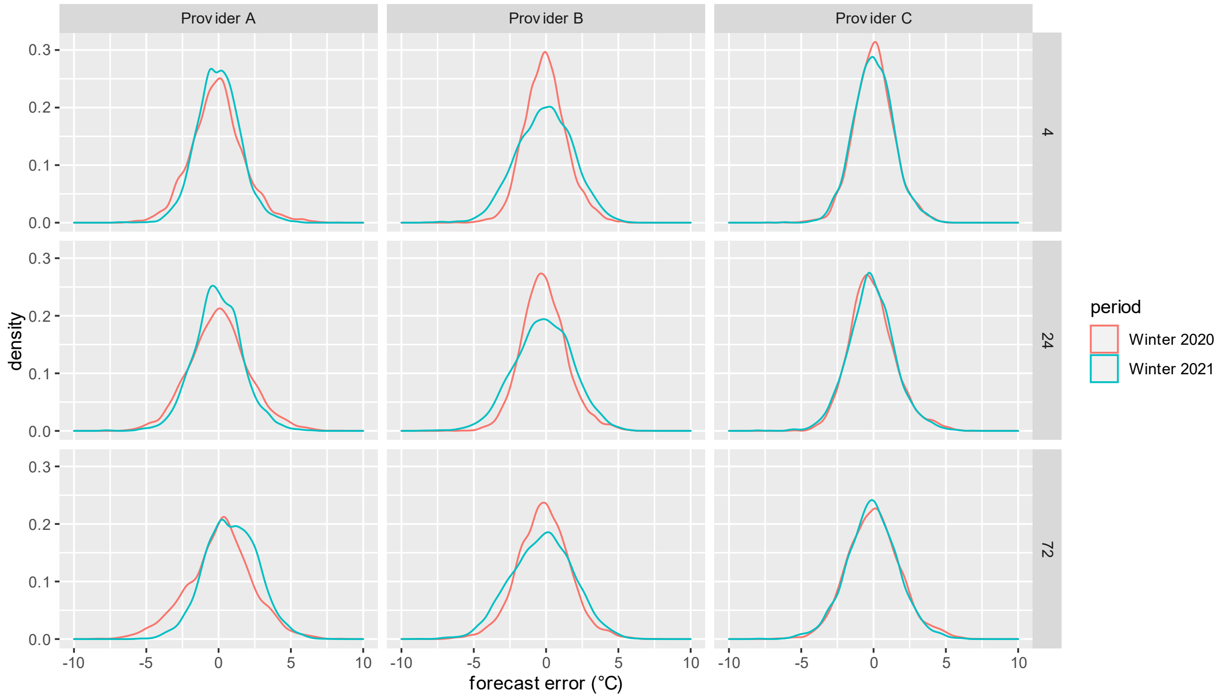
This performance is compared to winter 2020 in Figure 13, which shows Provider B had a greater tendency to both over- and under-forecast in 2021 than in the previous year. Provider A also had a greater tendency to over-forecast for the 72 HA forecast horizon. Although Provider C showed similar overall performance to winter 2020 at Penrith Lakes, the 4 HA forecasts were less precise.

Figure 12 Winter 2021 performance comparison at Penrith Lakes, all temperatures



[7] 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.

Figure 13 Winter 2020 and 2021 performance comparison at Penrith Lakes, all temperatures



2.6 Intraday insights

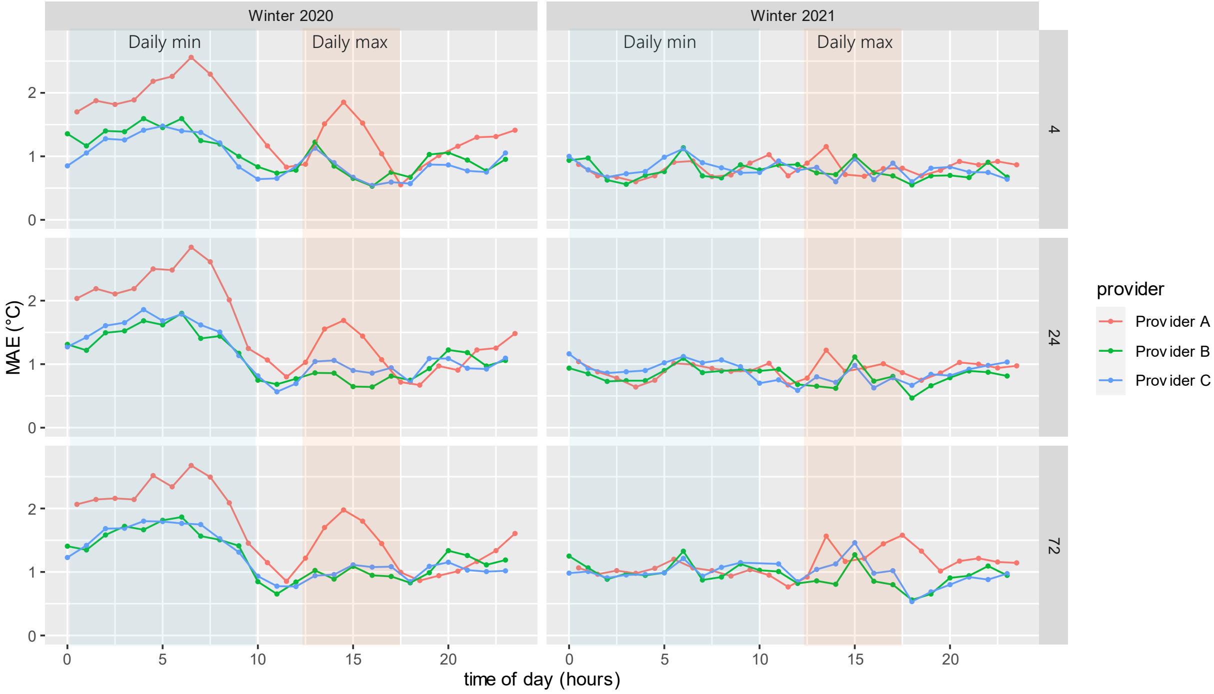
These insights were derived from Intraday Mean Absolute Error (MAE) profiles, which show the magnitude of the absolute average error for each hourly interval. Intraday analysis for winter 2021 focuses on the lowest 10% of temperatures, as these were the most challenging to forecast in the winter forecast performance analysis above.

For the lowest 10% of winter 2020 temperatures, Provider A had greater MAEs than Providers B and C during early morning and mid-afternoon when minimum and maximum daily temperatures respectively can typically occur.

This was observed at major weather stations including Adelaide WT, Archerfield, Bankstown, Hobart AP, and Melbourne AP. These errors materially improved in 2021 at these weather stations such that Provider A's MAEs are now more aligned with Providers B and C during these periods, as can be seen in Figure 14 for Adelaide WT below.

Melbourne OP and Sydney AP forecasts by Provider A, however, which had greater mid-afternoon errors yet similar early morning errors to other providers in 2020, still had greater 72 HA mid-afternoon MAEs in 2021. MAE profiles for major weather stations can be seen in in Appendix A2.

Figure 14 Adelaide West Terrace, intraday MAE profile, all providers, winter 2020 and 2021, all time horizons, lowest 10% of temperatures



3 Case study: New South Wales on 10 June 2021

This case study explores the temperature forecasts of an extreme cold day in New South Wales on Thursday 10 June 2021, and the subsequent impacts this had on the demand forecasting.

Temperature forecasts and outcomes

On Thursday 10 June 2021, New South Wales experienced an extreme cold day as maximum temperatures across large parts of the state fell below 10°C. Several temperature records were set, most notably:

Bankstown AP and Penrith Lakes are the heaviest weighted weather stations in the New South Wales demand forecast model, due to the proximity of these stations to major load centres. The accuracy of the temperature forecasts at these stations therefore has the largest impact on the accuracy of the demand forecast.

On cold temperature days, particularly when extreme cold minima and maxima coincide, this can have a significant impact on both the morning and evening peak operational demand. Operational demand on these days is elevated by increased heating loads and has been shown to be amplified due to COVID-19 impacts as a greater proportion of people work from home.

Figure 15 Forecast temperatures at various horizons against actual temperature observations for each provider at Bankstown on 10 June 2021

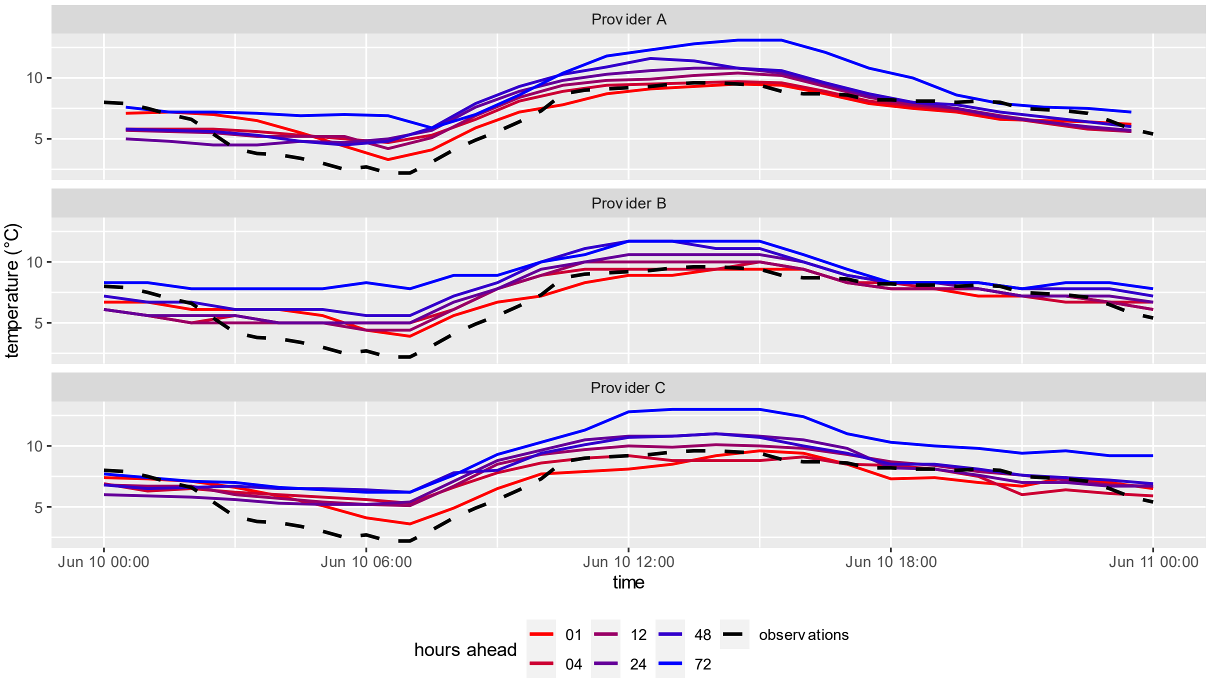
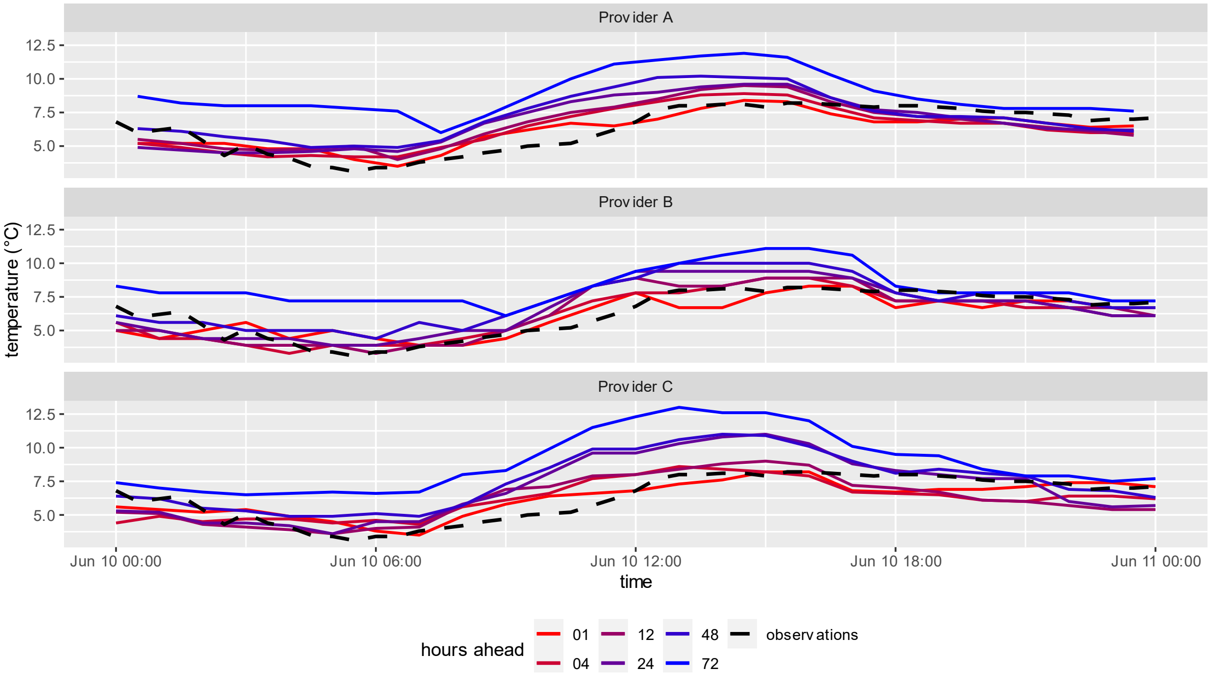


Figure 16 Forecast temperatures at various horizons against actual temperature observations for each provider at Penrith on 10 June 2021



Demand forecasts and outcomes

The extreme cold conditions drove the New South Wales operational demand to peak at 13,007 MW, the highest winter demand since 2010 (which reached 13,345 MW), noting that peak demand on this day was lowered by price-responsive industrial loads reacting to market conditions. The all-time New South Wales winter demand record is 14,289 MW set on 28 July 2008[8].

Additionally, operational demand on 10 June 2021 was the highest observed in New South Wales since summer 2019-20, surpassing the peak of the 2020-21 summer period which reached 12,546 MW (on 28 November 2020)[9].

There are four main error attributions that account for the deviation between forecast and observed demand, these are model, variability, industrial, and rooftop photovoltaic (PV) error. The definition of each of these error types can be found in the table below.

Error type	Definition
Model	Inherent deviations not captured by the demand forecast model
Variability	Deviations of forecast inputs (for example, temperature, humidity)
Industrial	Deviation of observed major industrial loads from the forecast
Rooftop PV[10]	Deviation of estimated actual rooftop PV generation from the forecast

[8] Until October 2012, the New South Wales operational demand included the Kurri Kurri aluminium smelter (300-320 MW). Winter peaks since 2012 have not included this load.

[9] Operational summer defined as 1 November to 31 March (inclusive).

[10] Rooftop PV deviations have an inverse impact on operational demand (that is, lower estimated actual rooftop PV generation results in an increase in operational demand and vice versa).

Figure 17 shows the deviation between the day-ahead operational demand forecast and the observed demand in New South Wales on 10 June 2021.

The forecast deviations during the morning, daytime and evening (see numbers 1, 2 and 3 in the figure) can be attributed to:

1. Operational demand was under-forecast across the morning peak period and up to 750 MW at the time of the morning peak. This was due to a combination of model and variability error. Model error contributed to approximately 690 MW of the deviation, with variability the remainder.

   The significant model error observed was due to the model having difficulty forecasting demand at such low temperatures, due to limited historical sample size under the observed extreme conditions. Variability error also played a role in the under-forecasting of demand, as each weather provider was unable to accurately capture the extreme morning temperatures at the 24 HA horizon, particularly at Bankstown.

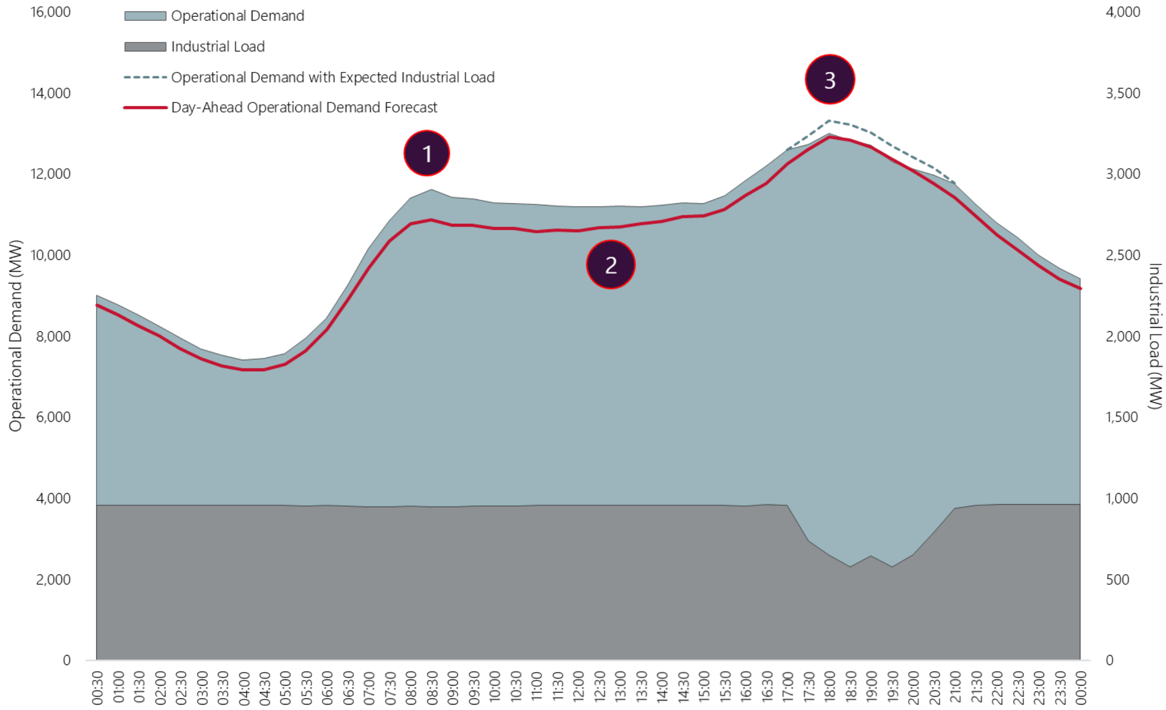
2. Under-forecasting was persistent throughout the daytime, however this was due to a combination of variability and rooftop PV error.

   Variability error was significant during the daytime as temperatures during this period, particularly the daily maximum temperature, were over-forecast at the 24 HA horizon by all providers at both Bankstown and Penrith Lakes. Rooftop PV was also over-forecast on this day and contributed to approximately 250 MW of the deviations.

3. Over the evening peak period, there was minimal deviation between the forecast and observed demand. During this time, forecasts by all providers at both weather stations captured the temperatures well at most horizons except 72 HA.

   Despite accurate forecast temperatures, at the time of the evening peak, there was approximately 340 MW of under-forecast model error present, which was balanced out by industrial error of a similar magnitude as major industrial load decreased.

Figure 17 Day-ahead operational demand forecast, observed demand, and major industrial load on 10 June 2021



This case study demonstrates the impact on demand forecasting when a combination of error attributions coincides, such as inaccurate temperature forecasts at both the long- and near-term horizons, rooftop PV deviations, inherent model errors, and changes in industrial load behaviour. These findings are consistent with the findings outlined in the *Temperature forecast Analysis for Winter 2020* report and highlight AEMO's need for accurate temperature forecasts.

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 will be shared with current and potential weather service providers to draw attention to areas of improvement and help assist 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 had the greatest improvement for all temperatures, yet a degraded accuracy at the lowest 10% of temperatures. MAEs during the lowest 10% of winter temperatures largely improved for Provider A compared with winter 2020, such that MAEs are now more aligned with Providers B and C.
- Provider B forecast performance degraded compared to winter 2020, including the lowest overall performance across all temperatures at Penrith Lakes, which continues to be challenging to forecast in winter.
- Provider C had the most accurate and precise performance overall, including at Penrith Lakes.
- At the lowest 10% of temperatures, all providers showed a tendency to over-forecast across all horizons in winter 2021.

In 2022, 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.
- Nearing conclusion of the work with Solcast, Weatherzone, and Tesla on the Australian Renewable Energy Agency (ARENA)-funded Nowcasting project to improve near-term weather forecasts in the 0-4 hour-ahead forecast horizon with promising results .
- Investigating the direct use of solar irradiance in demand forecasting to capture increased electricity demand due to heat island effects in major metropolitan areas.
- Exploring the utilisation of different weather models in the Australian Wind and Solar Energy Forecasting Systems (AWEFS/ASEFS) to better adapt the weather forecasts for renewable generation forecasting.
- Onboarding of a new weather forecast provider suitable for integration into demand forecast models. A review of the provider arrangements will take place if this assessment is favourable.

The next Temperature Forecast Analysis report, focusing on summer 2021-22, will be published later this year.

A1. Error density plots

A1.1 Station comparison by provider

Figure 18 Major weather stations, Provider A, bottom 10% winter temperatures 2020 and 2021, 24 HA

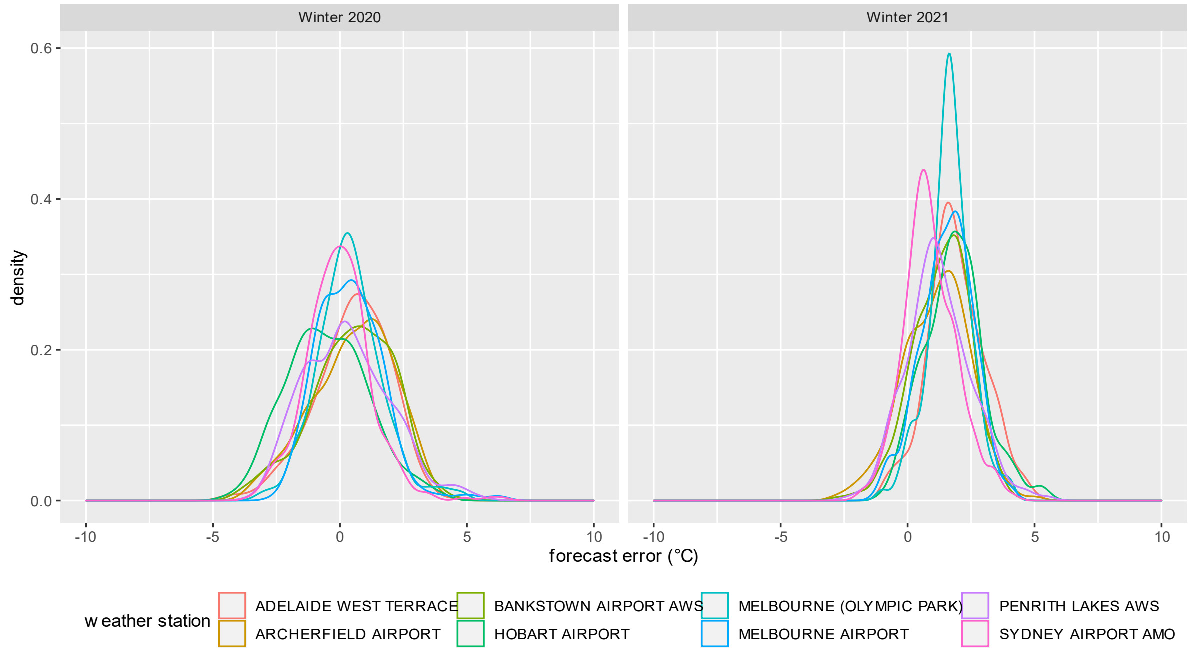


Figure 19 Major weather stations, Provider B, bottom 10% winter temperatures 2020 and 2021, 24 HA

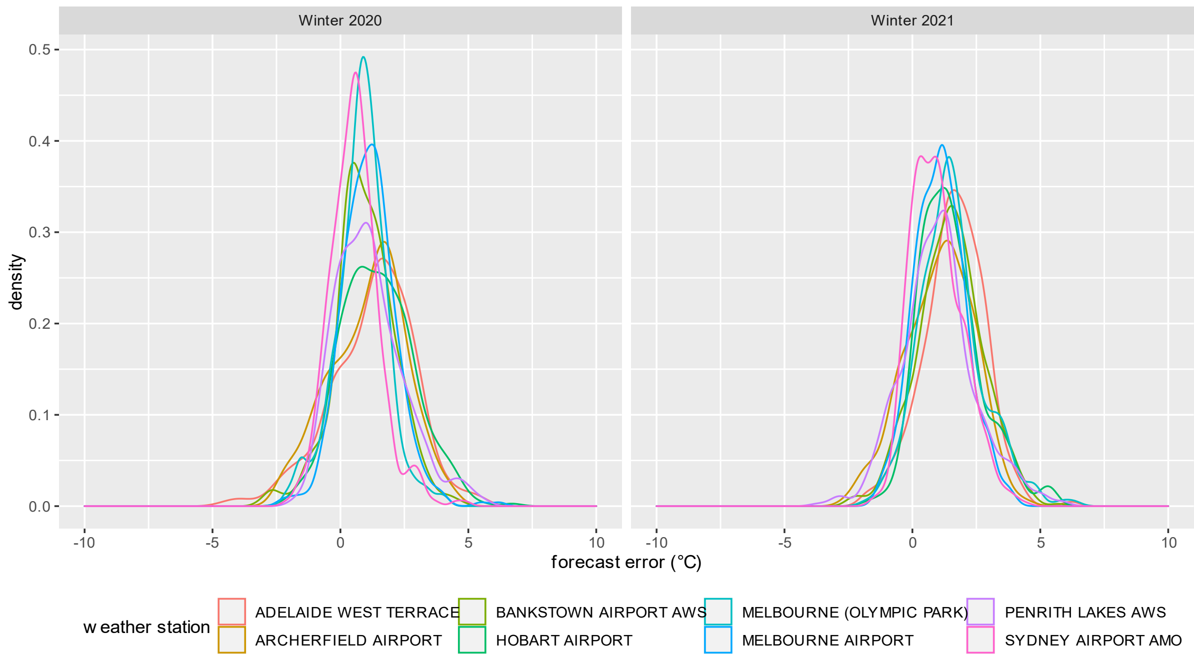
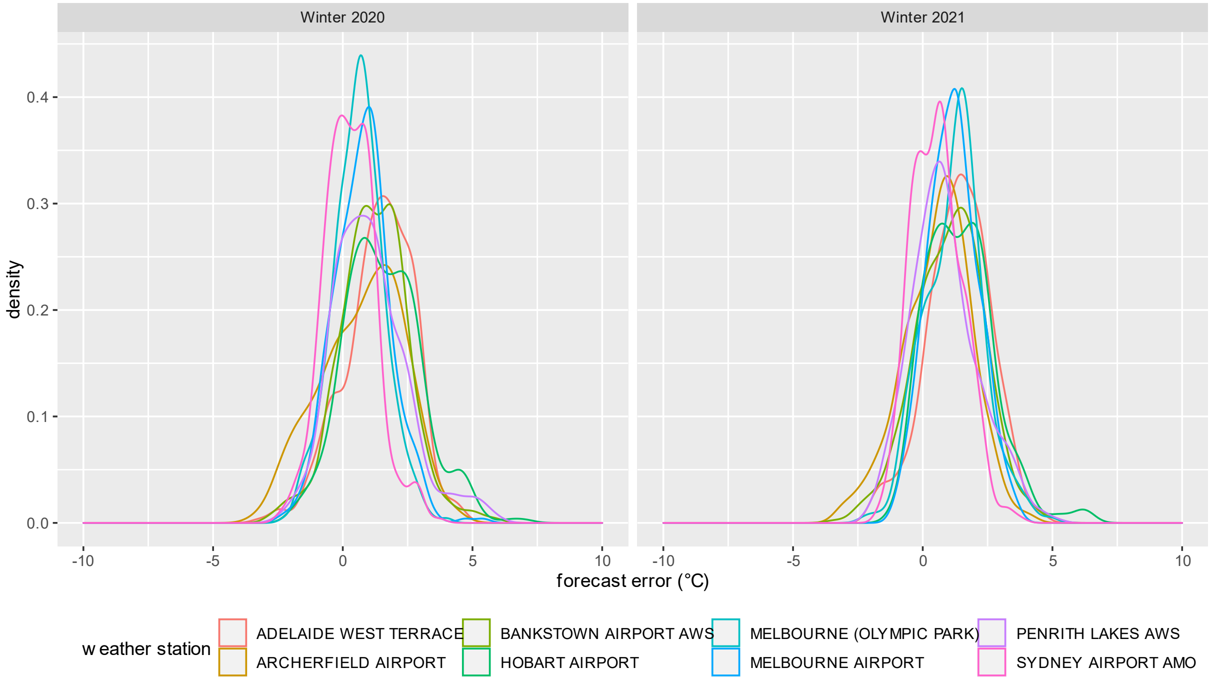


Figure 20 Major weather stations, Provider C, bottom 10% winter temperatures 2020 and 2021, 24 HA



A1.2 Provider comparison by weather station

Figure 21 Adelaide WT, all providers, all winter temperatures 2020 and 2021, all time horizons

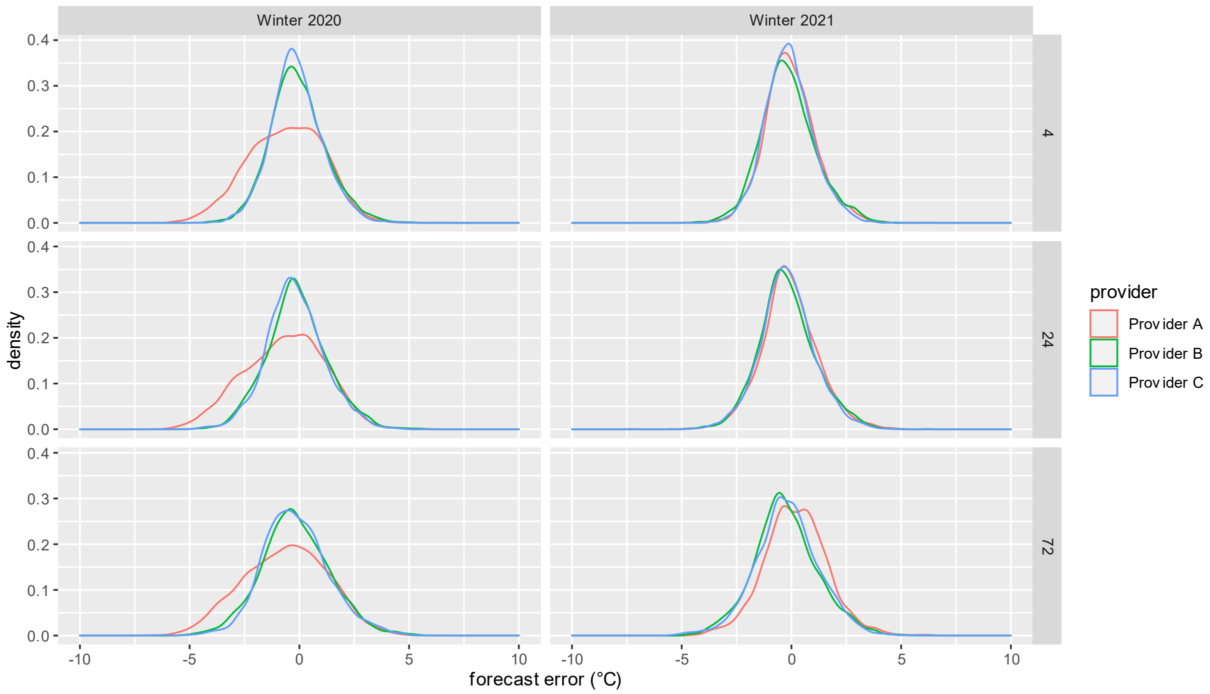


Figure 22 Archerfield AP, all providers, all winter temperatures 2020 and 2021, all time horizons

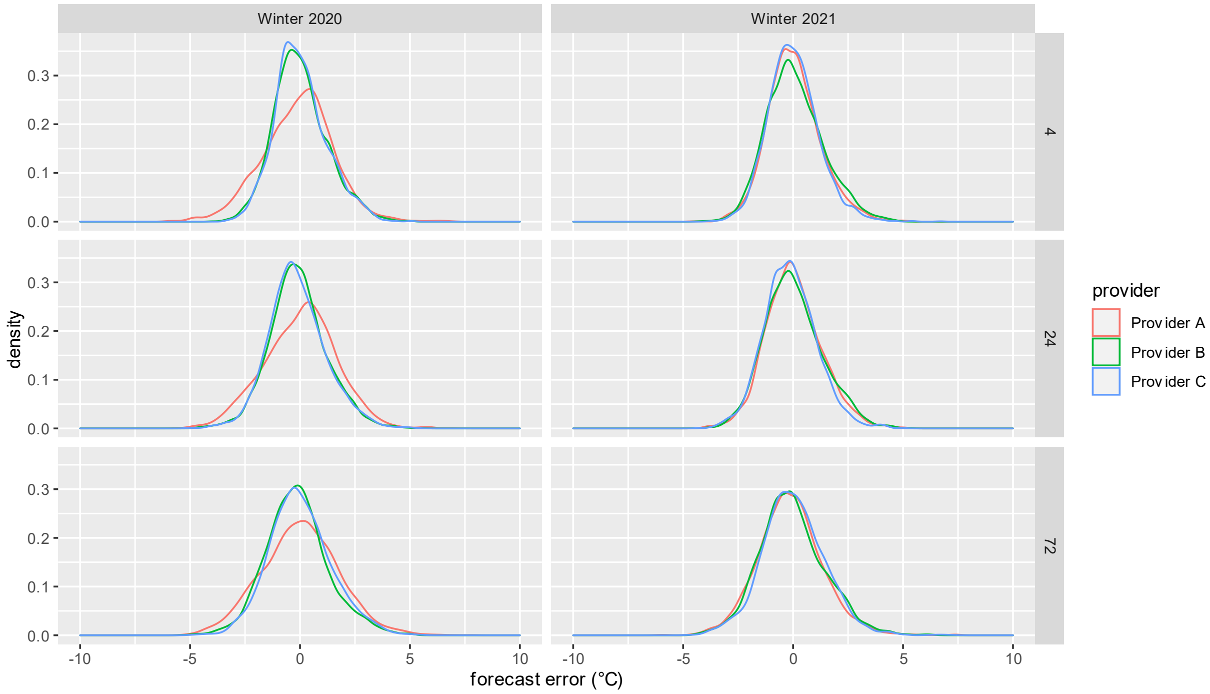


Figure 23 Bankstown AP, all providers, all winter temperatures 2020 and 2021, all time horizons

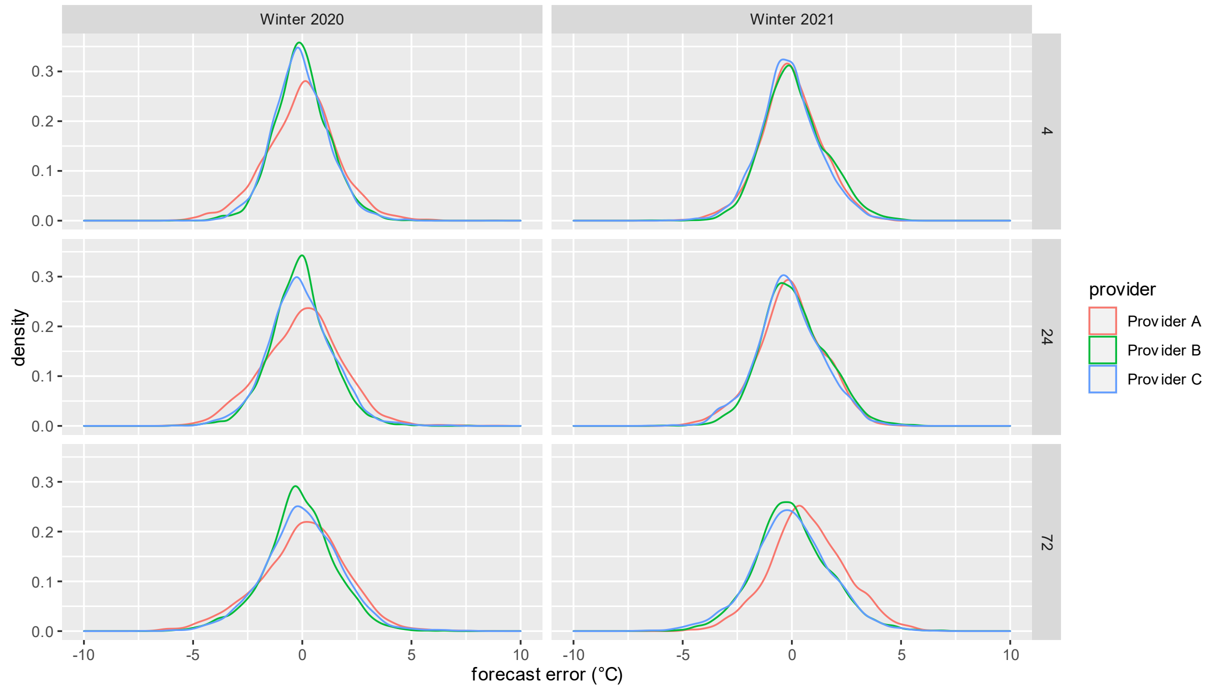


Figure 24 Hobart AP, all providers, all winter temperatures 2020 and 2021, all time horizons

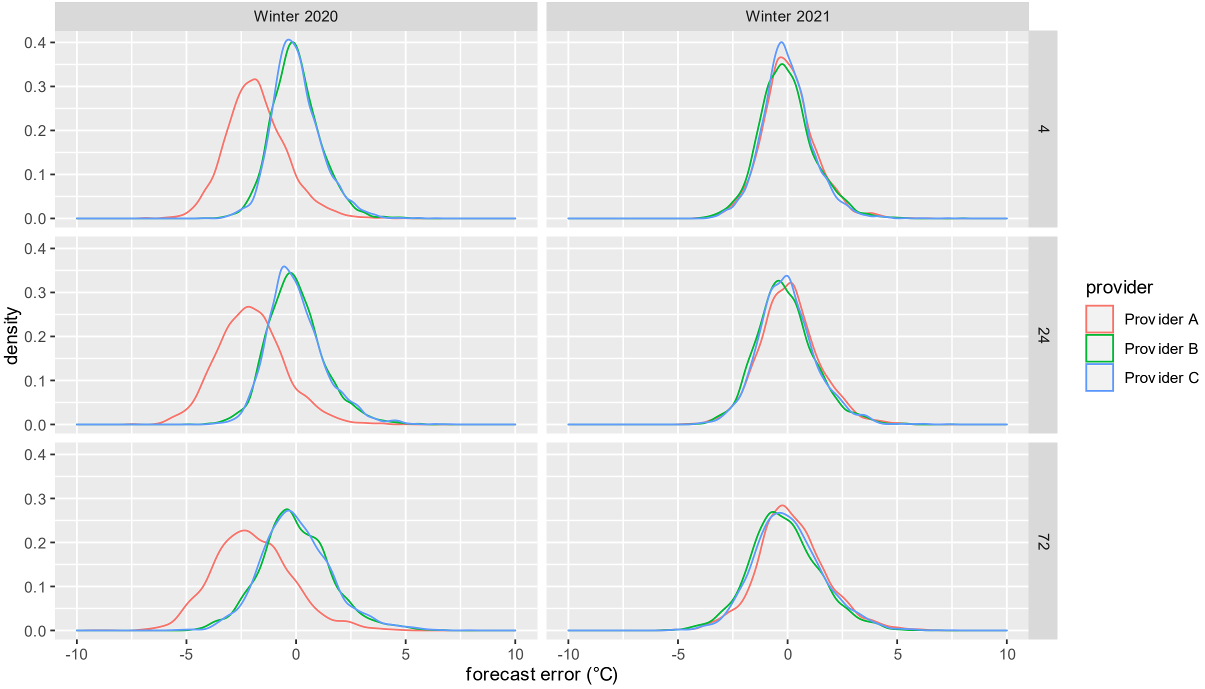


Figure 25 Melbourne AP, all providers, all winter temperatures 2020 and 2021, all time horizons

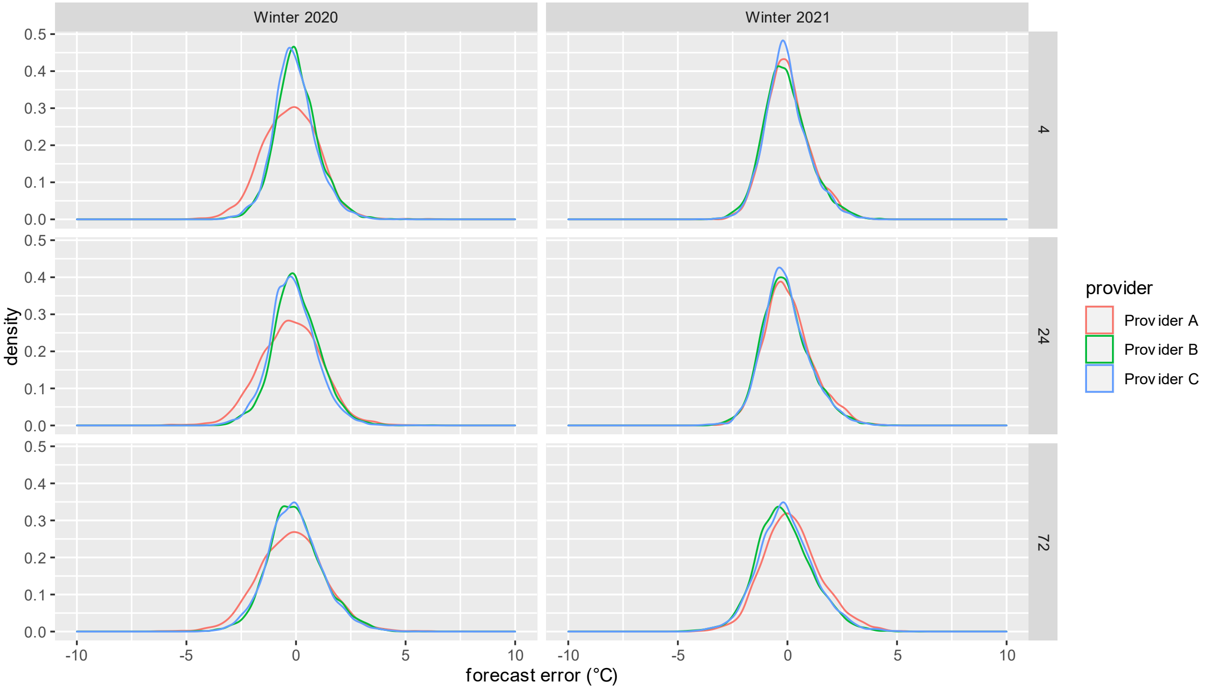


Figure 26 Melbourne OP, all providers, all winter temperatures 2020 and 2021, all time horizons

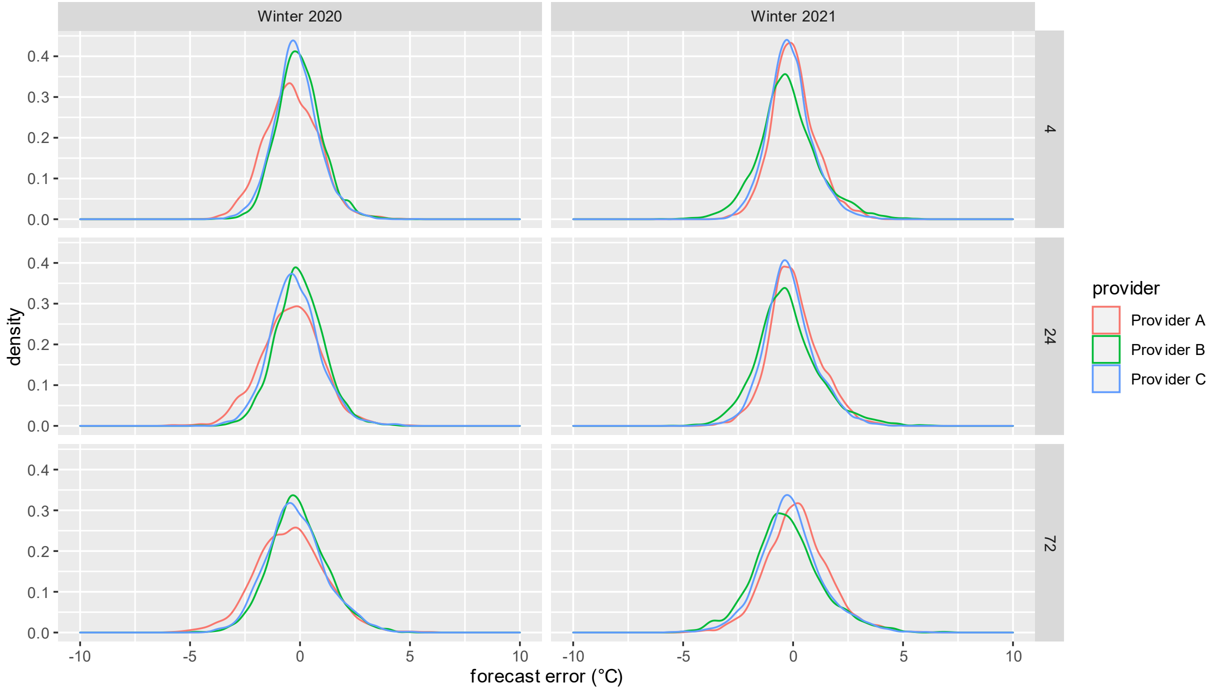


Figure 27 Penrith Lakes, all providers, all winter temperatures 2020 and 2021, all time horizons

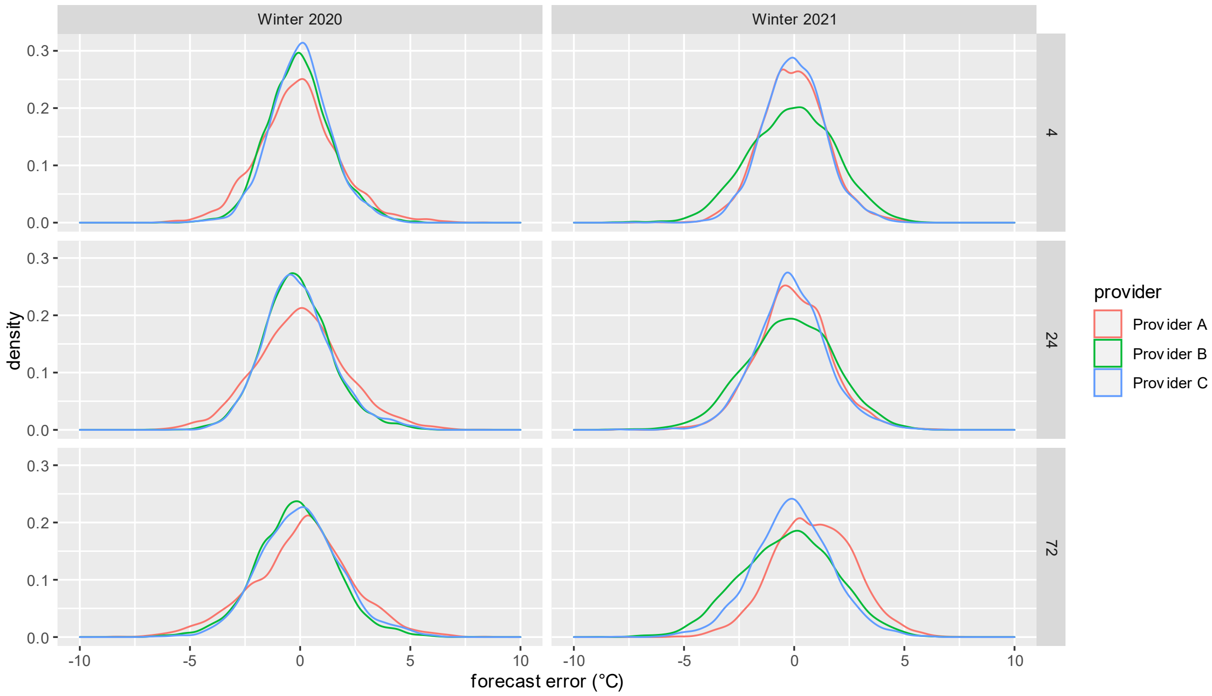
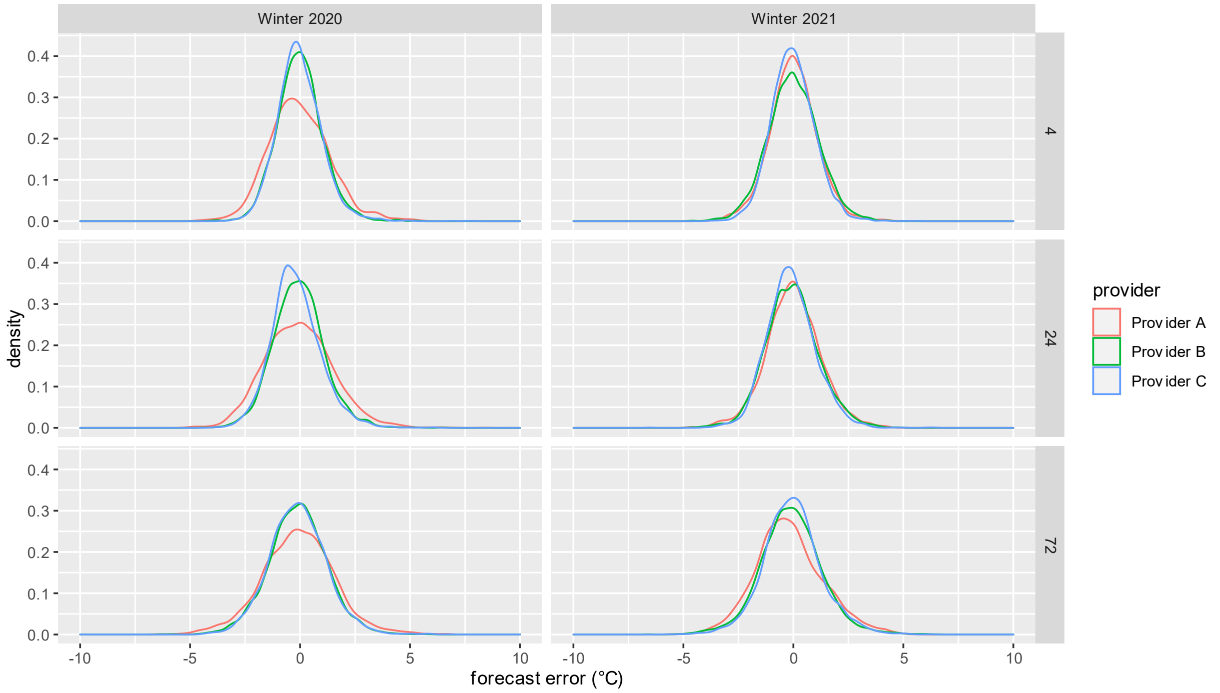


Figure 28 Sydney AP, all providers, all winter temperatures 2020 and 2021, all time horizons



A2. Intraday MAE profiles

Figure 29 Adelaide WT, intraday MAE profile, all providers, winter 2020 and 2021, all time horizons, lowest 10% of temperatures

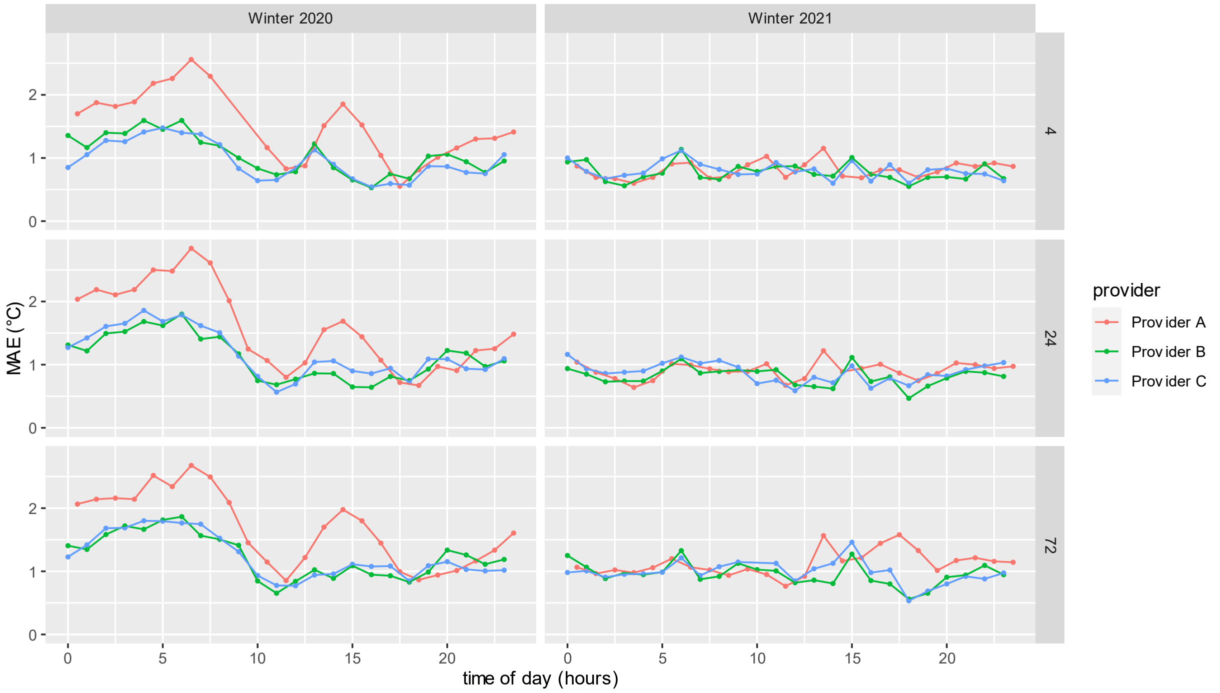


Figure 30 Archerfield AP, intraday MAE profile, all providers, winter 2020 and 2021, all time horizons, lowest 10% of temperatures

Figure 31 Bankstown AP, intraday MAE profile, all providers, winter 2020 and 2021, all time horizons, lowest 10% of temperatures

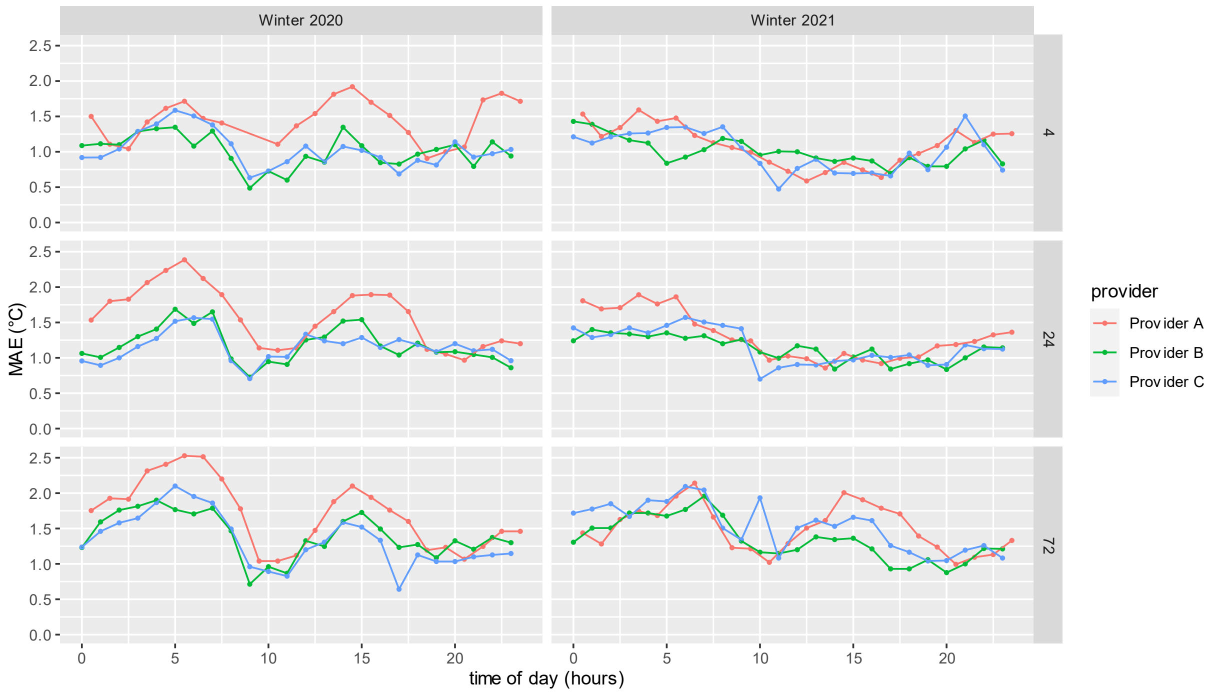


Figure 32 Hobart AP, intraday MAE profile, all providers, winter 2020 and 2021, all time horizons, lowest 10% of temperatures

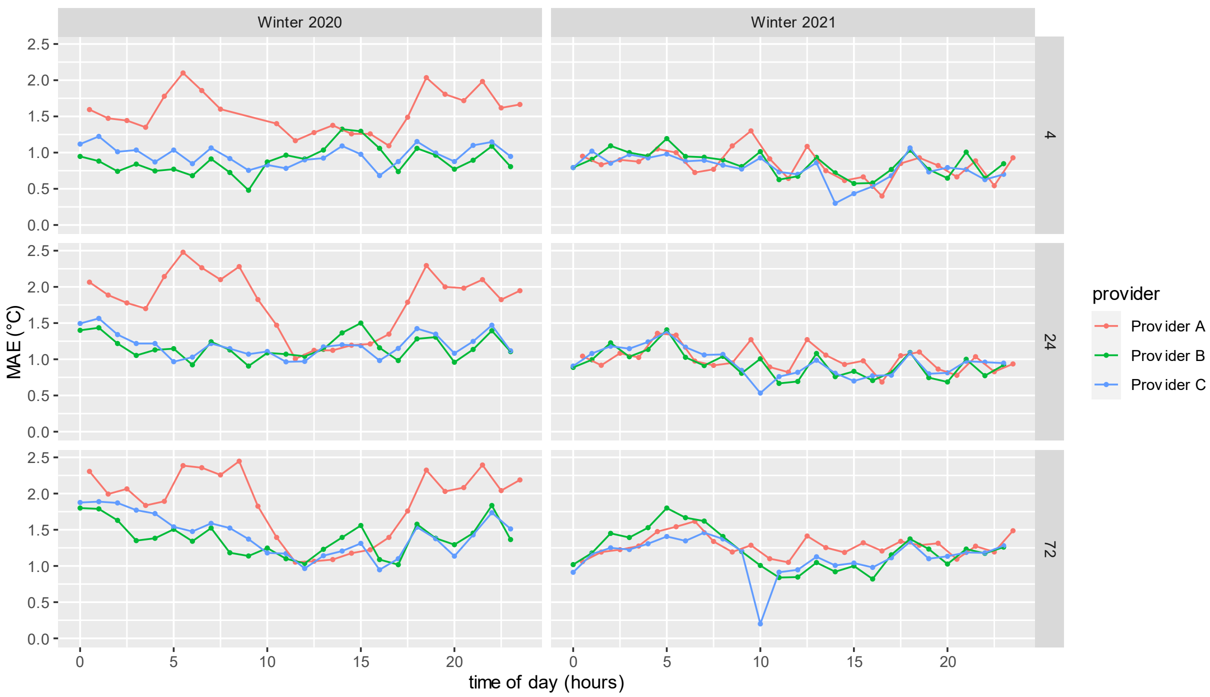


Figure 33 Melbourne OP, intraday MAE profile, all providers, winter 2020 and 2021, all time horizons, lowest 10% of temperatures

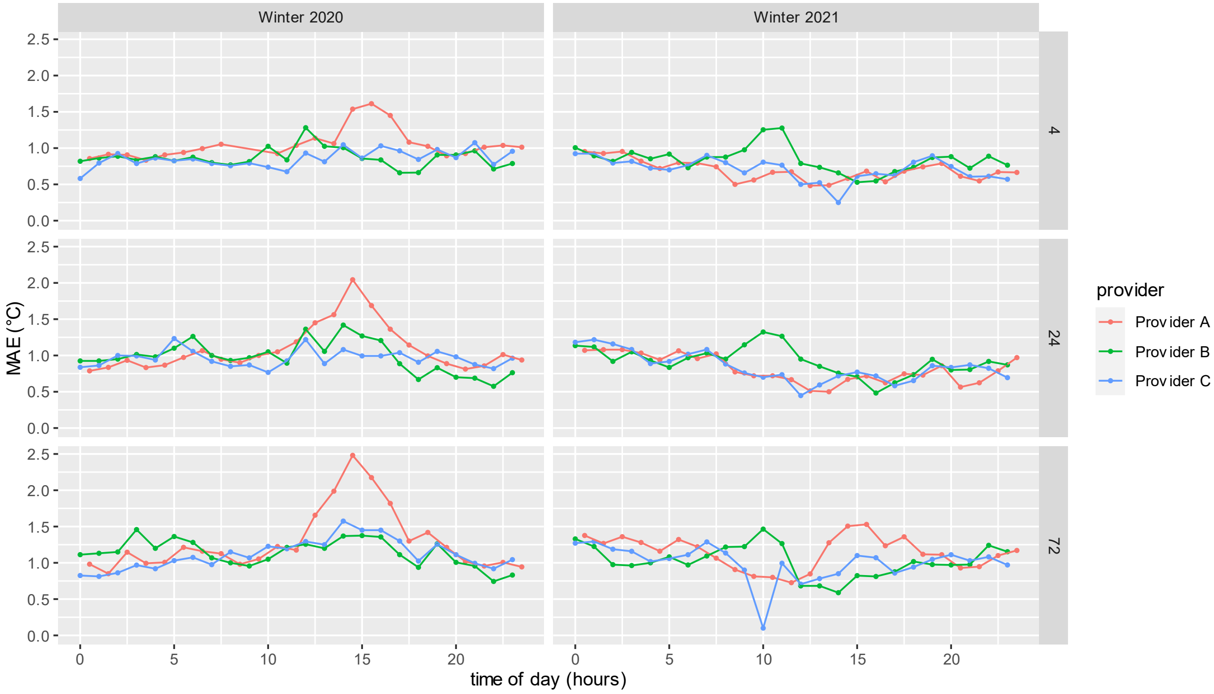


Figure 34 Melbourne AP, intraday MAE profile, all providers, winter 2020 and 2021, all time horizons, lowest 10% of temperatures, lowest 10% of temperatures

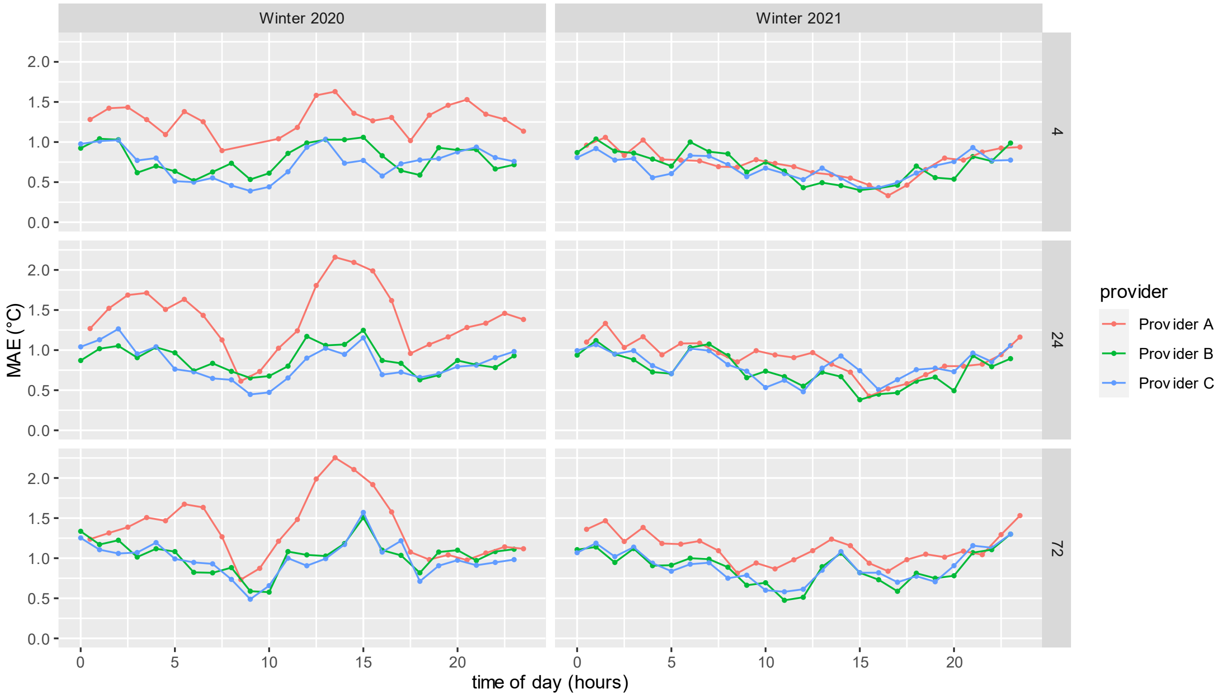


Figure 35 Penrith Lakes, intraday MAE profile, all providers, winter 2020 and 2021, all time horizons, lowest 10% of temperatures

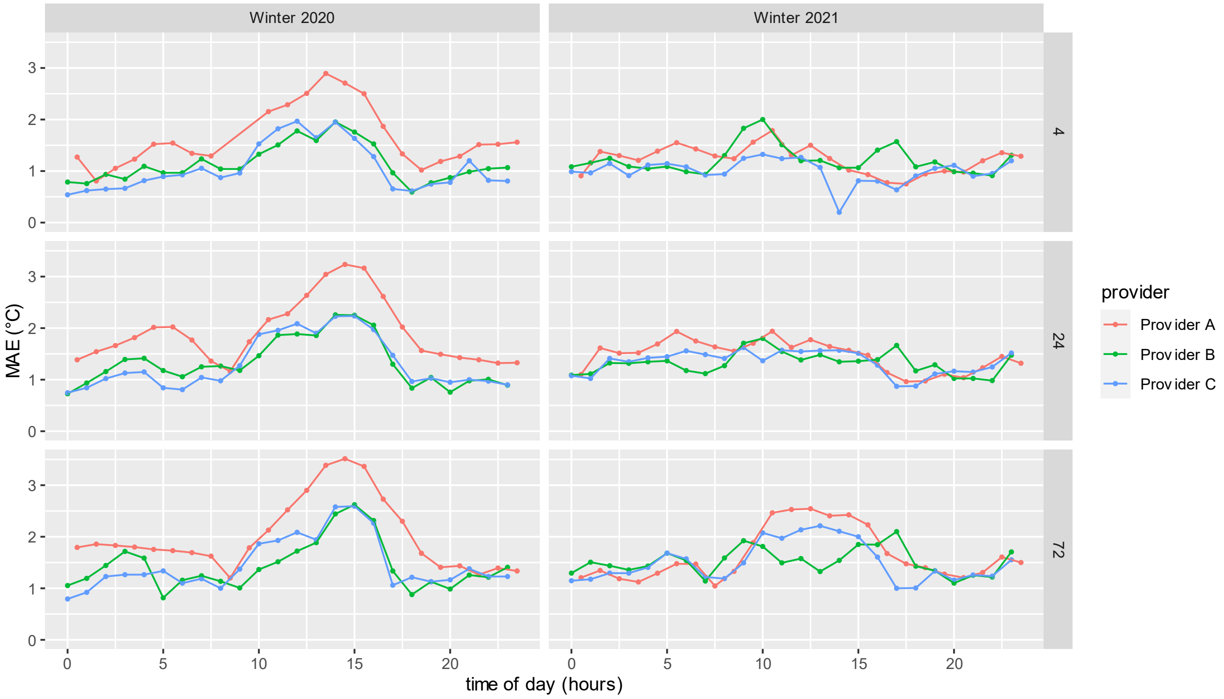


Figure 36 Sydney AP, intraday MAE profile, all providers, winter 2020 and 2021, all time horizons, lowest 10% of temperatures