Temperature Forecast Analysis for Summer 2021-22

August 2022

A report assessing the forecast precision and accuracy of AEMO's operational weather providers in the National Electricity Market from 1 December 2021 to 31 March 2022

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 National Electricity Market during the 2021-22 summer period.
- Give any intending weather providers information to assess the relative performance of their forecasts.
- Facilitate discussion and ongoing improvement of temperature forecast accuracy.

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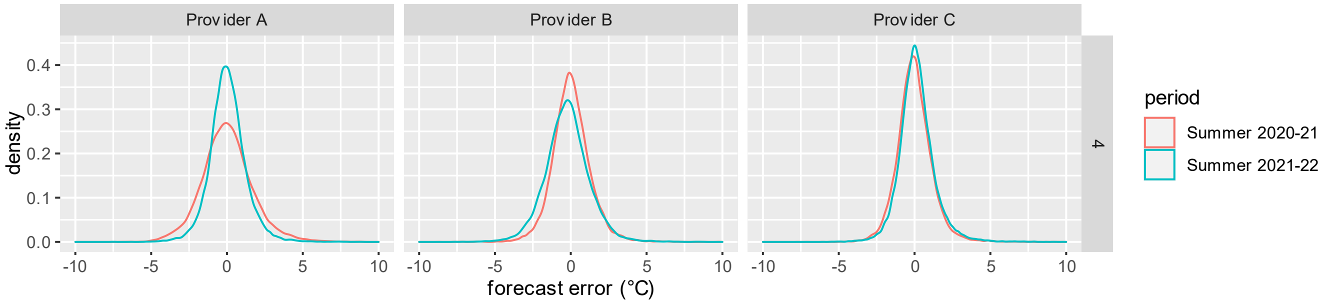
Glossary

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 paper.
Accuracy vs. 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 temperature forecast performance of AEMO's weather service providers in the National Electricity Market (NEM) from 1 December 2021 to 31 March 2022. 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 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.

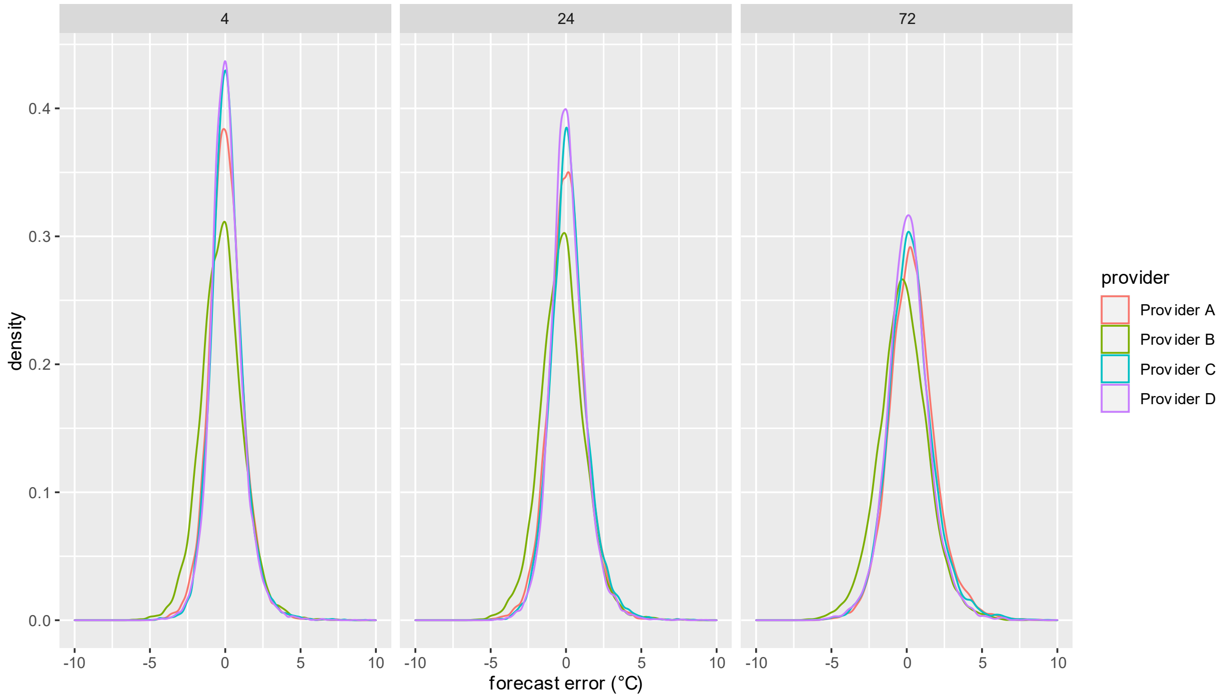
Figure 1 4 HA summer performance comparison across major weather stations, all temperatures



Key findings from summer 2021-22 performance analysis of AEMO's three weather forecast providers (see Figure 2) are:

- **Provider A** had the greatest overall improvement in both accuracy and precision when considering all temperatures in summer 2021-22, but reduced accuracy for the top 10% of temperatures. Provider A had a greater tendency to under-forecast the top 10% of temperatures compared to its performance in summer 2020-21.
- **Provider B** performance degraded in summer 2021-22 when compared to summer 2020-21. Significant degradation in winter forecast performance was also noted in the *Temperature Forecast Analysis for Winter 2021* report. Due to ongoing performance degradation, Provider B has been removed as one of AEMO's operational weather providers.
- **Provider C** demonstrated the most accurate and precise forecast performance of all providers in summer 2021-22. Provider C also delivered the most accurate forecasts (but not the most precise) at the top 10% of temperatures in summer 2021-22 for the forecast horizons considered in this report.
- **Provider D** was onboarded by AEMO in late summer 2021-22 and showed strong performance compared to other providers in the period 1 February to 31 March 2022. Provider D demonstrated accuracy and precision on par with Provider C, with slight under-forecasting tendencies at the top 10% of temperatures comparable to those of the other three providers.

Figure 2 February and March 2022 performance across all major weather stations and temperatures, including new Provider D



This report also includes a case study to discuss the impact of thunderstorms on temperature forecast performance on 2 February 2022 in Queensland.

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[1].
- Investigating the direct use of solar irradiance in demand forecasting to capture increased electricity demand due to irradiation effects due to building properties such as black roofs.
- Continued enhancement of Australian Wind and Solar Energy Forecasting Systems (AWEFS/ASEFS) to better adapt the weather forecasts for renewable generation forecasting.
- Analysis of the optimal weighting of Provider D in AEMO's demand forecast models to take place following initial performance verification. This will result in a higher weighting of Provider D feeds in the final demand forecast if performance remains favourable.
- Establishment of new weather observation stations located with renewable energy zones (REZs) near remote variable renewable energy (VRE) generators and in metropolitan heat islands to support weather forecasting.

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

Contents

Figures

1 Introduction

This report examines the temperature forecast performance of AEMO's three weather service providers in the National Electricity Market (NEM) from 1 December 2021 to 31 March 2022[2]. It also examines the performance of AEMO's new weather provider (Provider D) over the period 1 February to 31 March 2022.

This report aims to highlight the differences in forecasting performance between summer 2020-21 and 2021-22, while also drawing new performance insights from the summer 2021-22 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[3].

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 performance to support power system operation in the NEM and the broader energy industry. It also includes a case study to discuss the impact of thunderstorms on temperature forecast performance on 2 February 2022 in Queensland.

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 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.

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 performance 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 weather providers to produce accurate and precise temperature forecasts on these days.

Figure 3 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[4].

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.

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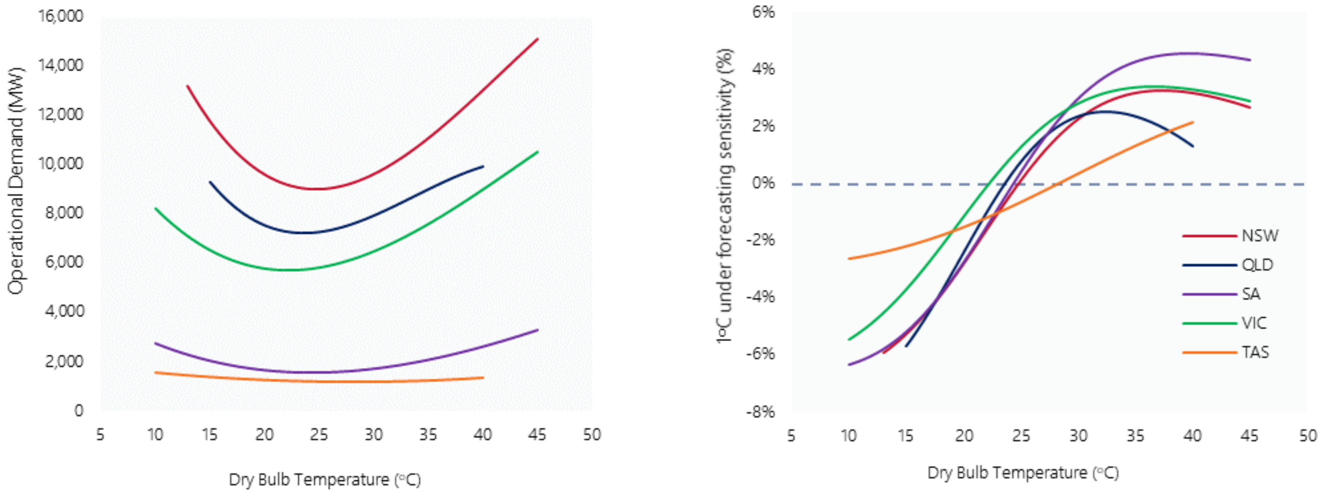
[2] All analysis refers to time in Australian Eastern Standard Time (AEST).

[3] 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.

[4] This analysis shows the relationship of maximum daily dry bulb temperature and 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 – Adelaide West Terrace, 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 3 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



Load growth in the NEM

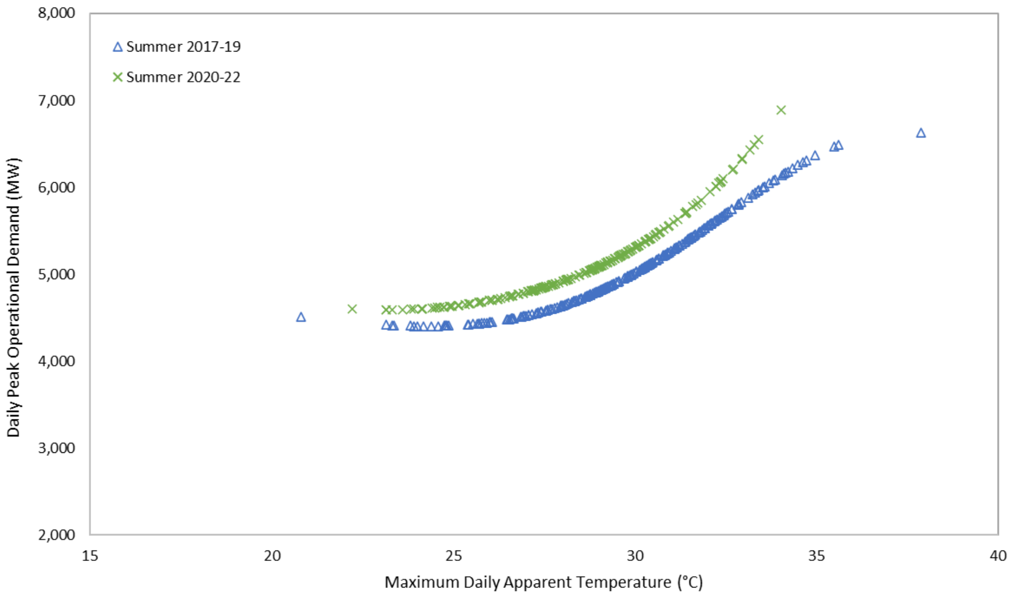
Over the past couple of years, there has been an increase in the proportion of people working from home. This in turn has elevated residential load and increased the temperature sensitivity of demand overall, particularly at extreme temperatures when there are significant heating and cooling loads.

In addition to increased temperature sensitivity, underlying load growth in select NEM regions has become apparent. Figure 4 demonstrates this for southern Queensland by showing daily maximum demand for weekdays in summer between 2017 and 2022 for different maximum daily apparent temperatures.

Compared to days between 2017-19, there is an apparent increase in demand for all temperatures during the 2020-22 summers, with a greater magnitude, or flex, at extreme temperatures. Northern Queensland also showed an increase in demand but was only material at extreme temperatures.

Analysis was performed for other NEM regions, however no underlying load growth was identified outside of extreme temperature flex.

Figure 4 Summer weekday maximum daily operational demand against maximum daily apparent temperature for southern Queensland



Humidity impact on summer electricity demand

Humidity's impact on electricity demand is felt most when it is combined with high dry bulb temperatures. In warm, humid weather, moisture in the air can impede the body's ability to cool down, making people feel hotter for longer. This in turn drives demand for electricity demand through air-conditioning. Also, when humidity levels are high, it negatively affects the cooling efficiency of air-conditioning units, meaning they consume more electricity.

The weather concept that best describes this relationship between humidity and the need for cooling is the dew point, which is the temperature to which air must be cooled to produce condensation (dew). Dew point is related to the quantity of moisture, while relative humidity expresses how close the air is to saturation. Because of its direct relationship to fluctuating temperature, relative humidity doesn't provide suitable guidance on how much moisture is available at a specific location.

The conditions someone is accustomed to, as well as their metabolism, vary the way dew point is experienced. For those living in Brisbane, a dew point above 20˚C would start to feel muggy and uncomfortable, but this same dew point would feel considerably oppressive in Melbourne where people are less acclimatised to this type of weather[5].

The accuracy of humidity forecasts is most critical for operational demand forecasting when temperatures are high and therefore so is demand. These conditions are typically only encountered on hot summer days in the northern states such as Queensland, although specific weather patterns can push high humidity into the southern parts of Australia.

[5] The weather concept of dew point provides a gauge of the impact of the combination of temperature and humidity and helps infer what the conditions may feel like. For more information on dew point visit https://media.bom.gov.au/social/blog/1324/feeling-hot-and-bothered-its-notthe-humidity-its-the-dew-point/

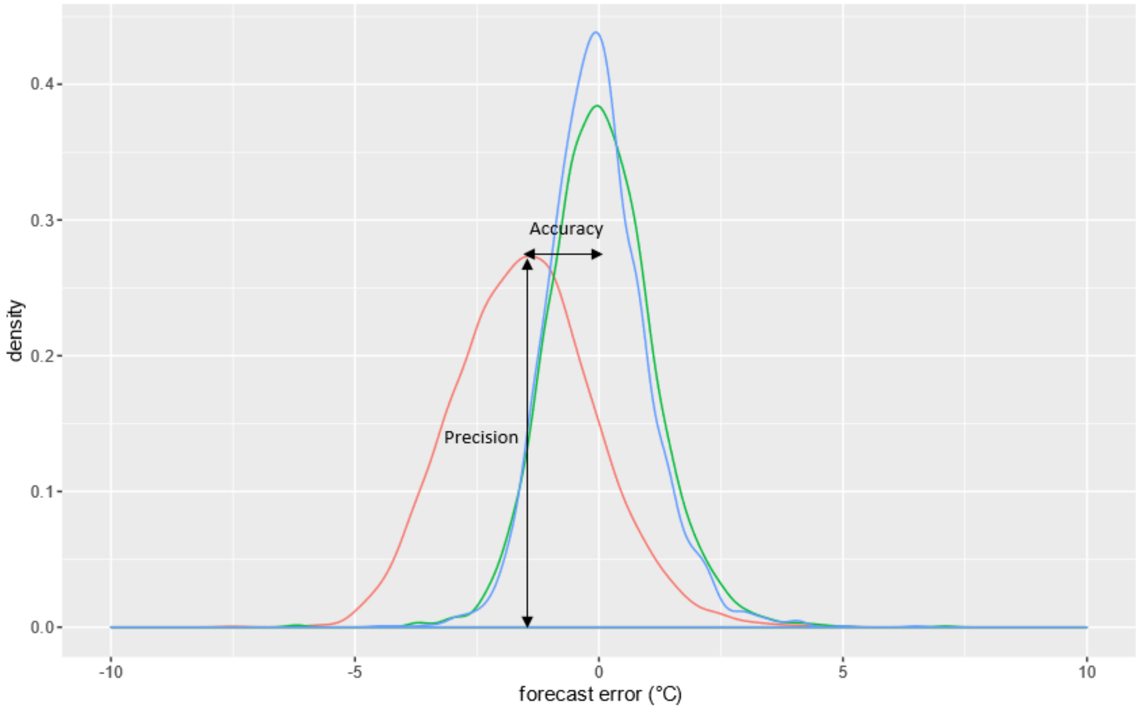
2 Summer forecast performance

This section contains a selection of temperature forecasting performance insights for summer 2021-22 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 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 5 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 5, 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 5, the forecast distribution in red is less accurate than the forecast distributions in green and blue.

Figure 5 Accuracy and precision in the error density plot



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 initial results for Provider D performance for the months of March and February 2022.

2.1 Overall performance

Weather conditions in summer 2021-22

During summer 2021-22, national mean temperatures were 0.73˚C above the long-term average, with daytime and overnight temperature above to very much above average for most of Australia. Daytime temperatures were above to well above average for most of Western Australia, including Perth, northern Australia, far south-eastern South Australia, most of Victoria except the north-east and East Gippsland, and all of Tasmania[6].

The active La Niña drove cooler than average daytime temperatures for much of eastern New South Wales, including Sydney, and adjacent inland southern Queensland. The La Niña also drove above average rainfall along the east coast, from the Wide Bay district of Queensland to East Gippsland in Victoria, with many sites recording their highest total summer rainfall on record. Significant rainfall totals over the last week of February resulted in widespread flooding in south-east Queensland and parts of northern New South Wales, causing extensive damage. In addition, rainfall was well above average across Greater Sydney in March 2022 with many parts receiving 3 to 5 times their monthly average, as well as their highest monthly total on record. This resulted in significant flash flooding across Sydney, along with major flooding in the Hawkesbury-Nepean catchment[7].

While maximum temperatures were above average for parts of the NEM, extreme temperatures did not reach record levels, with Adelaide the only NEM centre to exceed 40˚C (on one occasion), therefore relatively moderate peak electricity demand was observed during summer. An exception to this was Queensland, where extreme humidity events drove extreme electricity demand. The first was on 2 February 2022, where hot and humid conditions saw operational demand reach 9,831 megawatts (MW), just below the record of 10,044 MW on 13 February 2019 (see Case Study in Section 3). Following this, on 8 March 2022, another extreme humidity event saw dewpoints reach 26˚C at Archerfield, which drove a new Queensland operational demand record of 10,058 MW.

Overall summer 2021-22 performance insights

Figure 6 and Figure 7 below show the performance comparison of 2020-21 and 2021-22 summer 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 summer 2021-22 but had reduced accuracy for the top 10% of temperatures, with a greater tendency to under-forecast compared to its performance in summer 2020-21.
- **Provider B performance degraded in summer 2021-22** with significant reduction in forecasting accuracy for all temperatures in summer, as well as for the top 10% of temperatures, when compared to summer 2020-21. Significant degradation in winter forecast performance was also noted in the Temperature Forecast Analysis for Winter 2021 report. Due to ongoing performance degradation, Provider B has been removed as one of AEMO’s operational weather providers.

[6] Australia in Summer 2021-22, Bureau of Meteorology, at http://www.bom.gov.au/clim_data/IDCKGC2AR0/202202.summary.shtml

[7] Greater Sydney in March 2022, Bureau of Meteorology, at http://www.bom.gov.au/climate/current/month/nsw/archive/202203.sydney.shtml

- **Provider C produced the most accurate and precise overall performance in summer 2021-22**, consistent with winter forecast performance noted in the Temperature Forecast Analysis for Winter 2021 report. Provider C delivered the most accurate forecasts at the top 10% of temperatures in summer 2021-22 for the forecast horizons considered in this report.
- **Provider D shows indicative promising performance on par with Provider C** following onboarding during Summer 2021-22, with slight under-forecasting tendencies at the top 10% of temperatures comparable to that of the other three providers. To fairly compare performance, Provider D analysis only considers the months of February and March, with further commentary in Section 2.5.

Figure 6 Summer 2020-21 and 2021-22 performance comparison across major weather stations, all temperatures

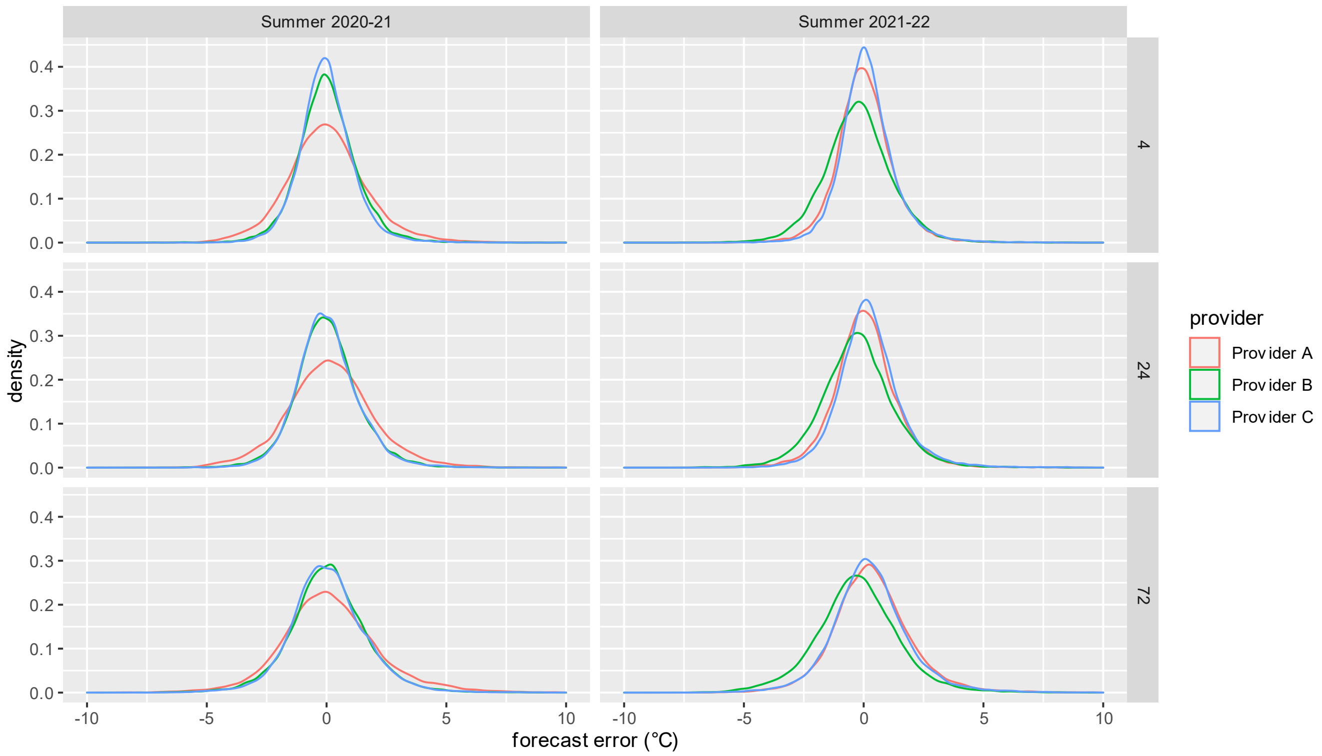
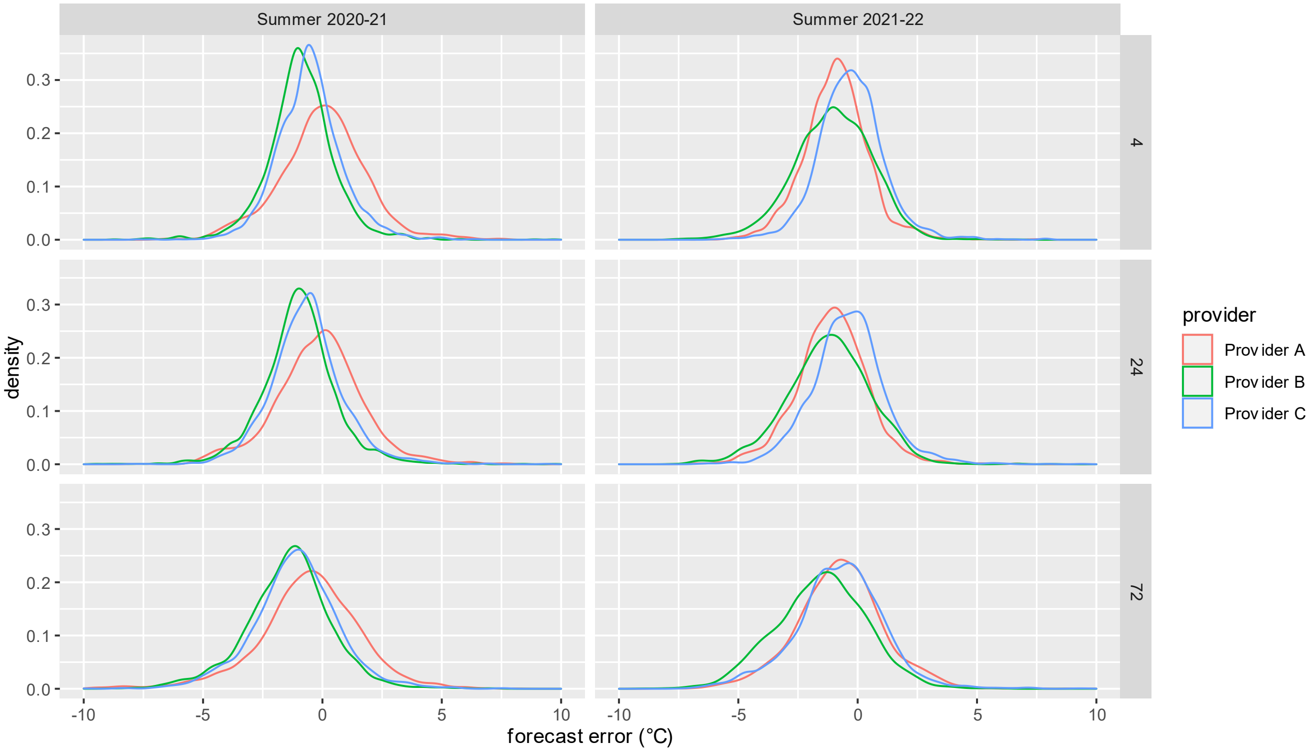


Figure 7 Summer 2020-21 and 2021-22 performance comparison across major weather stations, top 10% of temperatures



2.2 Provider A forecast performance

Provider A had the greatest performance improvement for all temperatures, but an increased tendency to under-forecast at the top 10% of temperatures.

In the *Temperature Forecast Analysis for Winter 2021* report, a considerable improvement in winter forecasting performance was observed following a switch to improved forecast feeds, with a change in the way forecast data is assimilated, in March 2021. Similarly, Provider A's forecast accuracy and precision improved significantly during summer 2021-22 across all temperatures when compared to summer 2020-21. This can be seen in Figure 8.

In summer 2020-21, Provider A was the lowest performing provider across all temperatures for the major weather stations. When looking at MAE profiles in Appendix A2, which show the magnitude of the absolute average error for each hourly interval, Provider A performance improved to be comparable to Provider B and C, and for Bankstown Provider A is now the best performer. One of the most notable improvements is at Hobart Airport, with signification reductions in MAE also observed during the top 10% of temperatures, as seen in Figure 9.

Figure 8 Major weather stations, Provider A, all summer temperatures 2020-21 and 2021-22, 24 HA

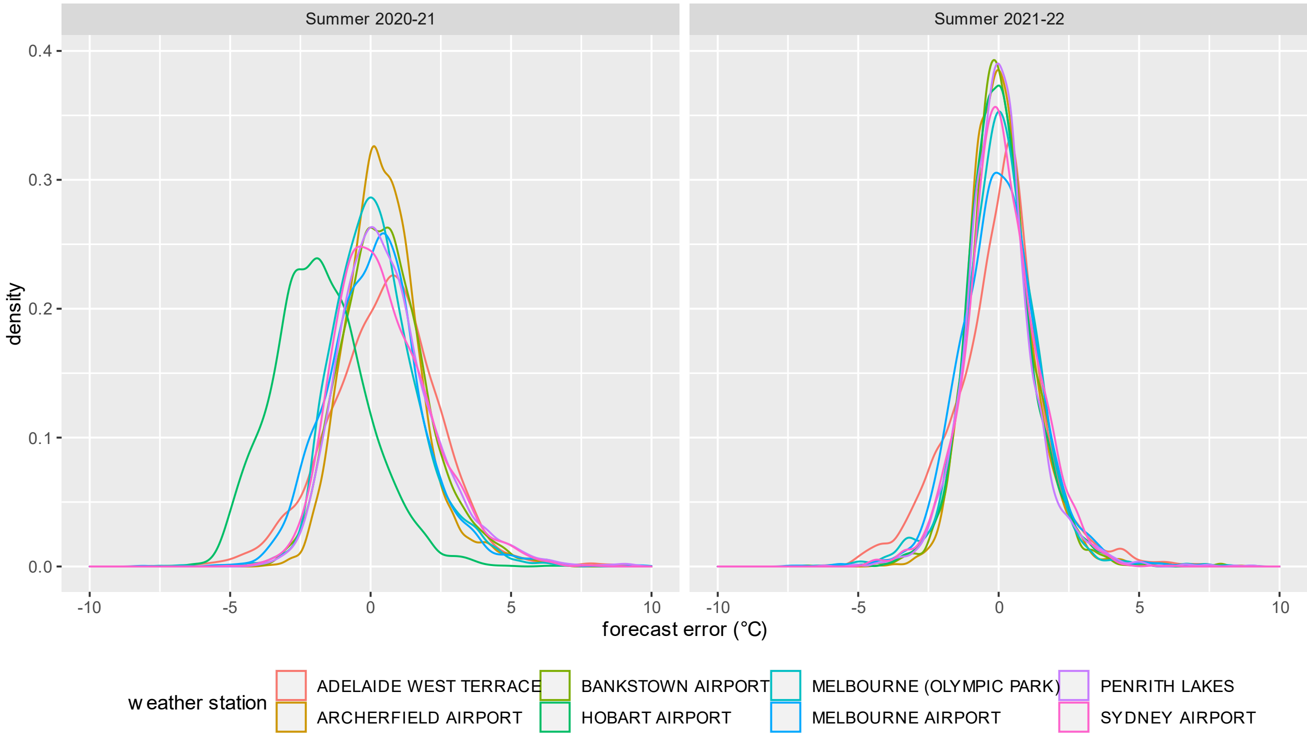
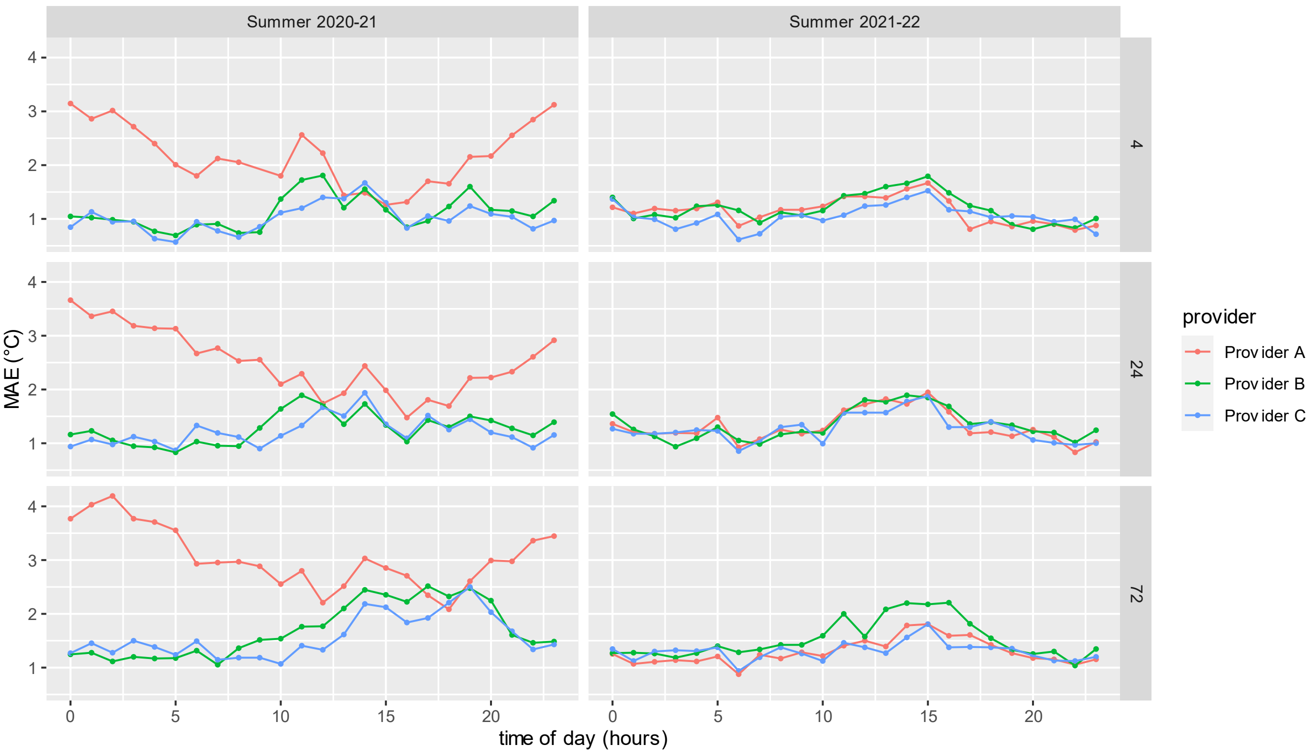
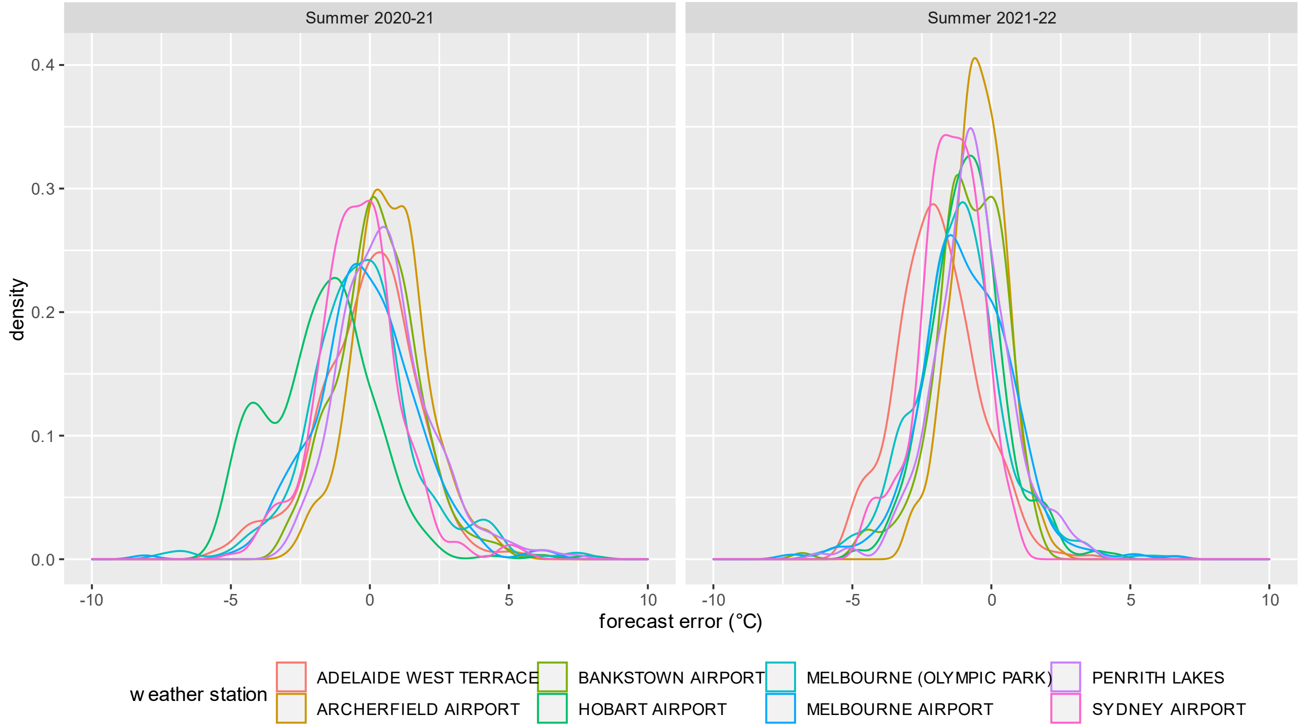


Figure 9 Hobart Airport, intraday MAE profile, top 10% temperatures, summer 2020-21 and 2021-22, all horizons



However, compared to summer 2020-21, Provider A demonstrated an increased tendency to under-forecast at the top 10% of temperatures for 4 HA and 24 HA forecast horizons, with a focus on the 24 HA horizon performance for major stations shown in Figure 10 below.

Figure 10 Major weather stations, Provider A, top 10% summer temperatures 2020-21 and 2021-22, 24 HA



2.3 Provider B forecast performance

Provider B forecast performance degraded when compared to summer 2020-21.

In the *Temperature Forecast Analysis for Winter 2021* report, a considerable degradation in winter forecasting performance was observed when compared to winter 2020. Similarly, Provider B's overall forecast performance degraded significantly in accuracy and precision for summer 2021-22, especially at top 10% of temperatures, when compared to summer 2020-21. This can be seen in Figure 24 and Figure 25 (Appendix A1.1) with a focus on the 24 HA horizon performance for major stations shown in Figure 11 and Figure 12 below.

When looking at MAE profiles in Appendix A2, Provider B has demonstrated significant degradation in overall performance at some major weather stations including Archerfield, Melbourne OP, Melbourne AP, and Penrith Lakes. In particular, Provider B had a greater tendency to under-forecast at Penrith Lakes when compared to summer 2020-21 performance, while Provider A and B both improved in performance, as can be seen in Figure 13 below.

Due to ongoing performance degradation, Provider B has been removed as one of AEMO's operational weather providers. A new provider was onboarded in late summer 2021-22 (Provider D) and is to replace Provider B as an input into demand forecasting models following performance verification.

Figure 11 Major weather stations, Provider B, all summer temperatures 2020-21 and 2021-22, 24 HA

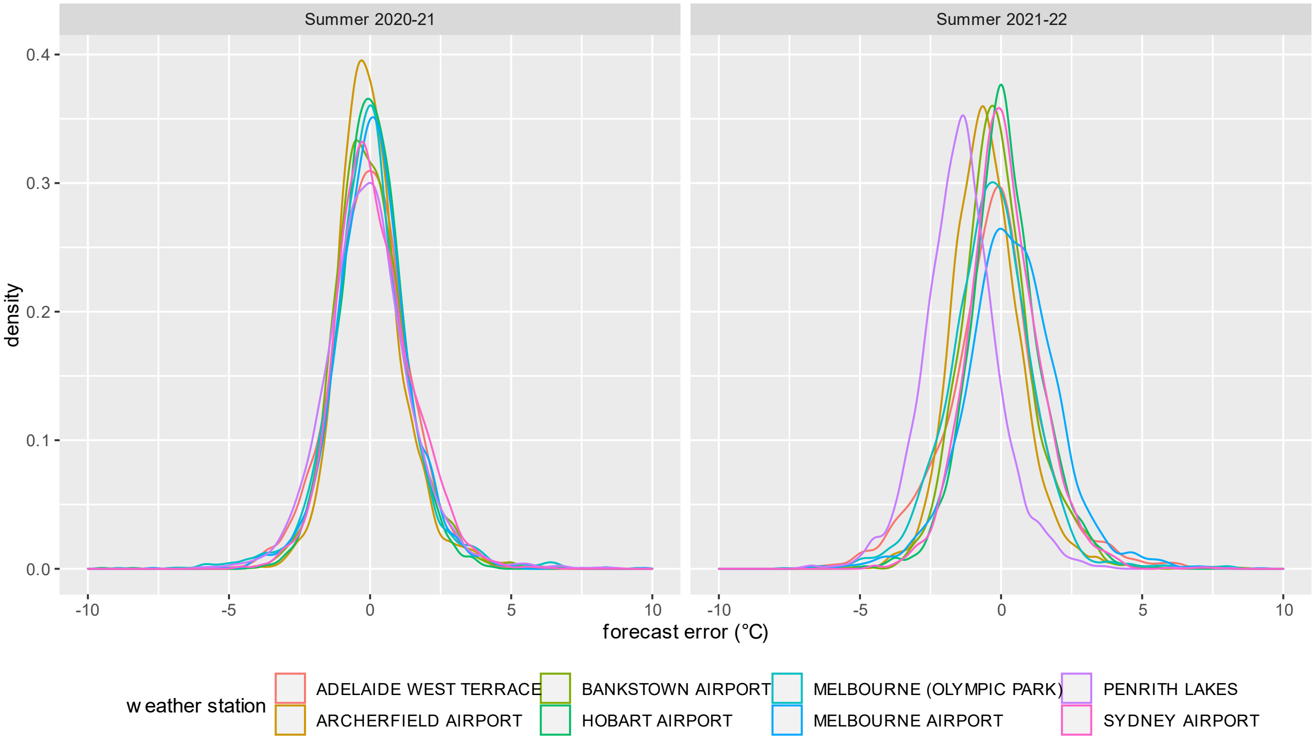


Figure 12 Major weather stations, Provider B, top 10% summer temperatures 2020-21 and 2021-22, 24 HA

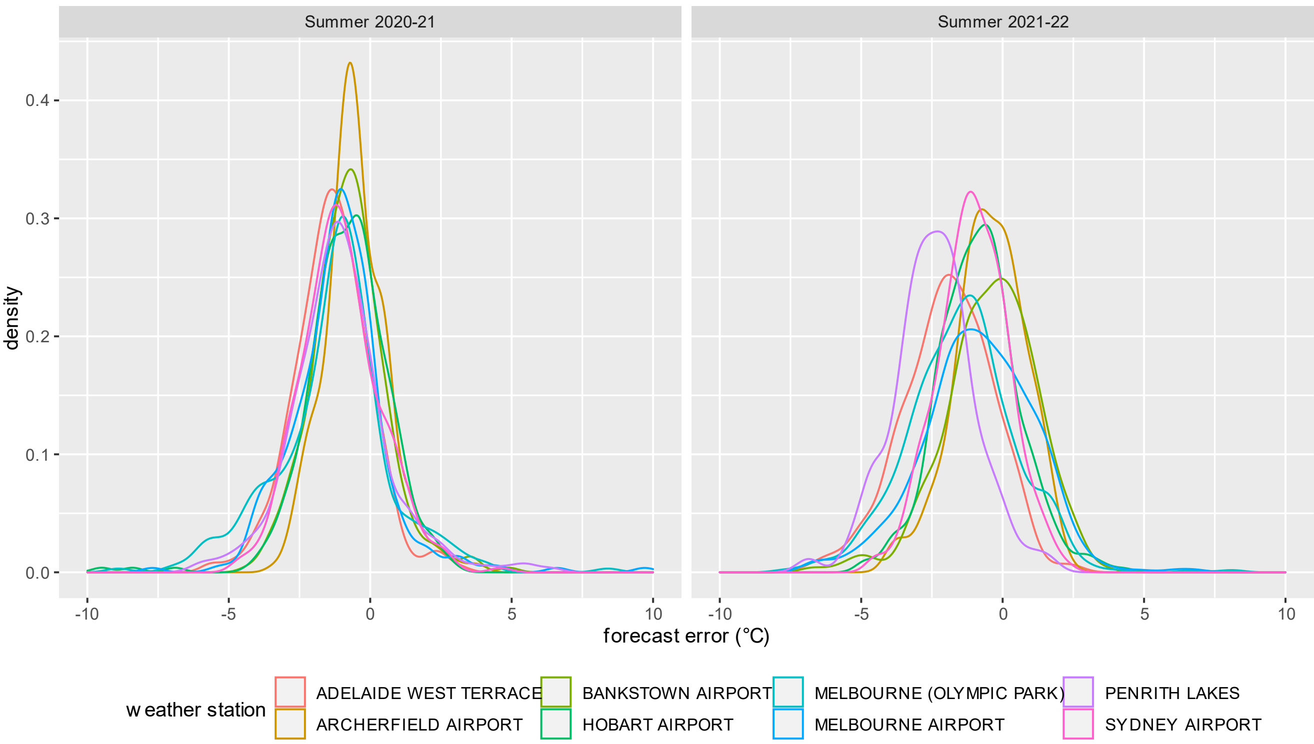
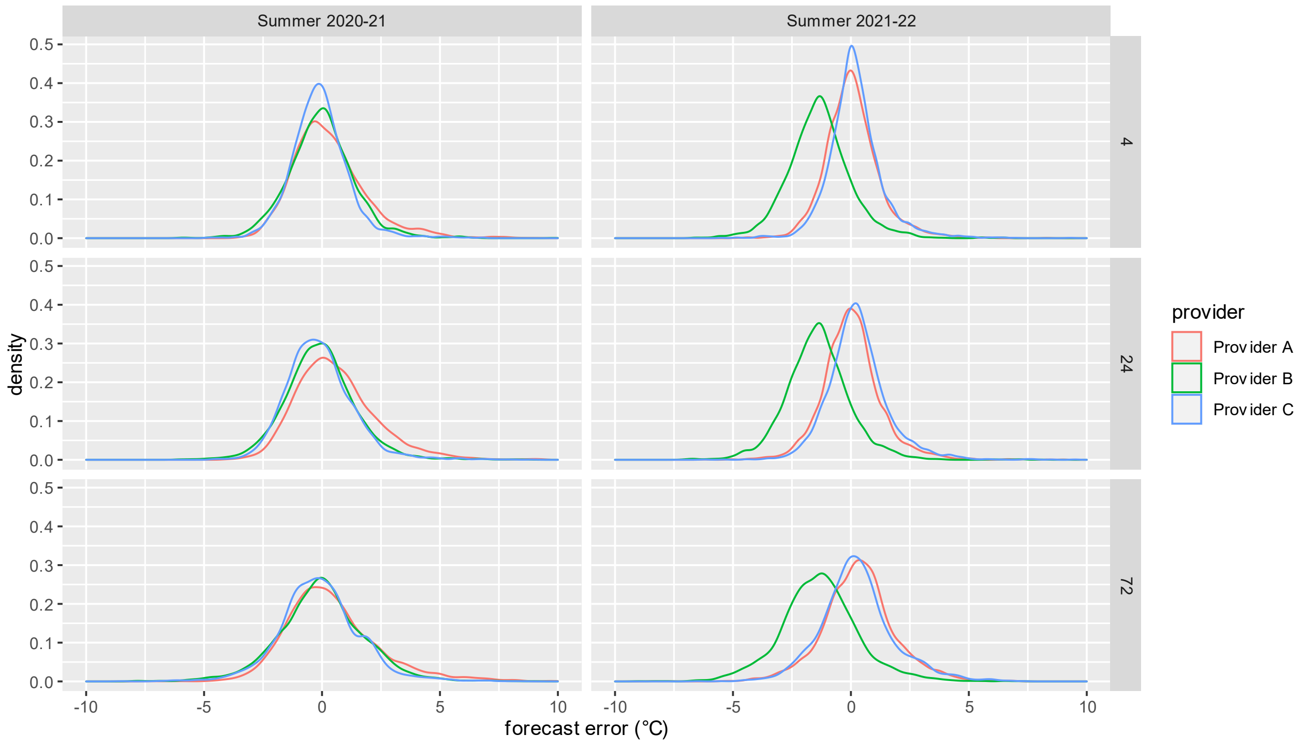


Figure 13 Penrith Lakes, all temperatures, summer 2020-21 and 2021-22, all time horizons



2.4 Provider C forecast performance

Provider C had the most accurate and precise performance overall.

Provider C performed best overall in Summer 2021-22 in terms of accuracy and precision when considering the 4, 24 and 72 HA forecast horizons. In the *Temperature Forecast Analysis for Winter 2021* report, Provider C also performed as the most accurate and precise provider for winter forecasting when compared to Provider A and B.

Accurate and precise forecasting by Provider C was observed at almost all weather stations, with substantial improvements in accuracy when compared to summer 2020-21 as seen in Figure 14 for the 24 HA horizon. Accuracy improvements for 4 and 72 HA forecasting horizons were also noted when compared to overall performance the summer prior, as can be seen in Appendix A1.2 in Figure 24.

Provider C also delivered the most accurate forecasts at the top 10% of temperatures in summer 2021-22 for the forecast horizons considered in this report when compared to Provider A and B, as can be seen in Figure 15.

Figure 14 Major weather stations, Provider C, all summer temperatures 2020-21 and 2021-22, 24 HA

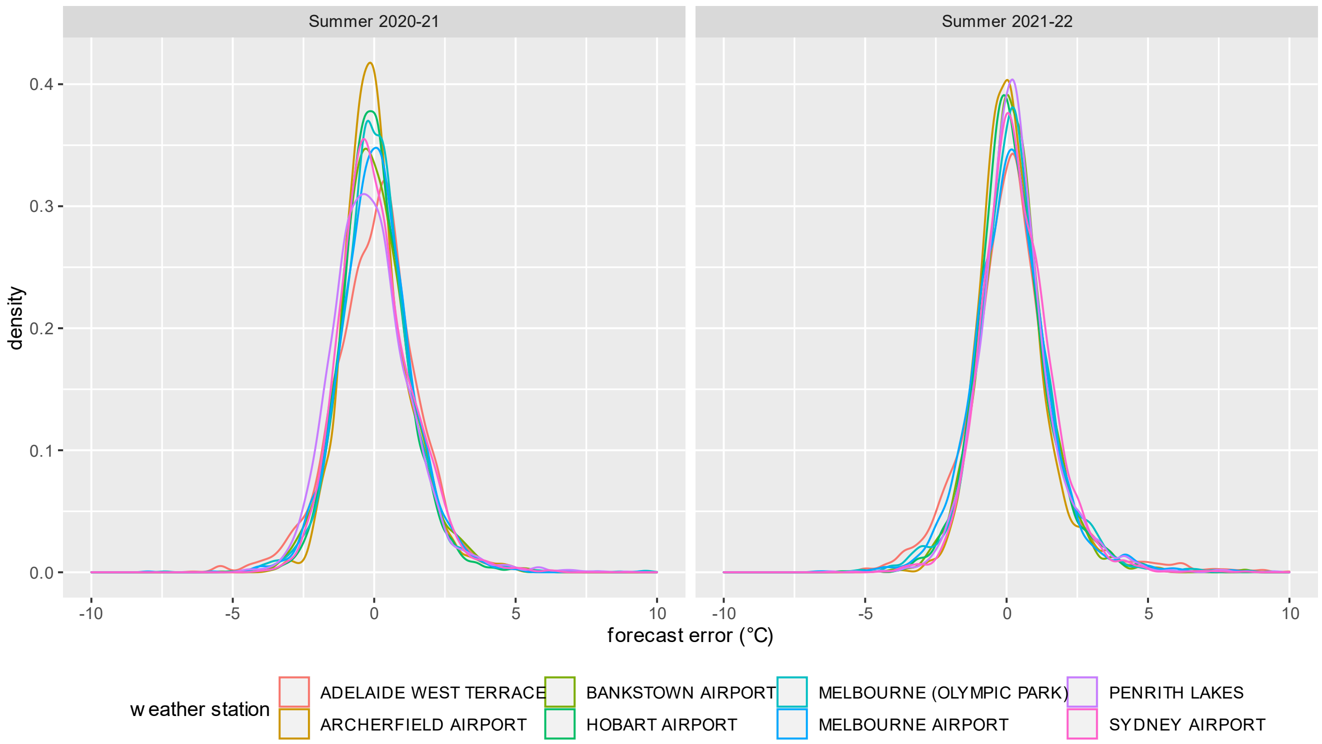
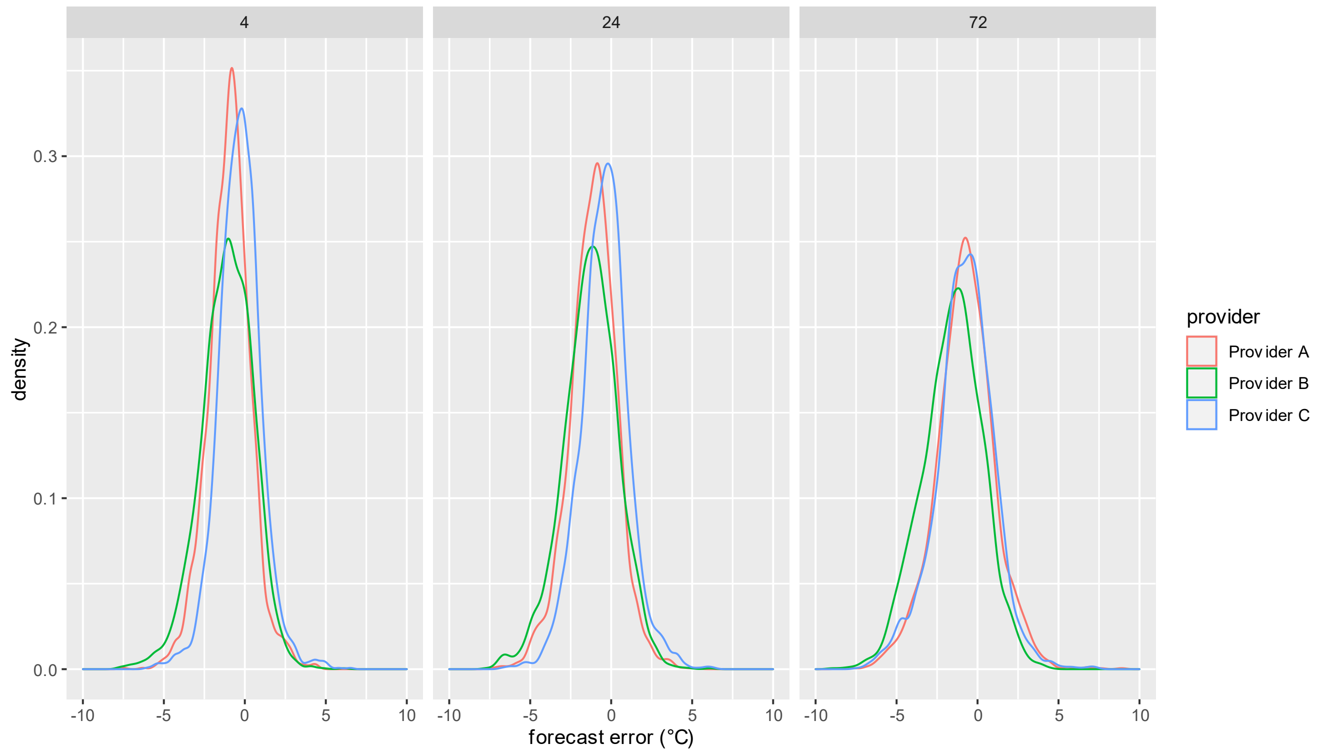


Figure 15 Summer 2021-22 performance comparison across major weather stations, top 10% temperatures



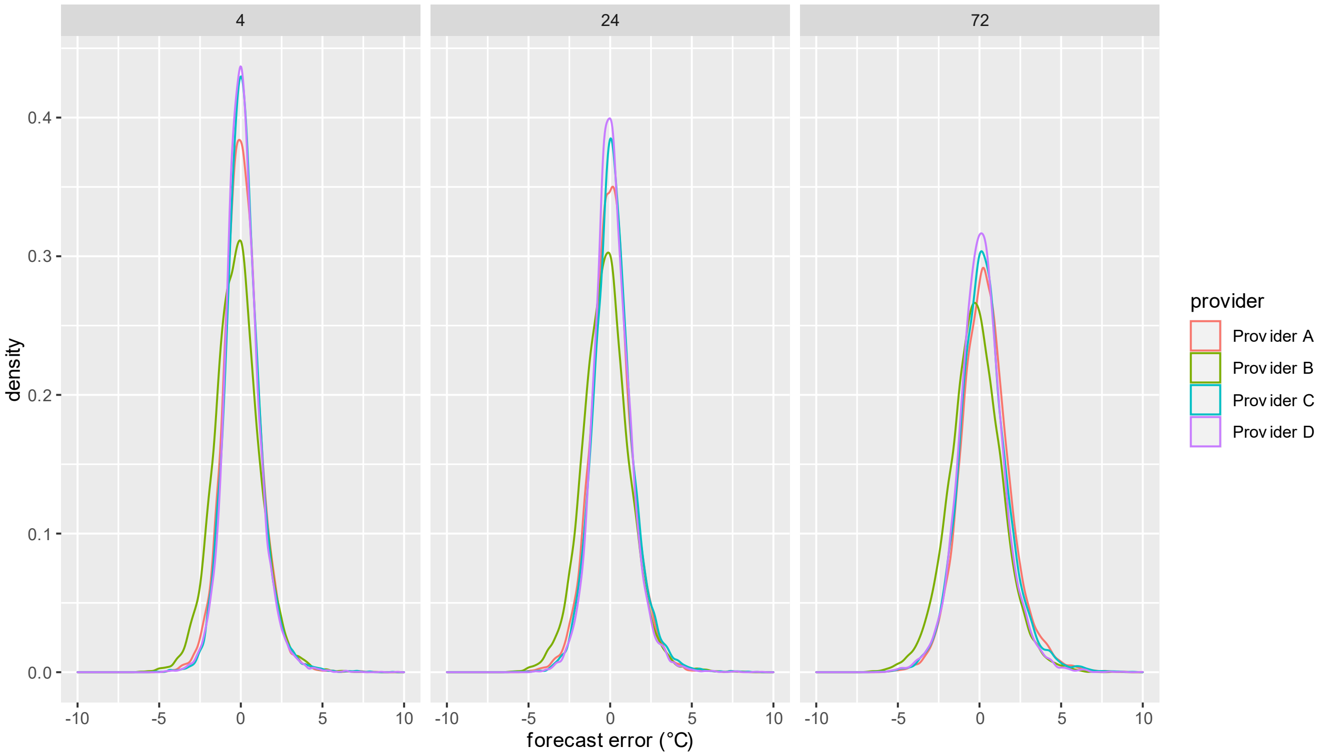
2.5 Provider D forecast performance

Provider D was onboarded during summer 2021-22, and indicates promising performance on par with Provider C.

Following material degradation in Provider B performance during winter 2021, AEMO onboarded a new provider which is under assessment for use in demand forecast models. Following onboarding, quality data for Provider D summer performance was available from 1 February to 31 March 2022. To fairly compare performance with Provider A, B and C, this section provides indicative temperature performance comparison for these four providers across the two-month period. In the *Temperature Forecast Analysis for Winter 2022* report, data for Provider D will be available for the full season and a more comprehensive analysis is to be included.

In February and March 2022, Provider D delivered the most overall accurate and precise performance across all temperatures, as can be seen below in Figure 16.

Figure 16 February and March 2022 performance across all major weather stations and temperatures, including new Provider D



Similarly, to Provider C's performance this summer, Provider D delivered consistently high accuracy and precision across all major weather stations with particularly high precision at Melbourne OP and Melbourne AP weather stations, with the latter shown in Figure 17. Further results can be seen in Appendix 1.4.

Top 10% temperatures were slightly under-forecast by Provider D, as shown in Figure 18. However, overall, this is comparable to under-forecasting tendencies at top 10% of temperatures displayed by the other three providers.

Figure 17 Melbourne Airport, all temperatures, February and March 2022 including Provider D, all time horizons

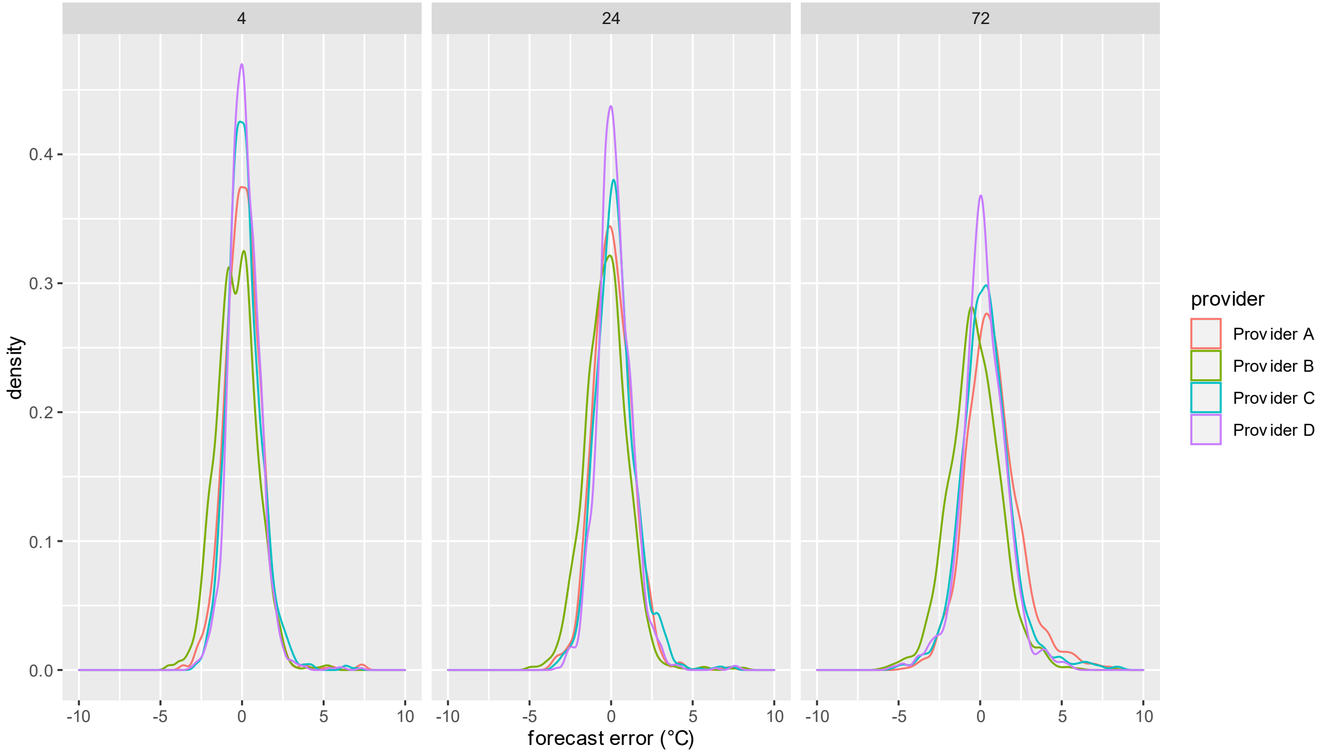
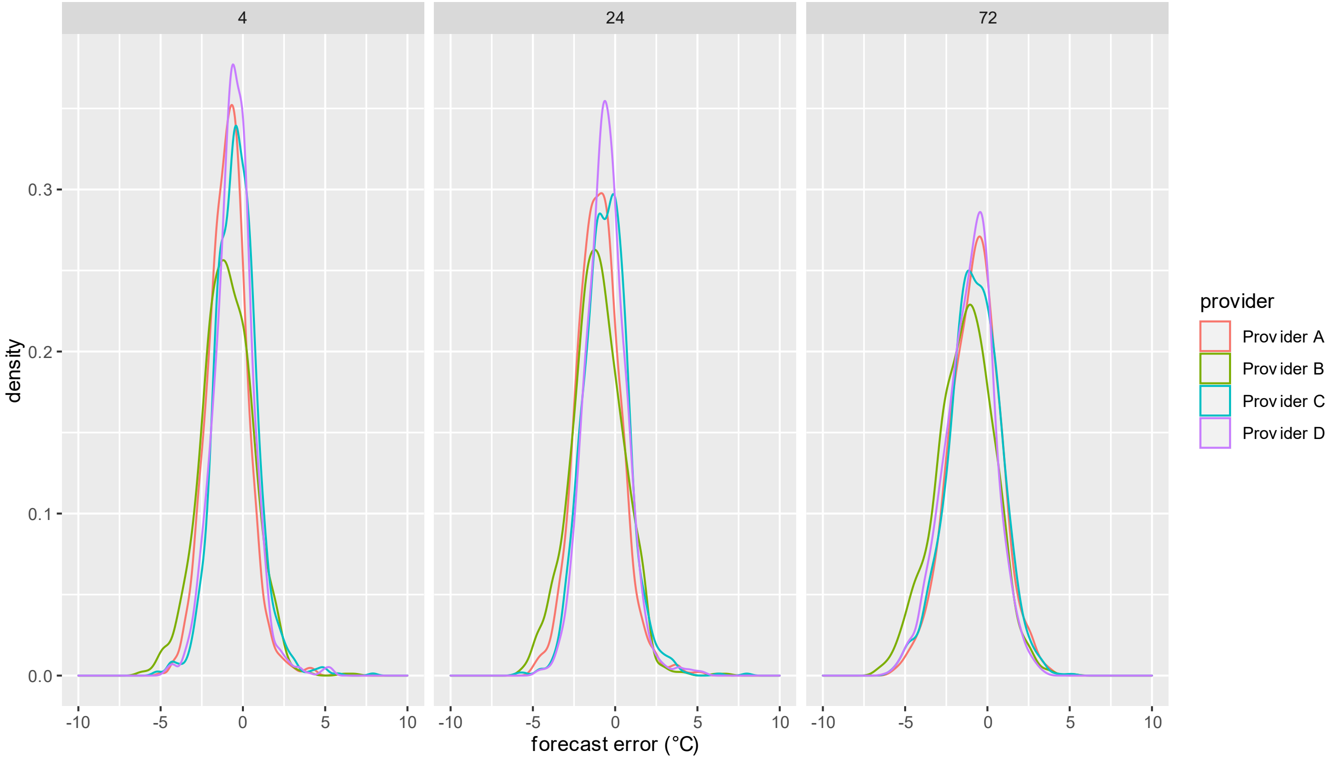


Figure 18 February and March 2022 performance comparison, top 10% temperatures



3 Case study: Queensland on 2 February 2022

This case study explores the temperature forecasts of a hot and humid day in Queensland on Wednesday 2 February 2022, and the subsequent impacts this had on electricity demand forecasting.

Temperature forecasts and outcomes

On Wednesday 2 February 2022, Queensland experienced an extreme heat day. High dry bulb temperatures were complemented by extremely high dew points, the result of a build-up of moisture in the atmosphere and moist onshore winds along the southern Queensland coast maintaining a high level of humidity over the greater south-east Queensland region. Maximum dry bulb temperature forecasts for 2 February 2022 were 34.4°C in Archerfield and 34.6°C in Amberley Amo. The 1500 hrs dew point forecast for Archerfield was 24.8°C, considerably higher than the February average of 18.8°C. Operational demand on these hot and humid days is significantly elevated by increased cooling loads.

Storm development on the west side of Brisbane and the associated precipitation had a dramatic impact on temperature forecast accuracy. Cloud development and cooling showers rapidly decreased dry-bulb temperature and increased humidity at both Amberley Amo and Archerfield weather stations, as seen Figure 19.

Figure 19 Forecast and actual precipitation, temperature and humidity showing the impact of storms passing between 1400 hrs and 1500 hrs on 2 February 2022 at Amberley Amo

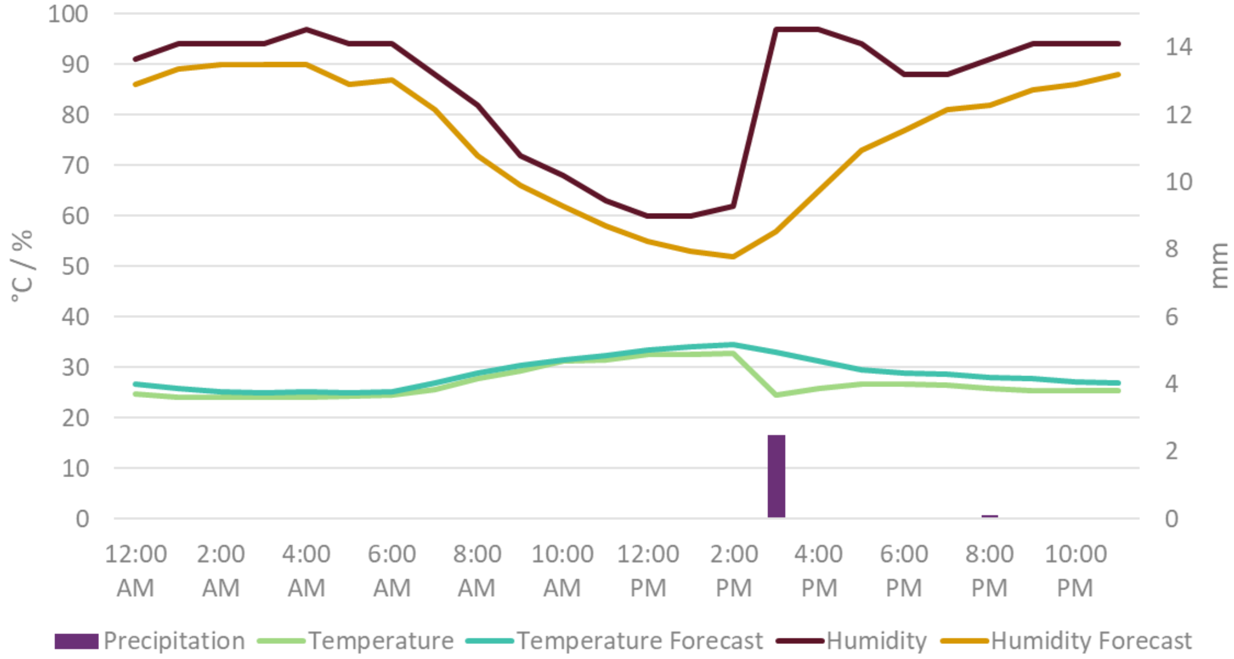
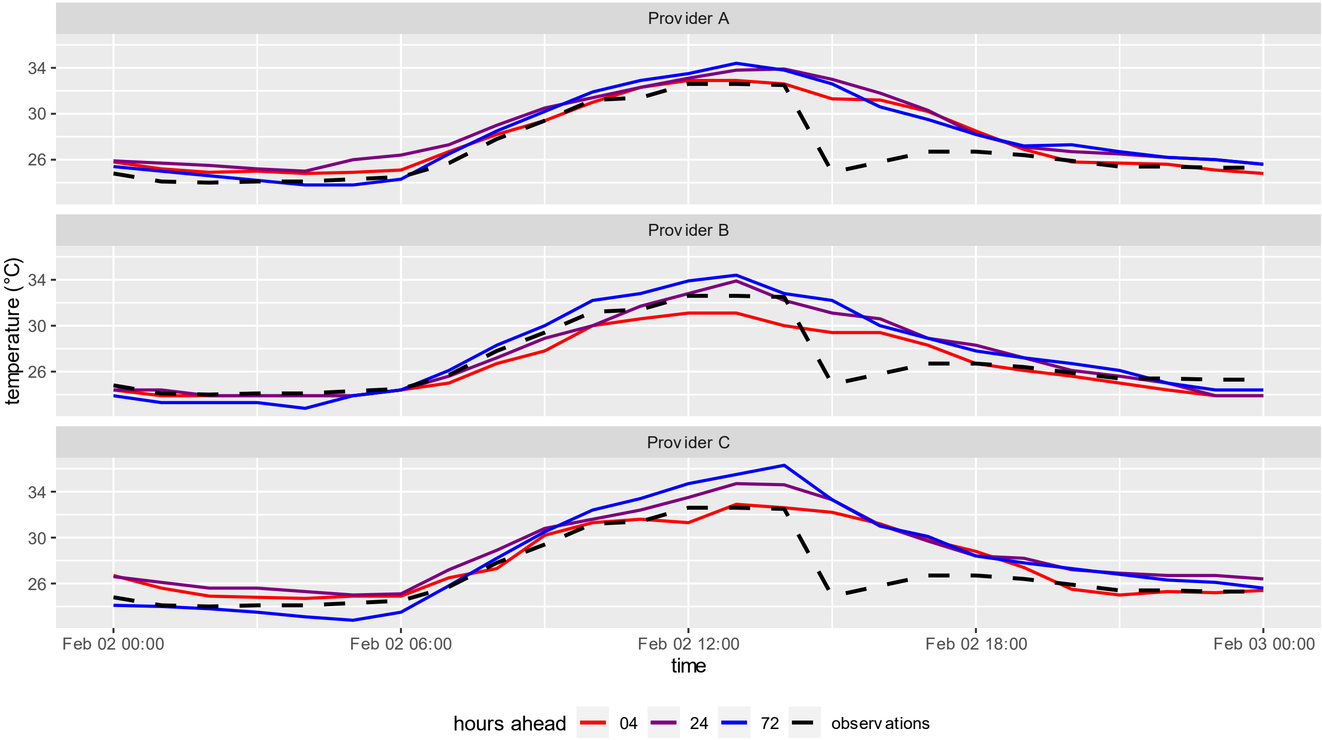


Figure 20 Forecast temperatures at various horizons against actual temperature observations for each provider at Amberley Amo on 2 February 2022[8]



Demand forecasts and outcomes

The high heat and humidity were driving a Queensland operational demand forecast peak of 10,143 MW, which, if it eventuated, would have set a record for the highest summer demand since record-keeping began in 2006.

Figure 21 shows the deviation between the day-ahead operational demand forecast and the observed demand in Queensland on 2 February 2022. It should be noted that QLD is split into three sub-regions, North, Central, and Southern, and that the major impact of this event was in Southern QLD.

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

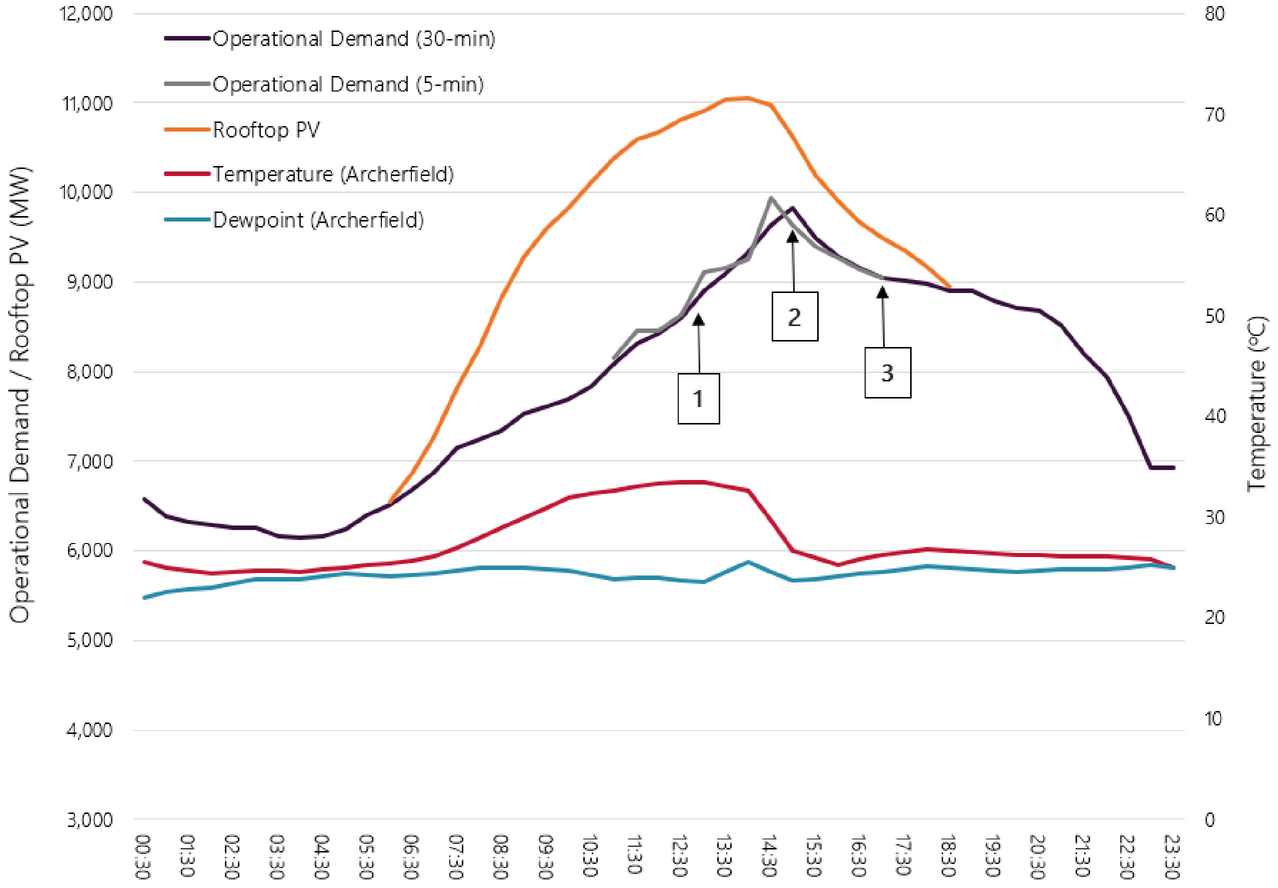
1. Operational demand ramped quickly with building temperatures and extreme humidity in Brisbane the main drivers.

2. The development of storms clouds over western Brisbane blocked solar irradiance. As the storm clouds moved eastwards over Brisbane there was an increase in operational demand as rooftop photovoltaic (PV) generation decreased rapidly. This ramp peaked at 3:00 pm.

3. The storm clouds also brought cooling showers. Once these showers began to fall, temperatures dropped rapidly, reducing the cooling load required from air-conditioners. As a result, operational demand decreased significantly. Dew points remained high due to the high humidity following the showers. However, a dew point with a lower dry bulb temperature and higher humidity is typically easier to tolerate than the inverse.

[8] Only Provider A, B and C has been included in this analysis as Provider D was not used in an operational capacity during this event.

Figure 21 Operational demand, rooftop PV, temperature, and humidity in Queensland on Wed 2 Feb 2022



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 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 performance had the greatest overall improvement** in both accuracy and precision when considering all temperatures in summer 2021-22, but had reduced accuracy for the top 10% of temperatures, with a greater tendency to under-forecast compared to its performance in summer 2020-21.
- **Provider B performance degraded in summer 2021-22** with significant reduction in forecasting accuracy for all temperatures in summer, as well as for the top 10% of temperatures, when compared to summer 2020-21. Significant degradation was also noted in the Winter 2021 report. Due to ongoing performance degradation, Provider B has been removed as one of AEMO's operational weather providers.
- **Provider C produced the most accurate and precise overall performance in summer 2021-22**, consistent with winter forecast performance noted in the Winter 2021 report. Provider C delivered the most accurate forecasts at the top 10% of temperatures for the forecast horizons considered in this report.
- **Provider D shows indicative promising performance on par with Provider C** for the months of February and March following onboarding during Summer 2021-22, with slight under-forecasting tendencies at the top 10% of temperatures comparable to that of the other three providers.

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.
- The South Australia gridded renewables nowcasting demonstration nearing completion, with promising results on intra-day (0-4 hours ahead) forecasting being demonstrated[9].
- Investigating the direct use of solar irradiance in demand forecasting to capture increased electricity demand due to irradiation effects due to building properties such as black roofs.
- Continued enhancement of Australian Wind and Solar Energy Forecasting Systems (AWEFS/ASEFS) to better adapt the weather forecasts for renewable generation forecasting.
- Analysis of the optimal weighting of Provider D in AEMO's demand forecast models to take place following initial performance verification. This will result in a higher weighting of Provider D feeds in the final demand forecast if performance remains favourable.
- Establishment of new weather observation stations located with renewable energy zones (REZs) near remote variable renewable energy (VRE) generators and in metropolitan heat islands to support weather forecasting.

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

The next *Temperature Forecast Analysis* report, focusing on winter 2022, is to be published later this year.

A1. Error density plots

A1.1 2021-22 summer performance

Figure 22 Summer 2021-22 performance comparison across all weather stations, all temperatures

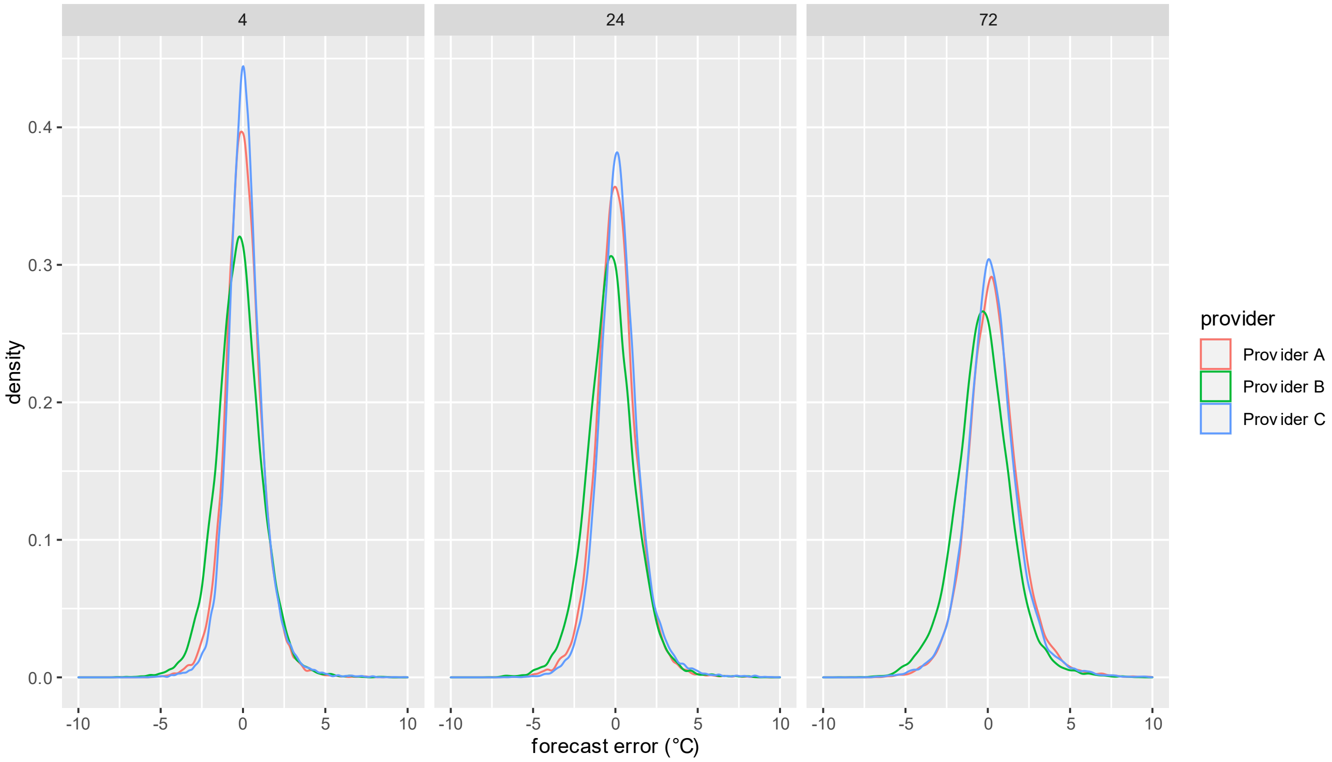
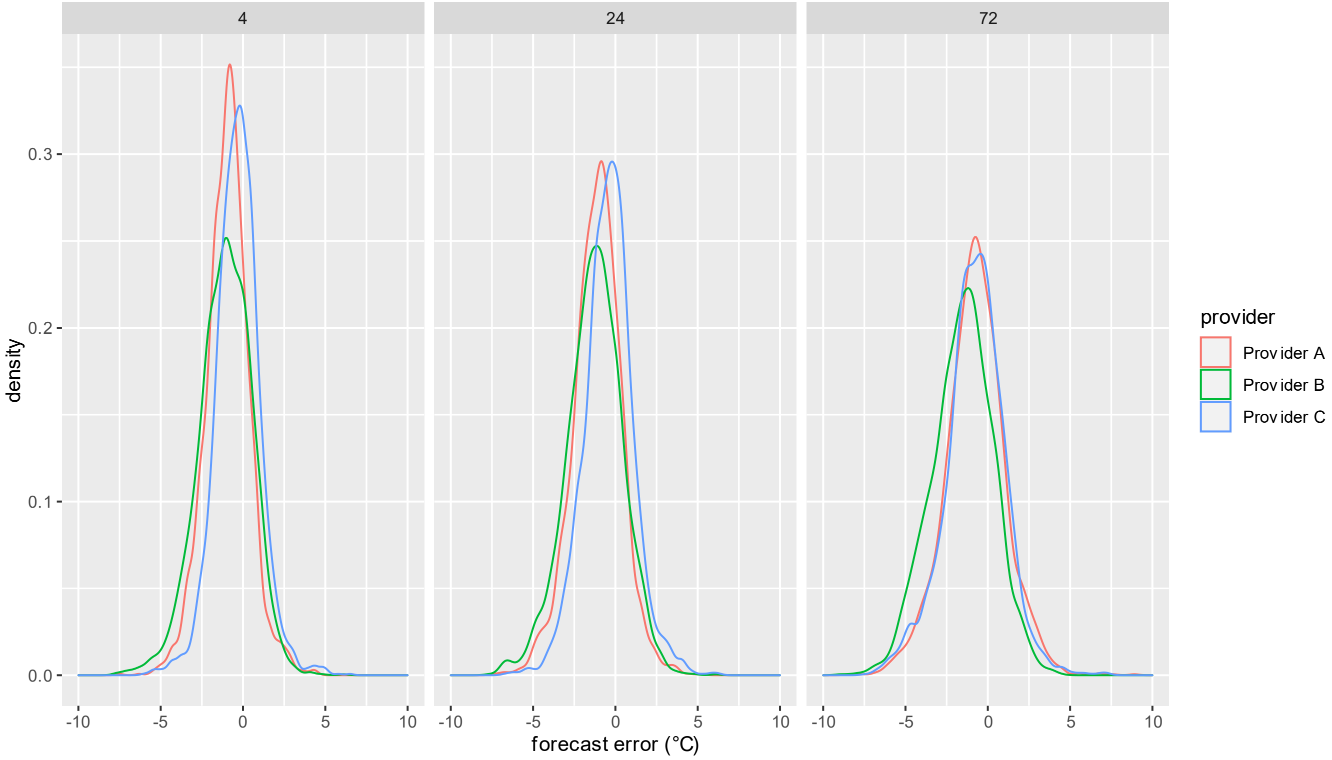


Figure 23 Summer 2021-22 performance comparison across all weather stations, top 10% of temperatures



A1.2 Summer performance comparison across all weather stations

Figure 24 Summer performance comparison across all weather stations (2020-21 and 2021-22), all temperatures

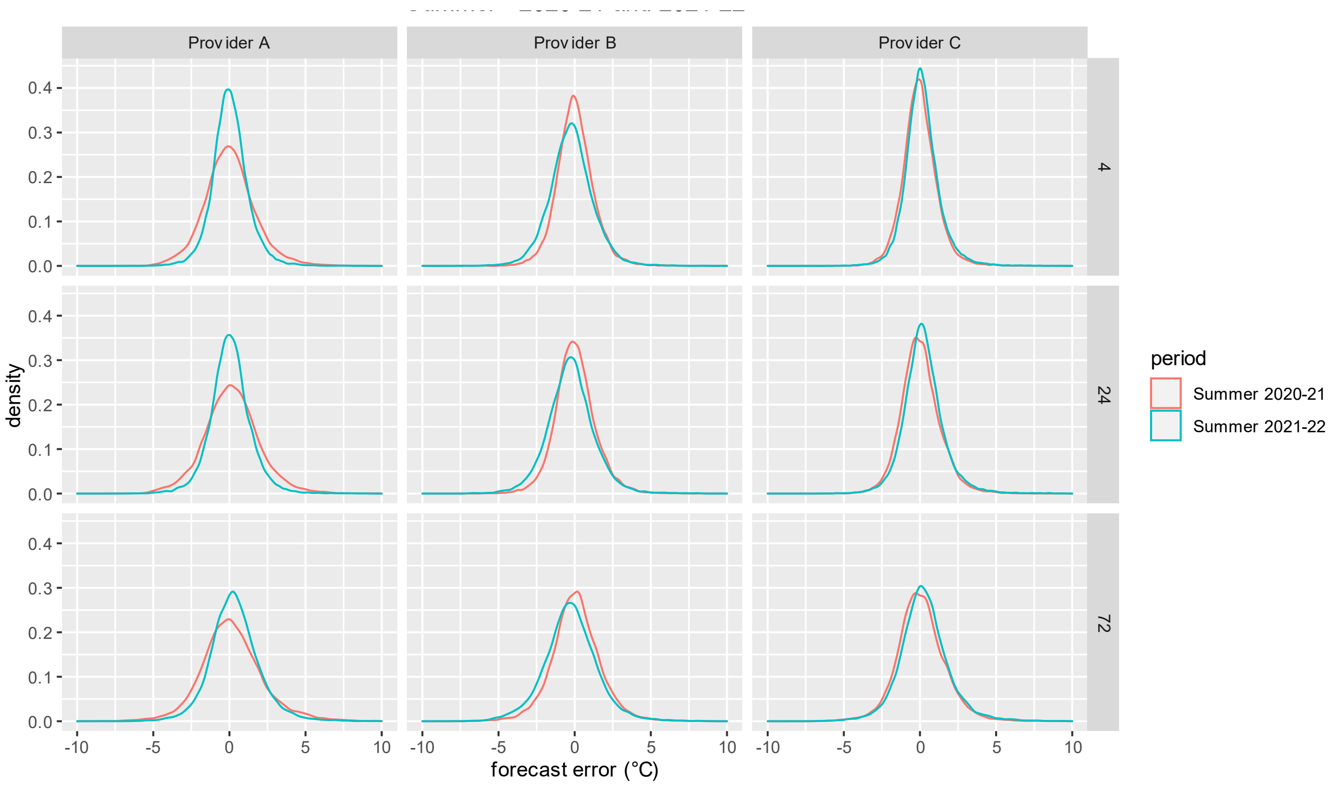
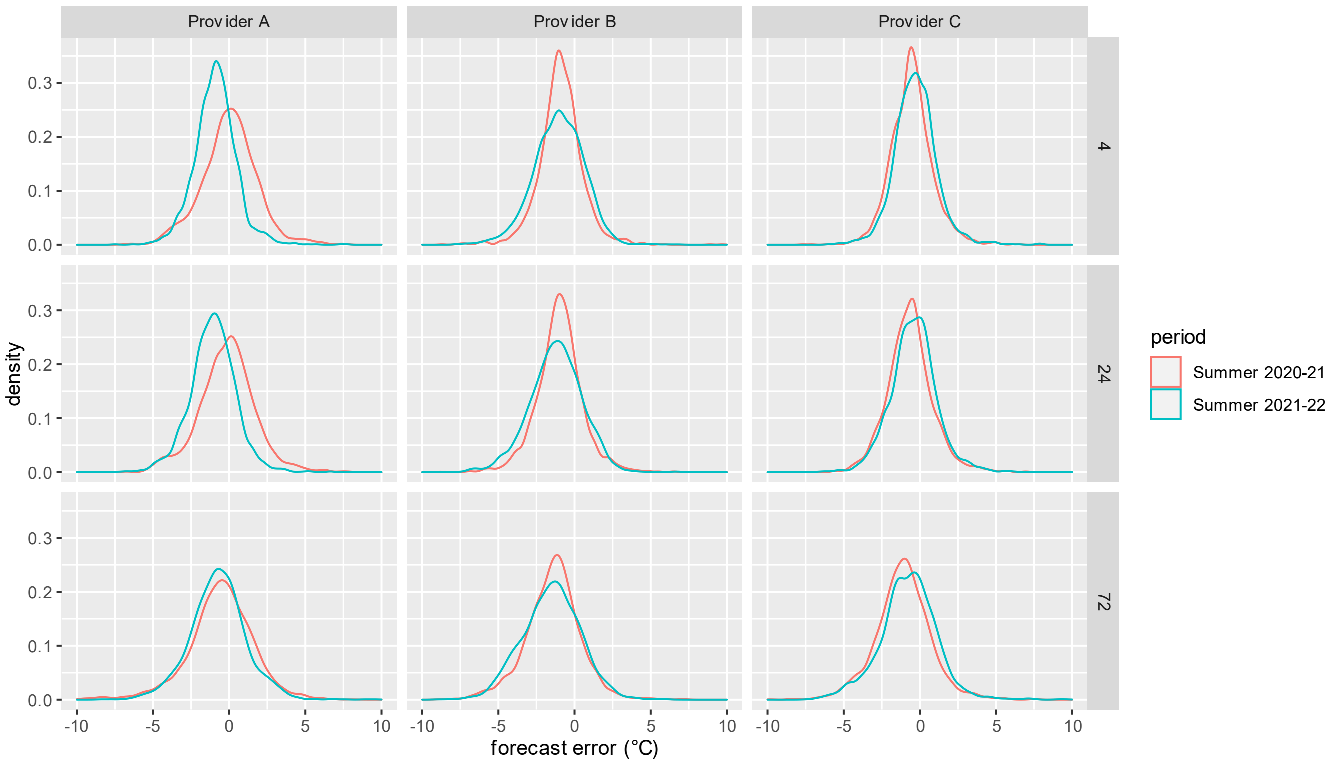


Figure 25 Summer performance comparison across all weather stations (2020-21 and 2021-22), top 10% temperatures



A1.3 Station comparison by provider

Figure 26 Major weather stations, Provider A, all summer temperatures 2020-21 and 2021-22, 24 HA

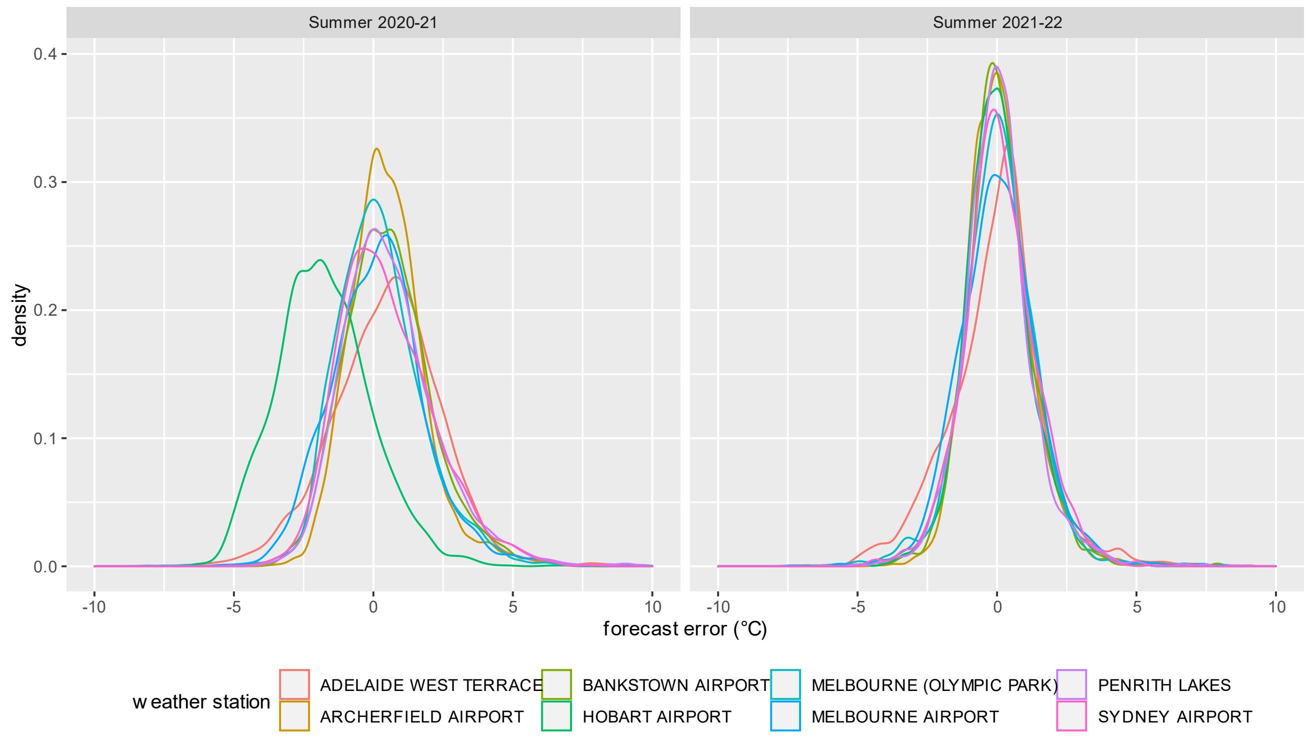


Figure 27 Major weather stations, Provider A, top 10% summer temperatures 2020-21 and 2021-22, 24 HA

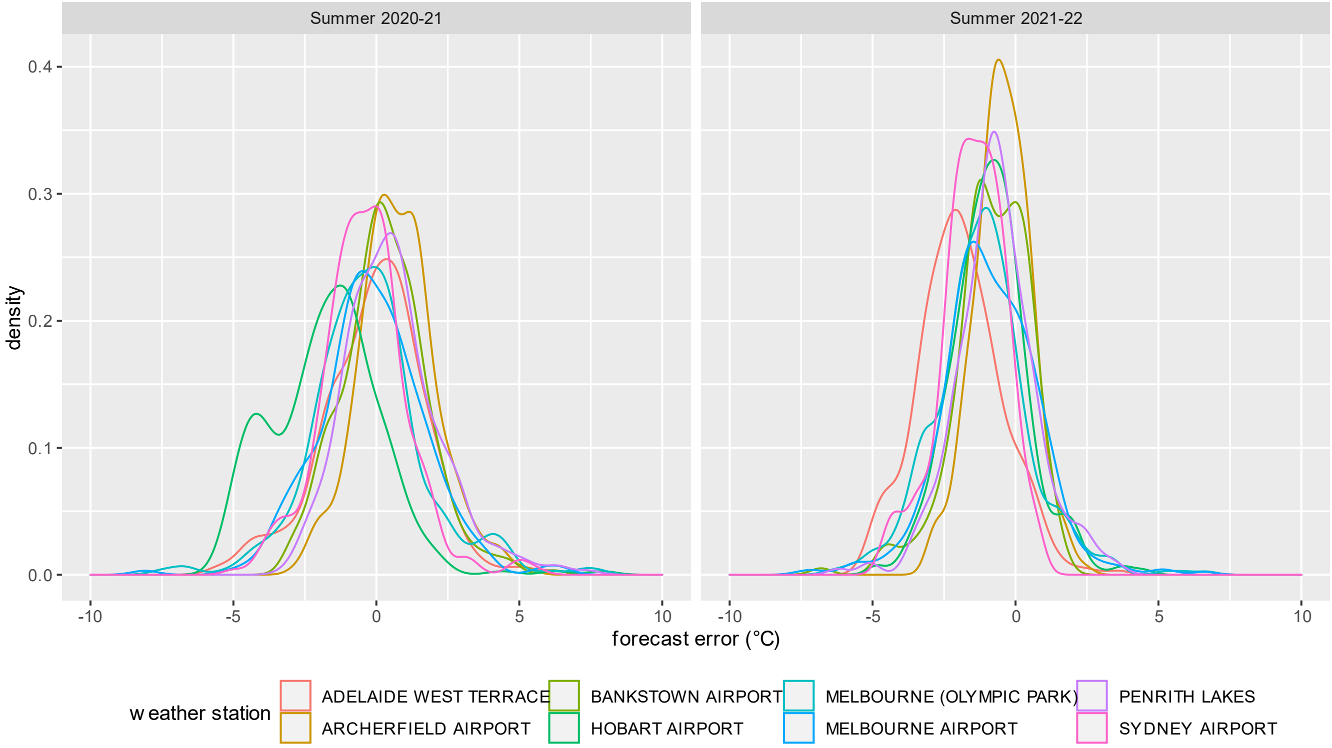


Figure 28 Major weather stations, Provider B, all summer temperatures 2020-21 and 2021-22, 24 HA

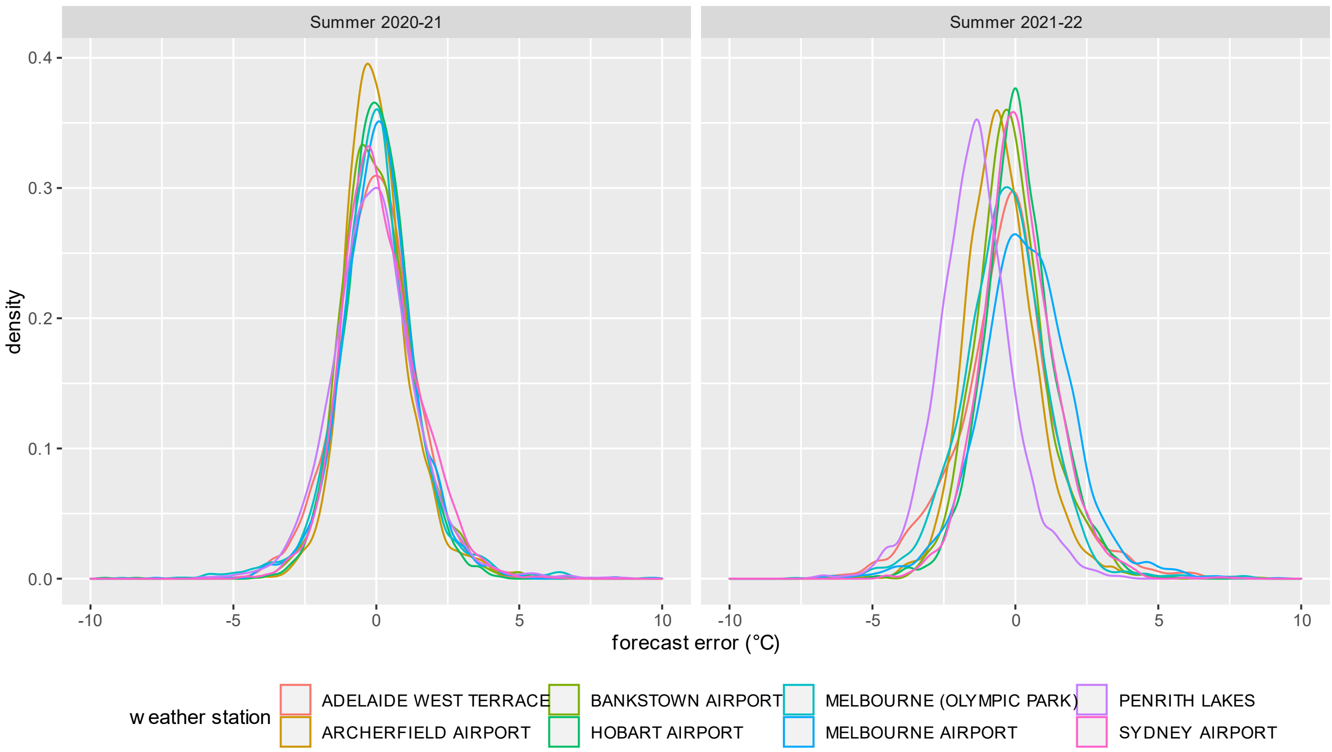


Figure 29 Major weather stations, Provider B, top 10% summer temperatures 2020-21 and 2021-22, 24 HA

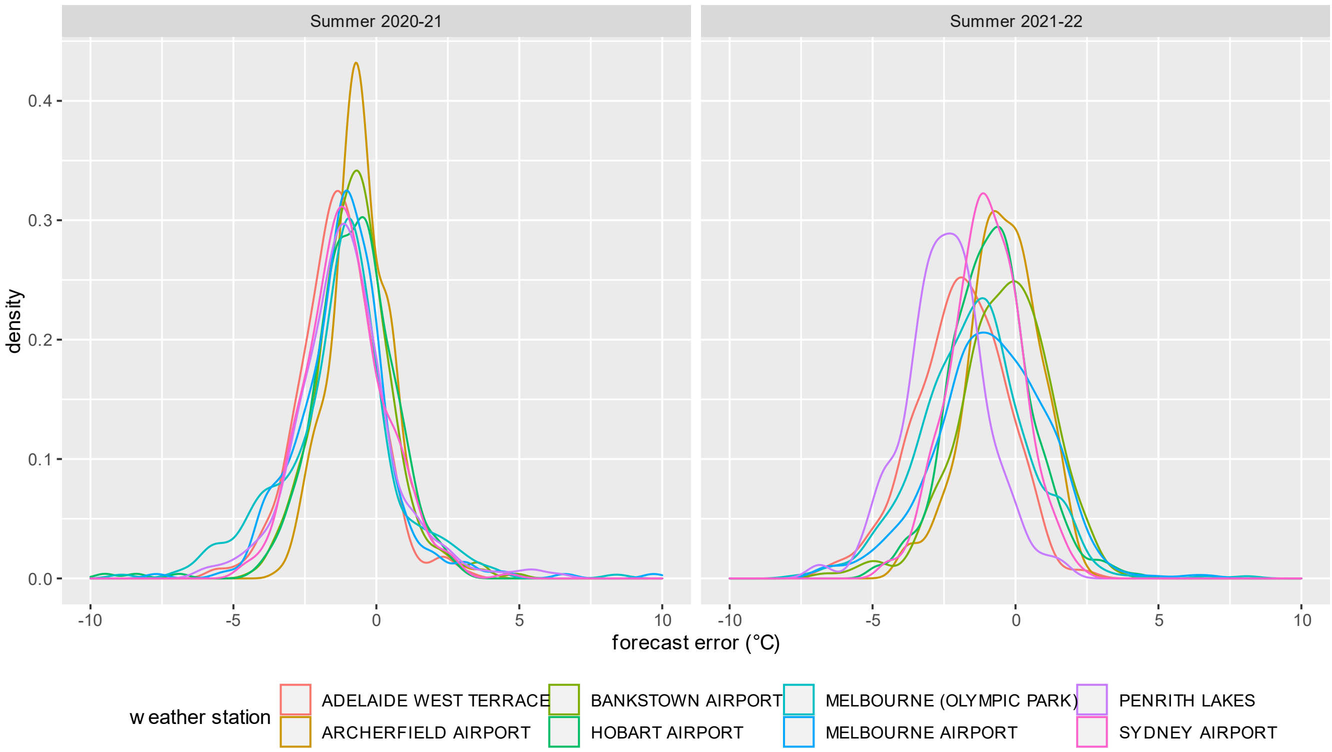


Figure 30 Major weather stations, Provider C, all summer temperatures 2020-21 and 2021-22, 24 HA

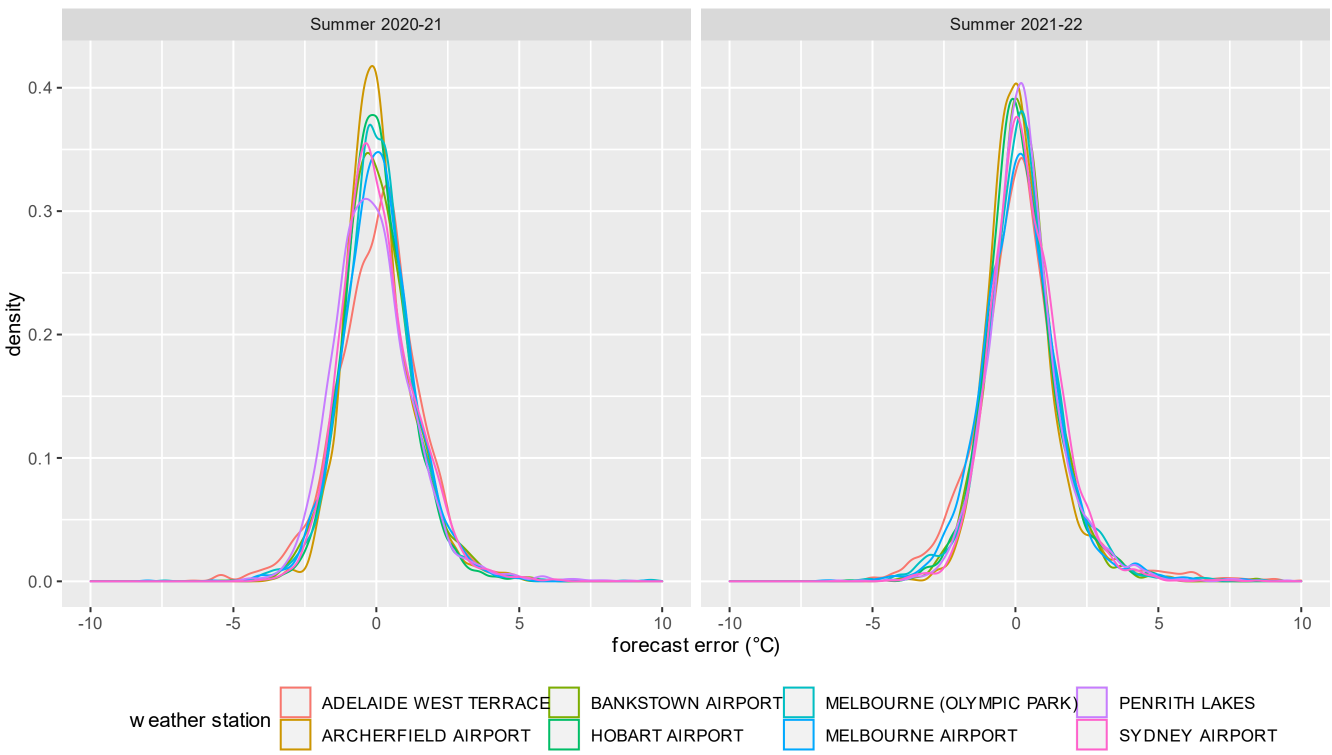
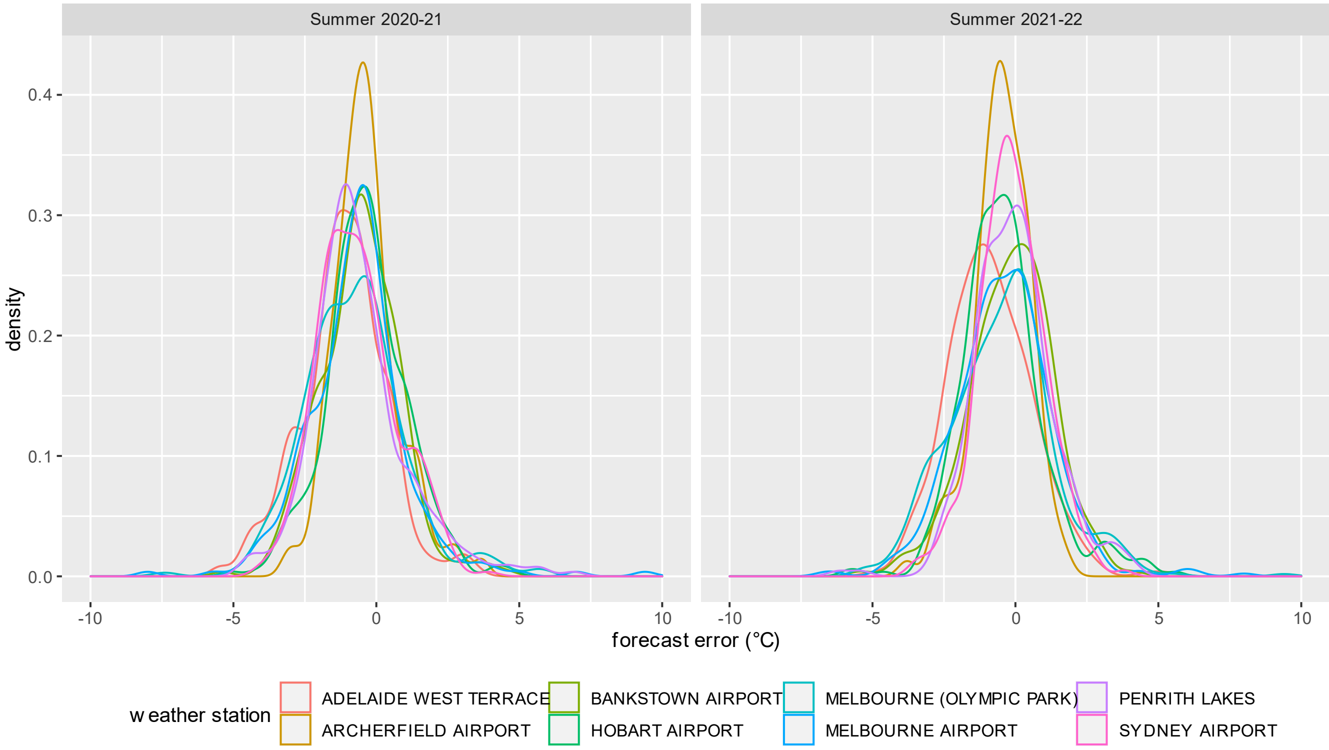


Figure 31 Major weather stations, Provider C, top 10% summer temperatures 2020-21 and 2021-22, 24 HA



A1.4 Provider comparison by weather station

Figure 32 Adelaide WT, all summer temperatures 2020-21 and 2021-22, all time horizons

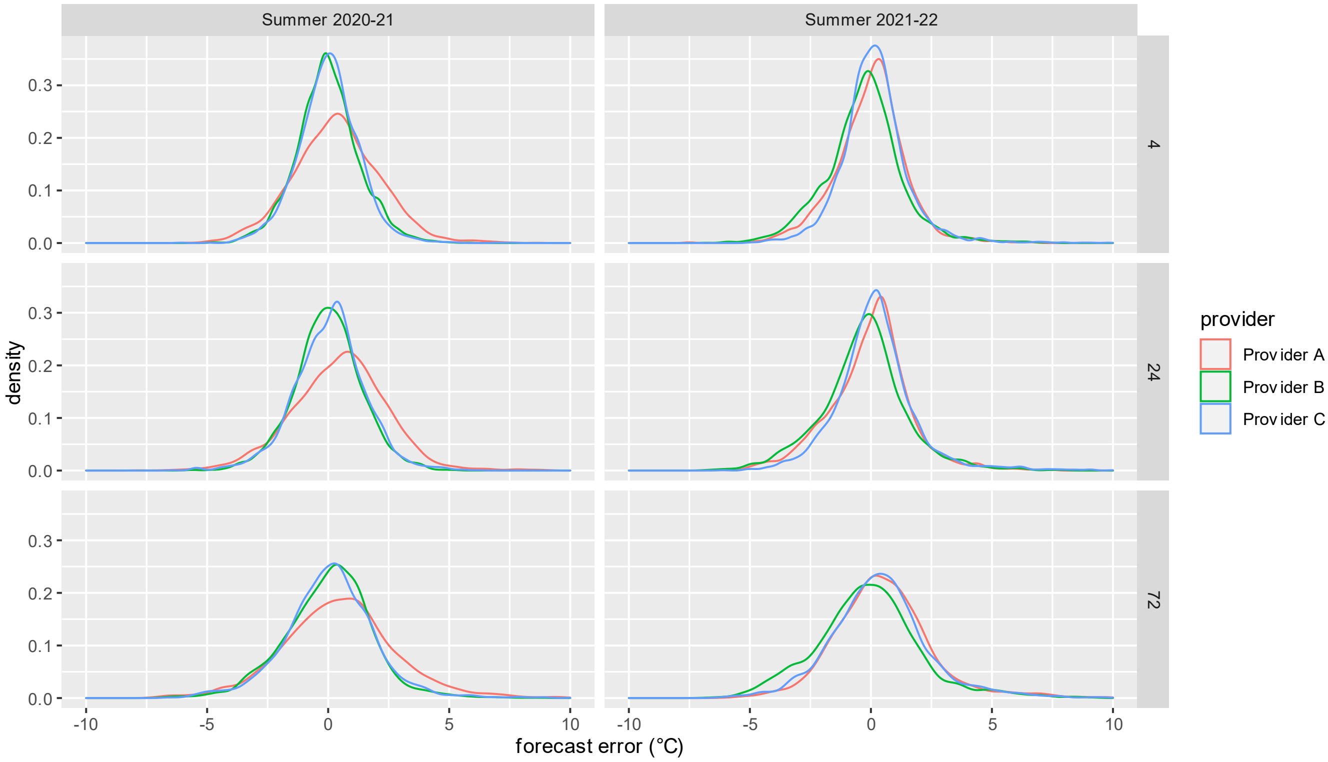


Figure 33 Archerfield AP, all summer temperatures 2020-21 and 2021-22, all time horizons

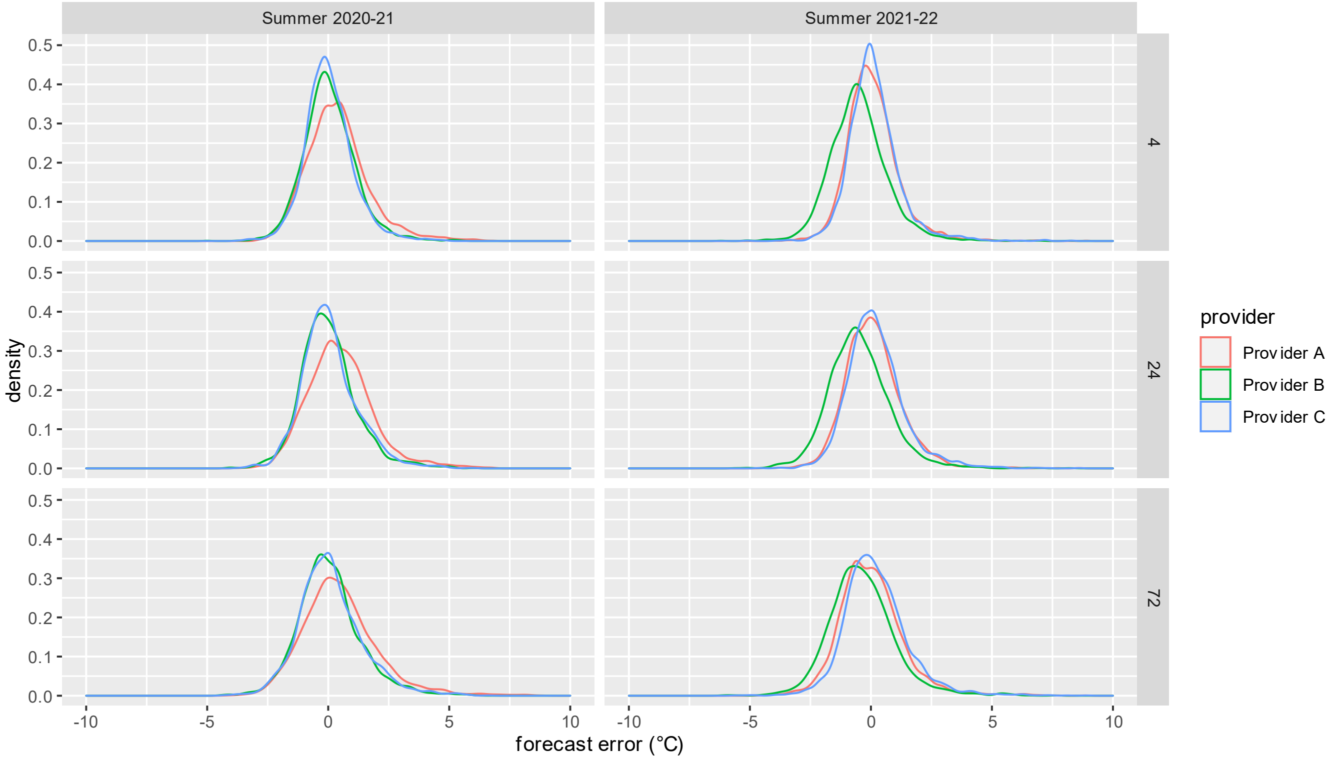


Figure 34 Bankstown AP, all summer temperatures 2020-21 and 2022-22, all time horizons

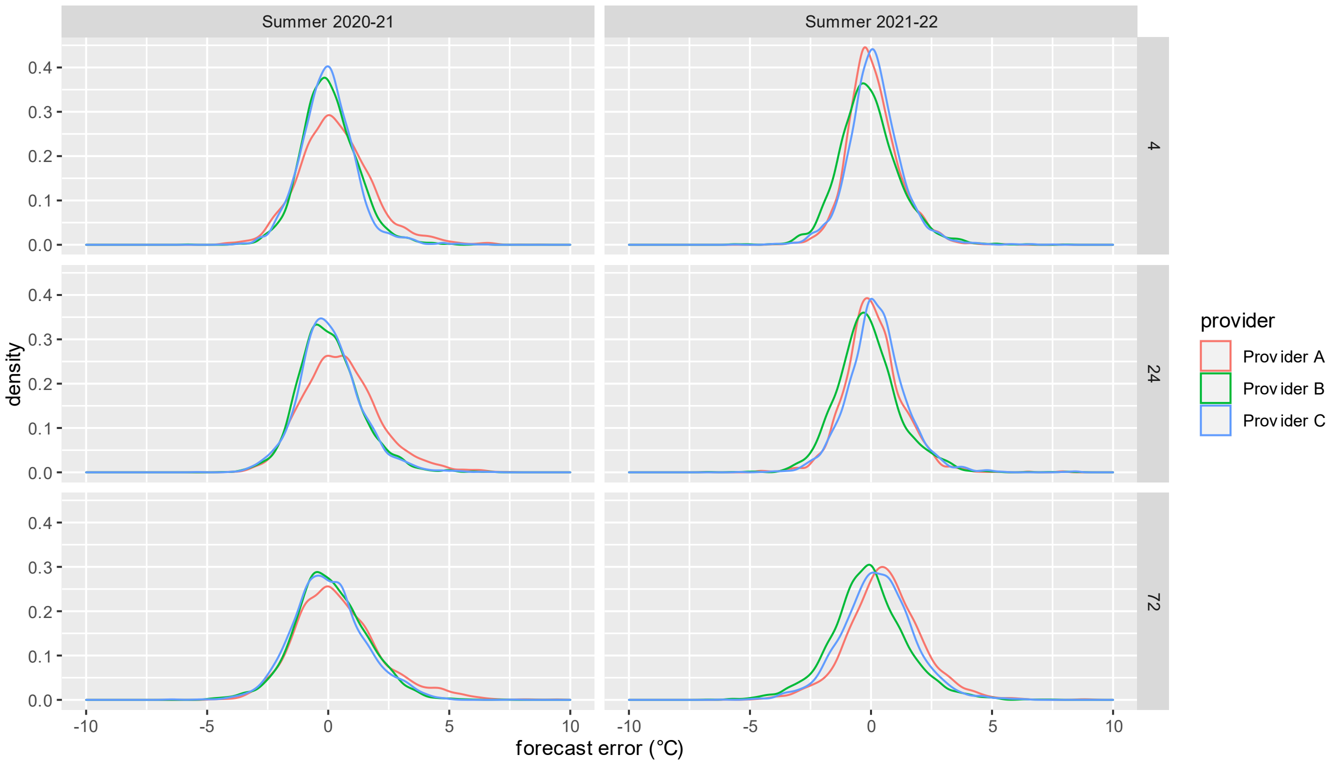


Figure 35 Hobart Airport, all summer temperatures 2020-21 and 2021-22, all time horizons

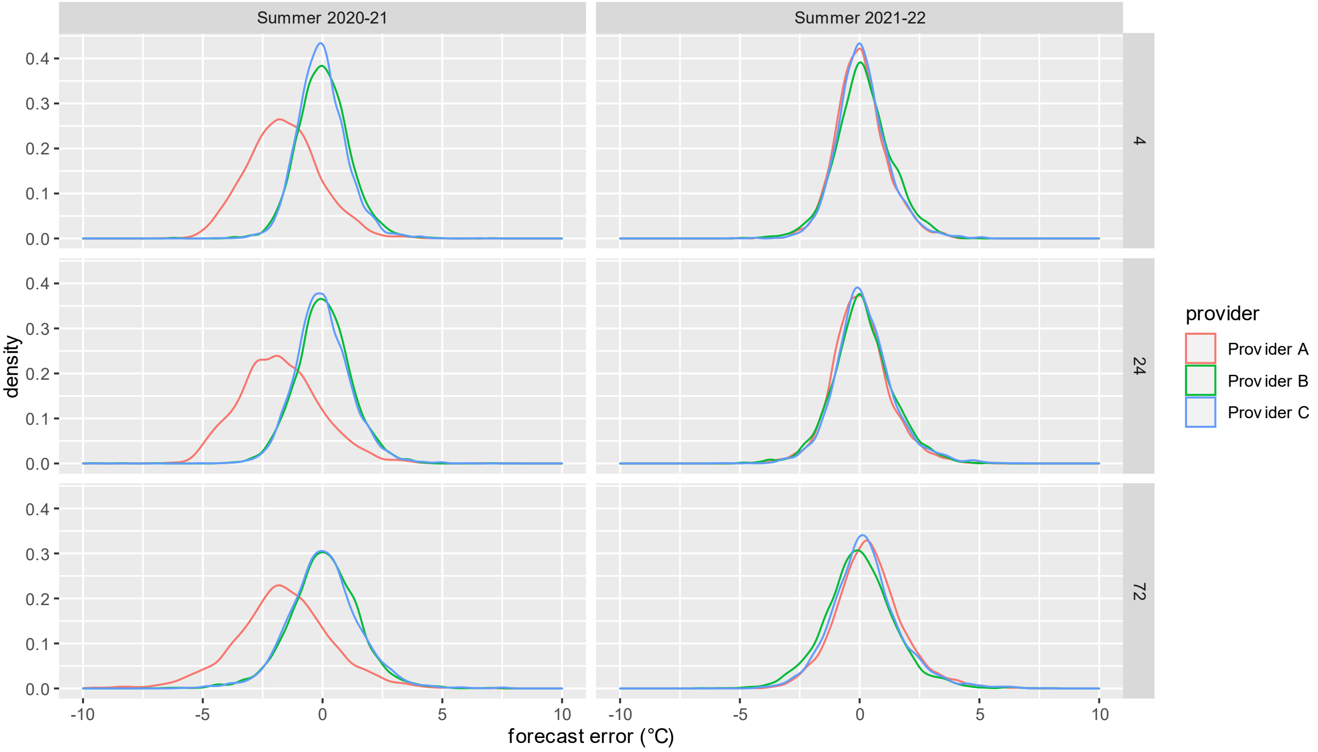


Figure 36 Melbourne AP, all summer temperatures 2020-21 and 2022-22, all time horizons

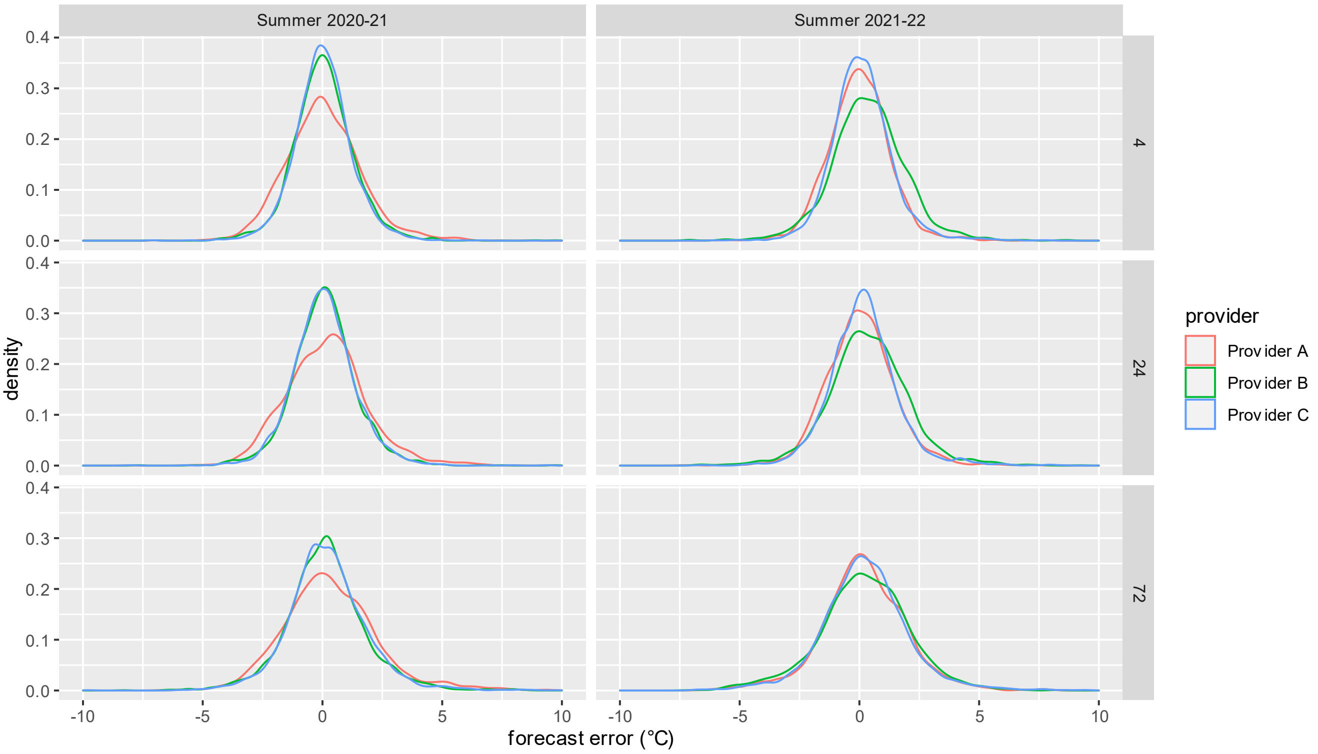


Figure 37 Melbourne OP, all summer temperatures 2020-21 and 2022-22, all time horizons

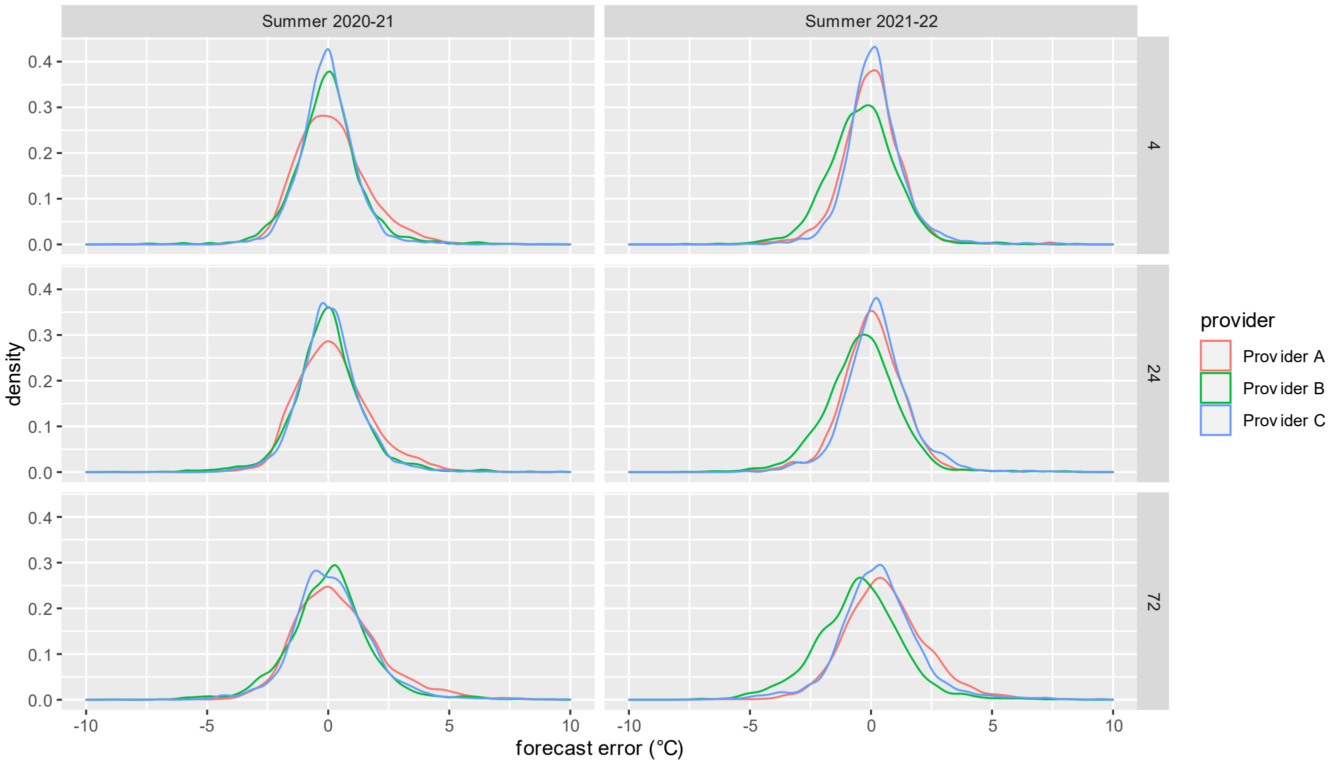


Figure 38 Penrith Lakes, all summer temperatures 2020-21 and 2022-22, all time horizons

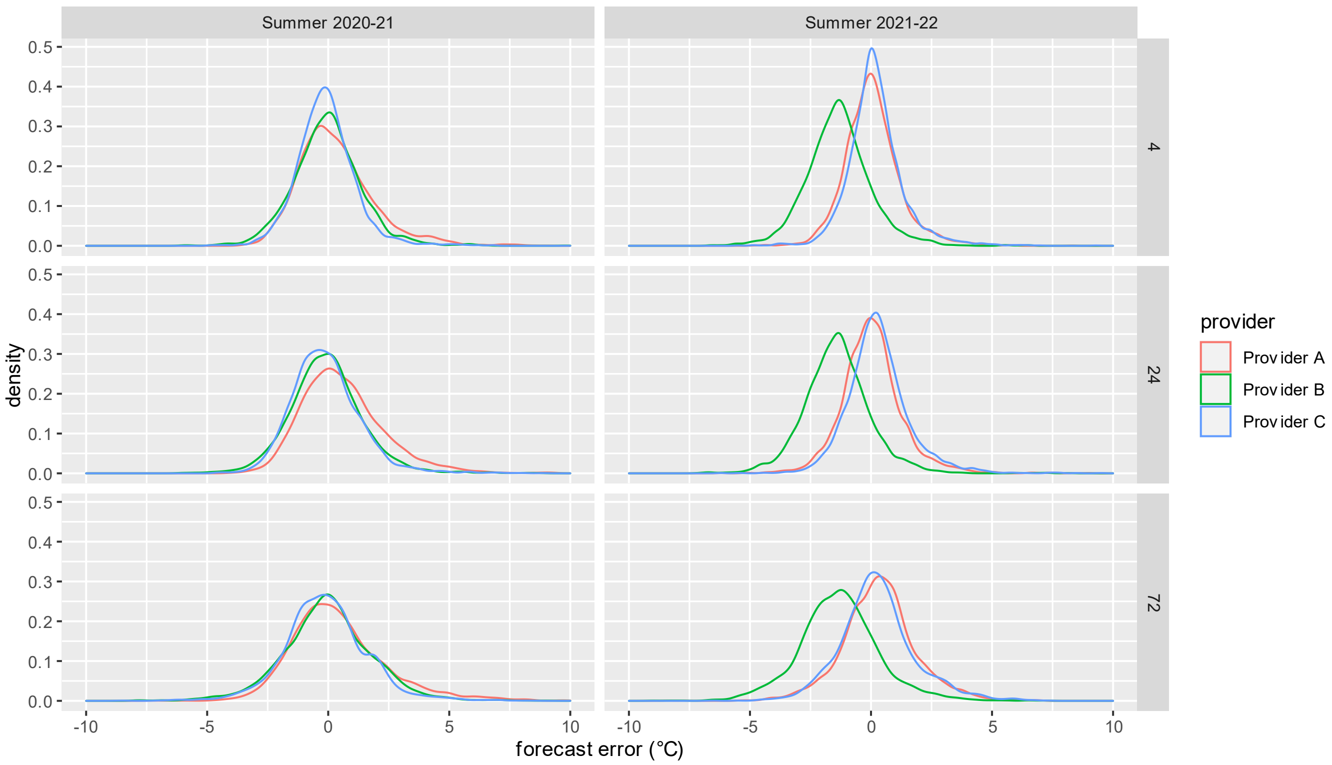
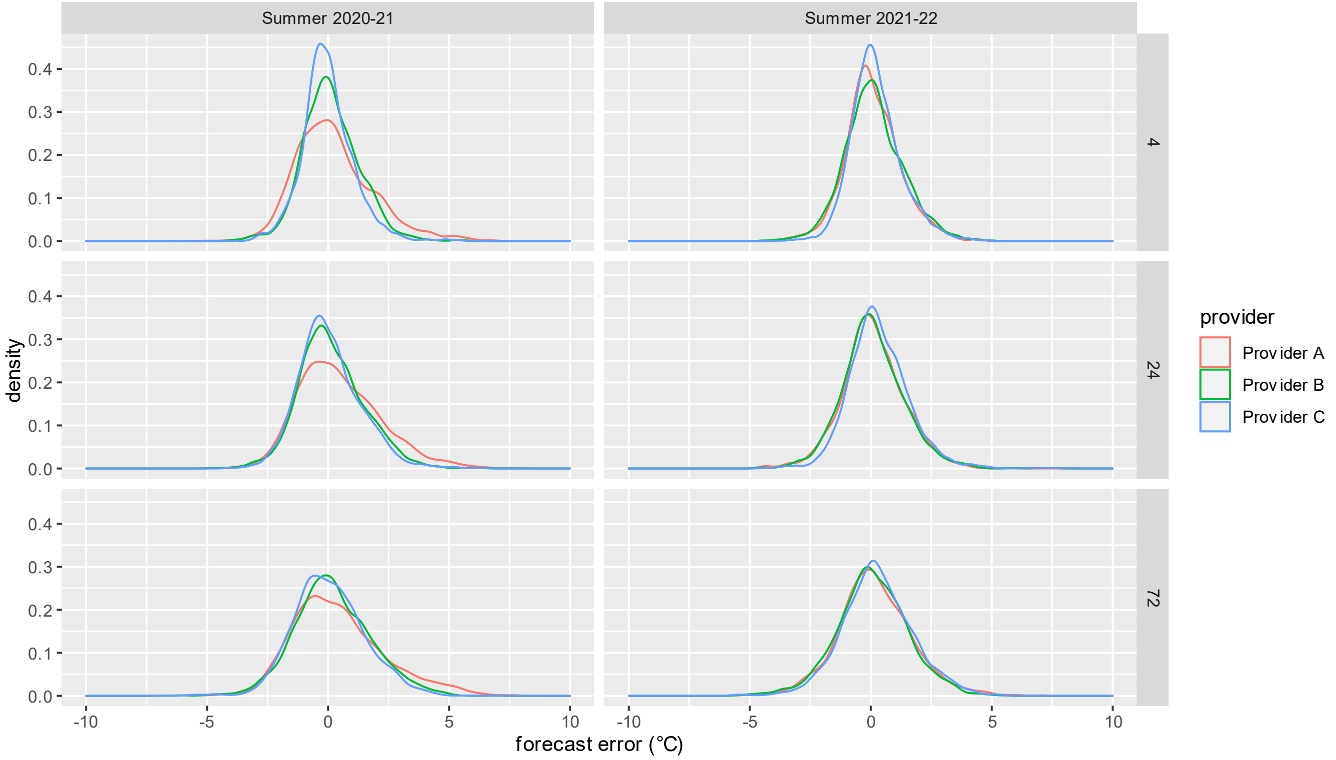


Figure 39 Sydney AP, all summer temperatures 2020-21 and 2022-22, all time horizons



A2. Intraday MAE profiles

Figure 40 Adelaide WT, intraday MAE profile, summer 2020-21 and 2021-22, all time horizons, all temperatures

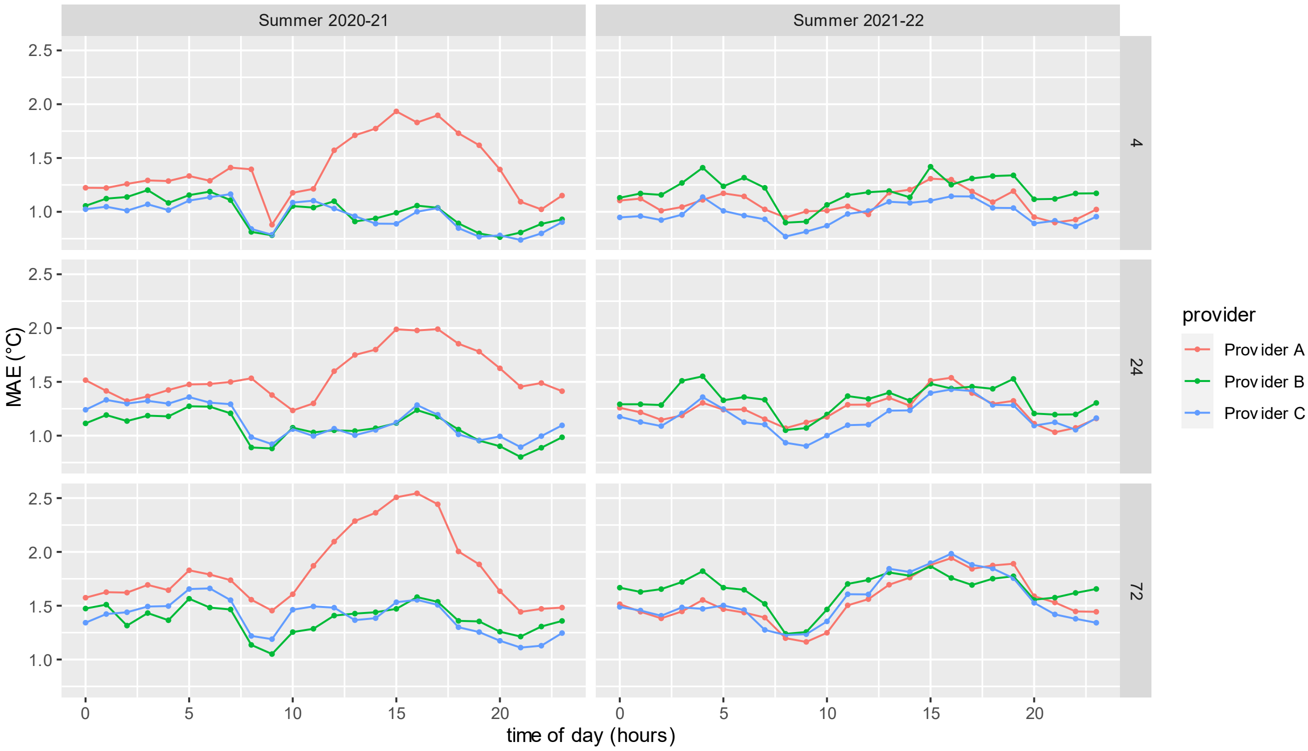


Figure 41 Archerfield AP, intraday MAE profile, summer 2020 and 2021, all time horizons, all temperatures

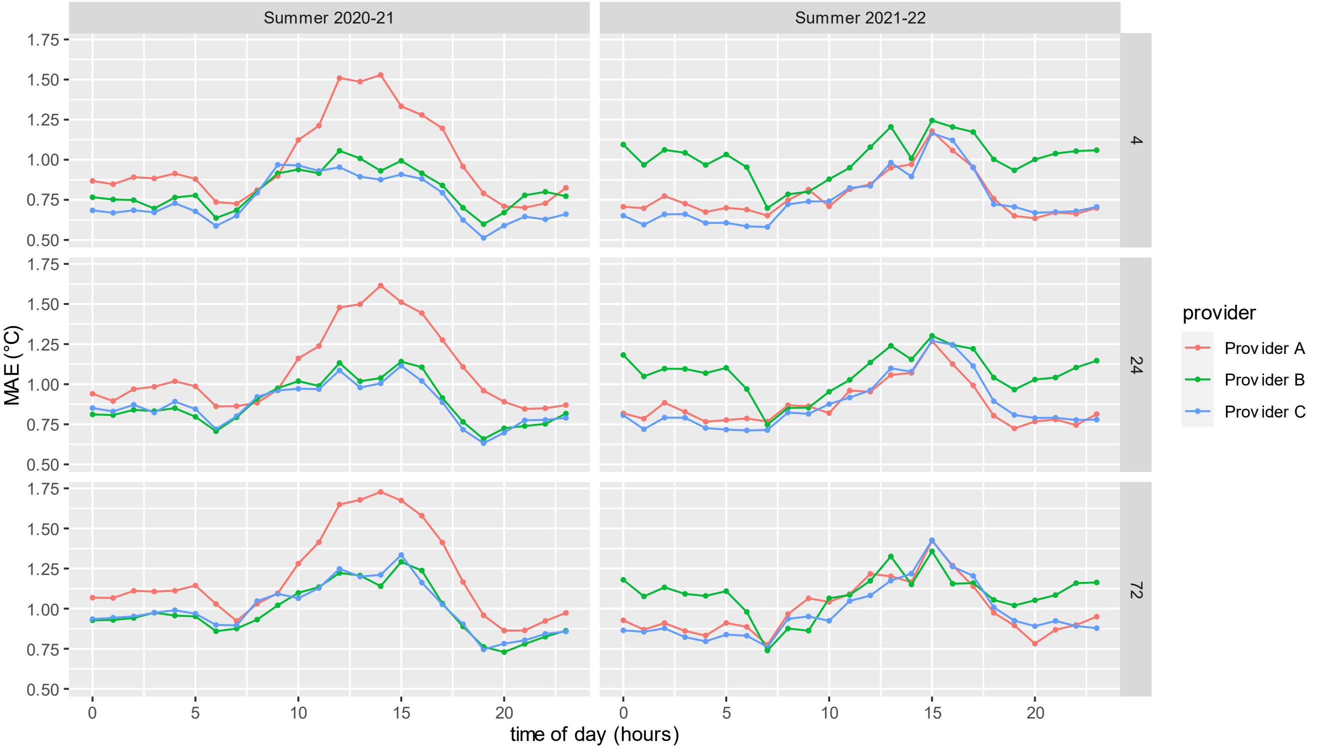


Figure 42 Bankstown AP, intraday MAE profile, summer 2020 and 2021, all time horizons, all temperatures

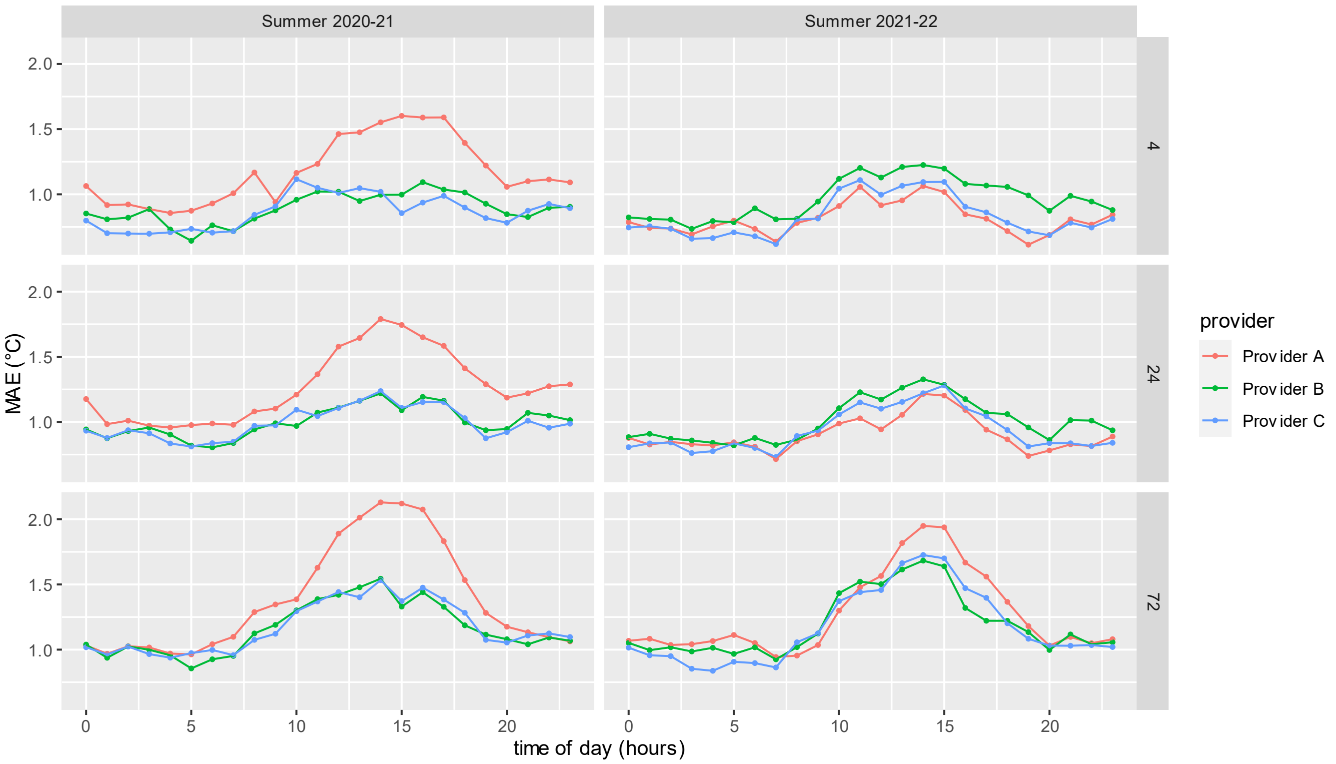


Figure 43 Hobart AP, intraday MAE profile, summer 2020 and 2021, all time horizons, all temperatures

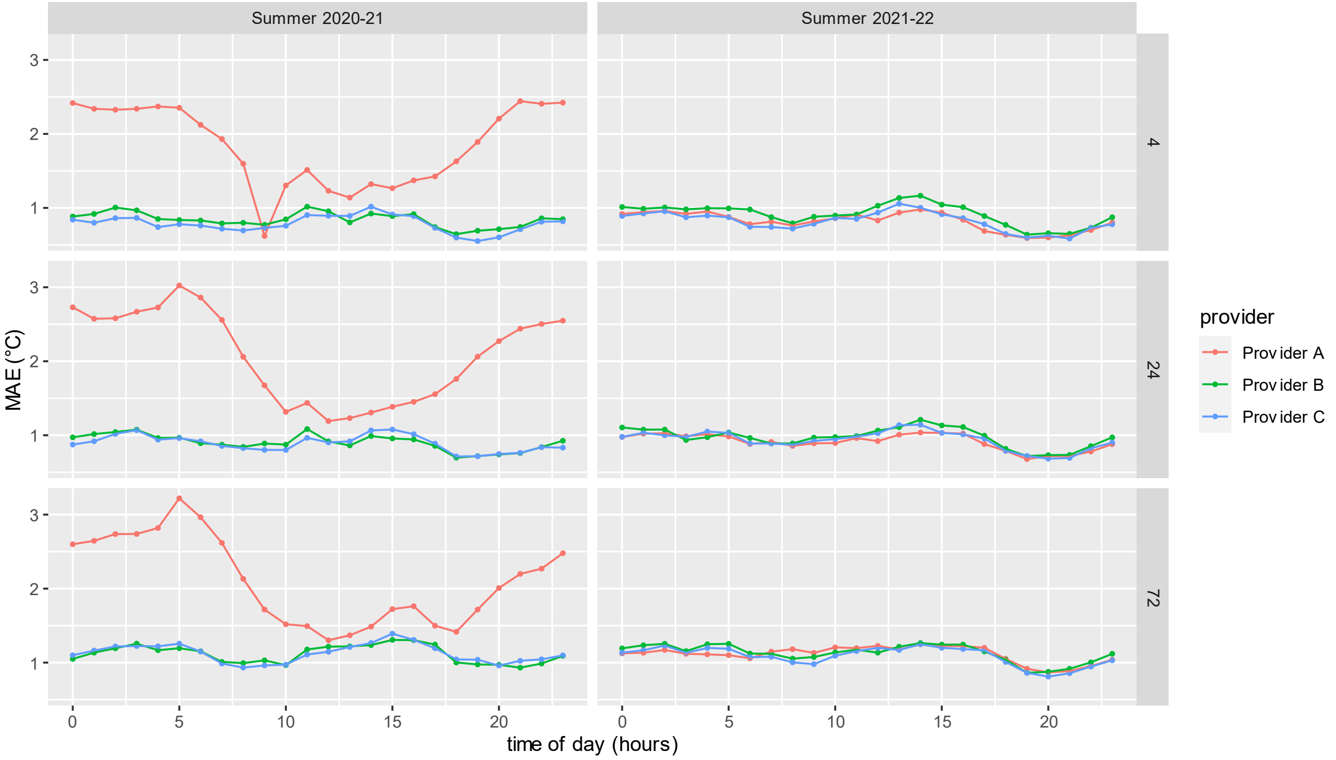


Figure 44 Melbourne OP, intraday MAE profile, summer 2020 and 2021, all time horizons, all temperatures

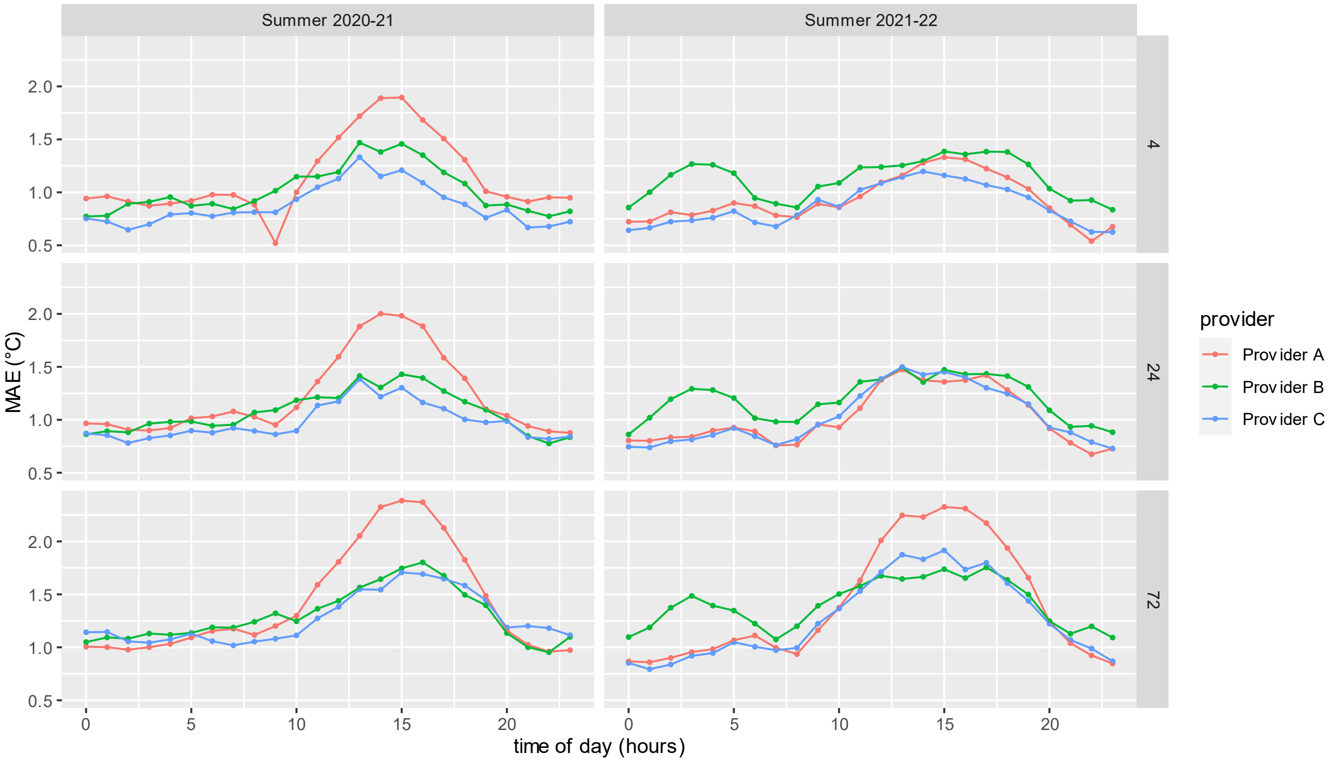


Figure 45 Melbourne AP, intraday MAE profile, summer 2020 and 2021, all time horizons, all temperatures

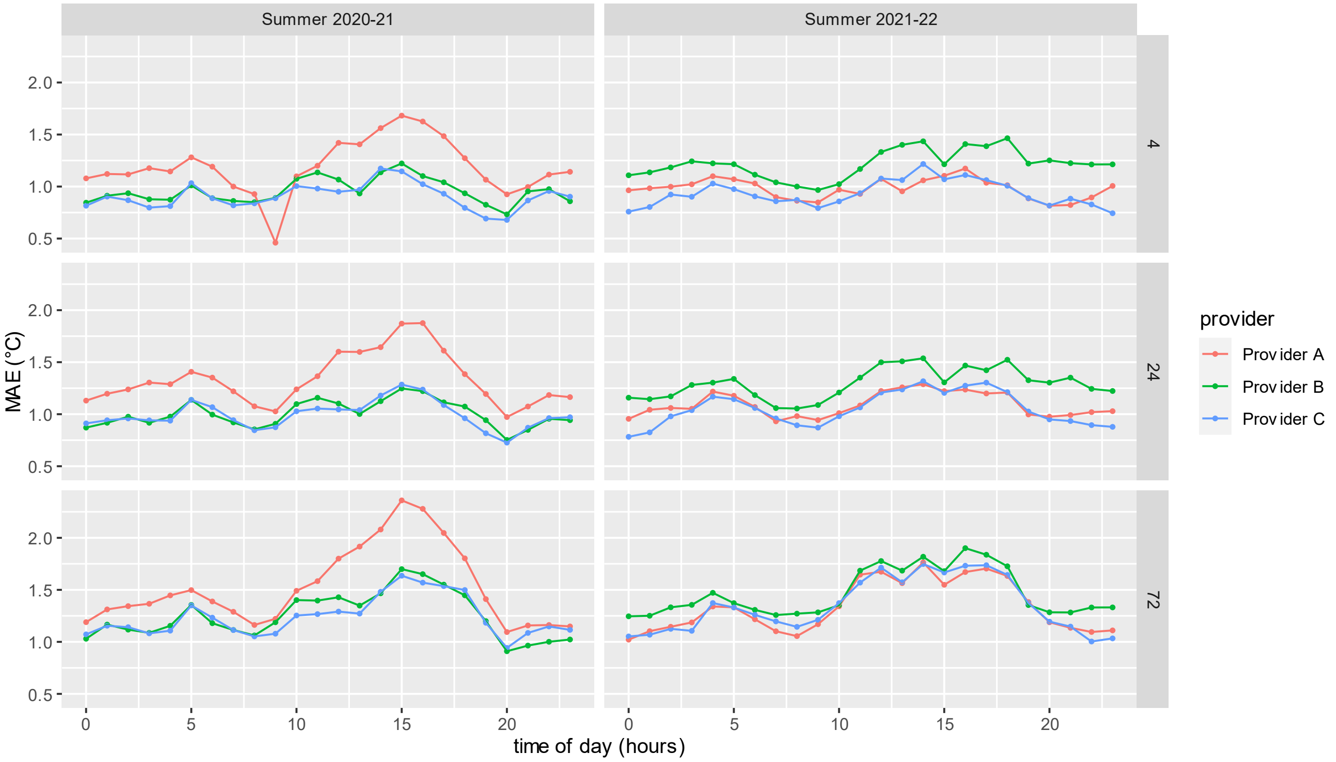


Figure 46 Penrith Lakes, intraday MAE profile, summer 2020 and 2021, all time horizons, all temperatures

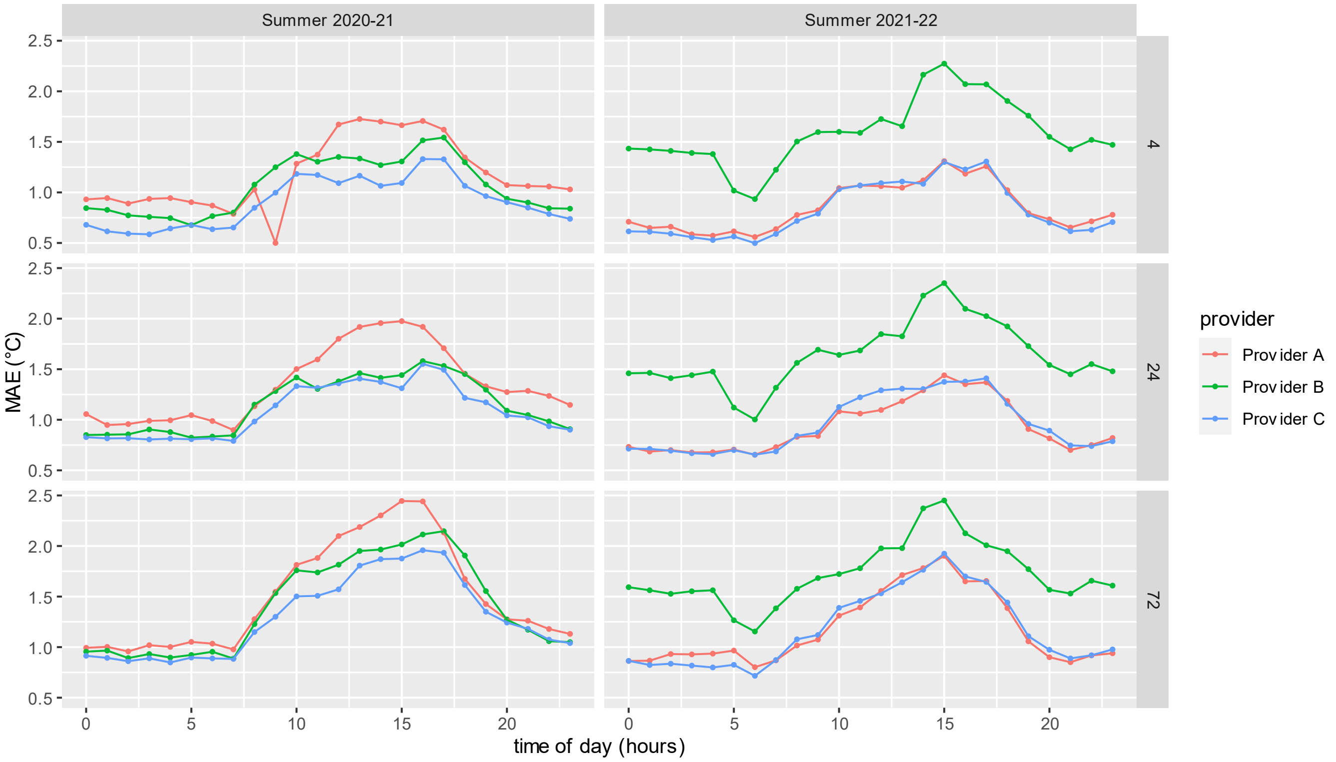
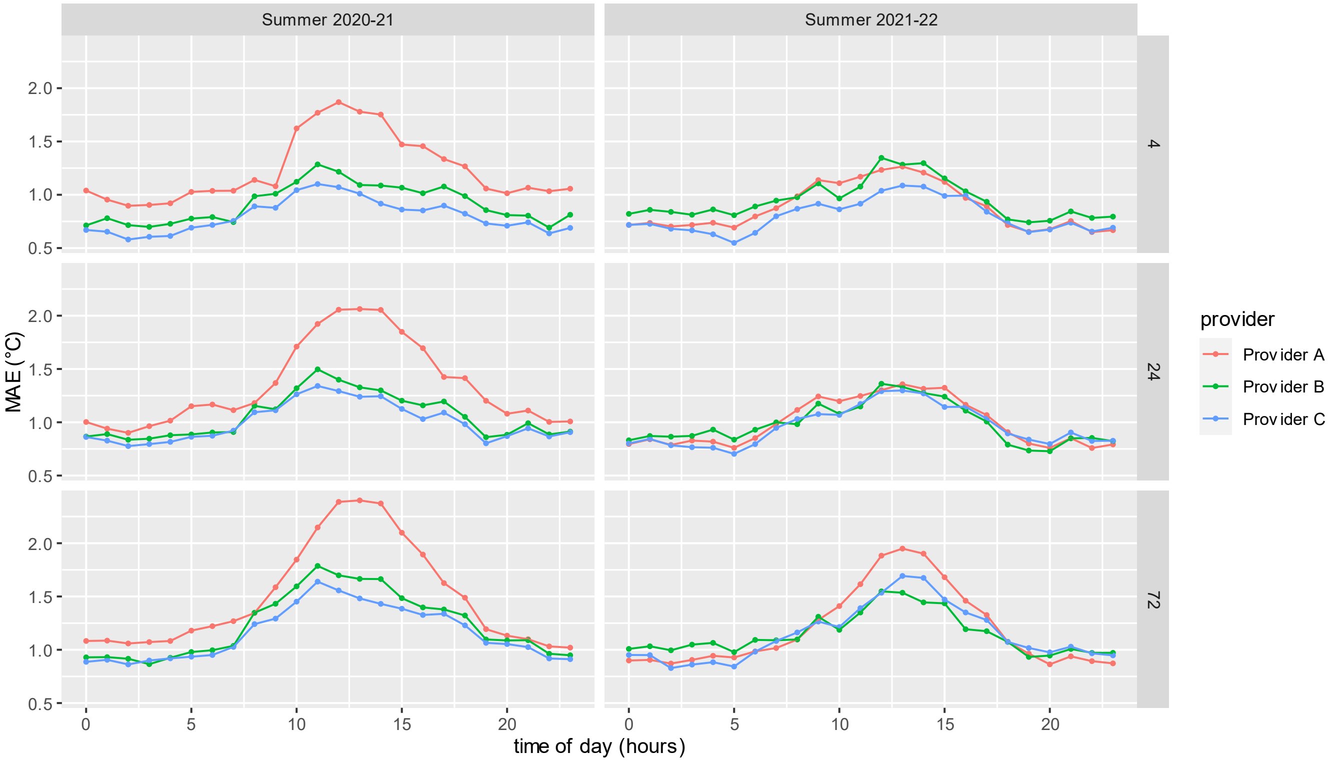


Figure 47 Sydney AP, intraday MAE profile, summer 2020 and 2021, all time horizons, all temperatures



A3. February and March 2022 plots

Figure 48 Major weather stations, Provider D, all temperatures in February and March 2022, 24 HA

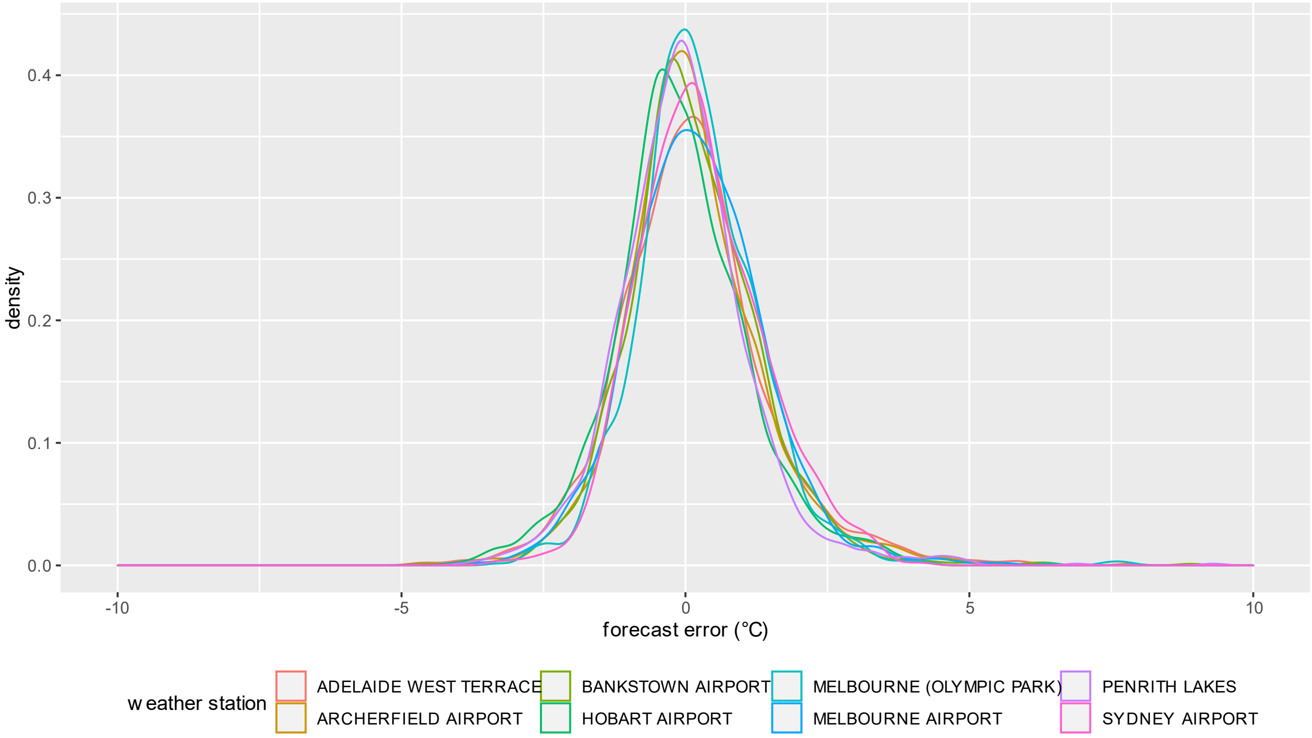


Figure 49 Major weather stations, Provider D, top 10% temperatures in February and March 2022, 24 HA

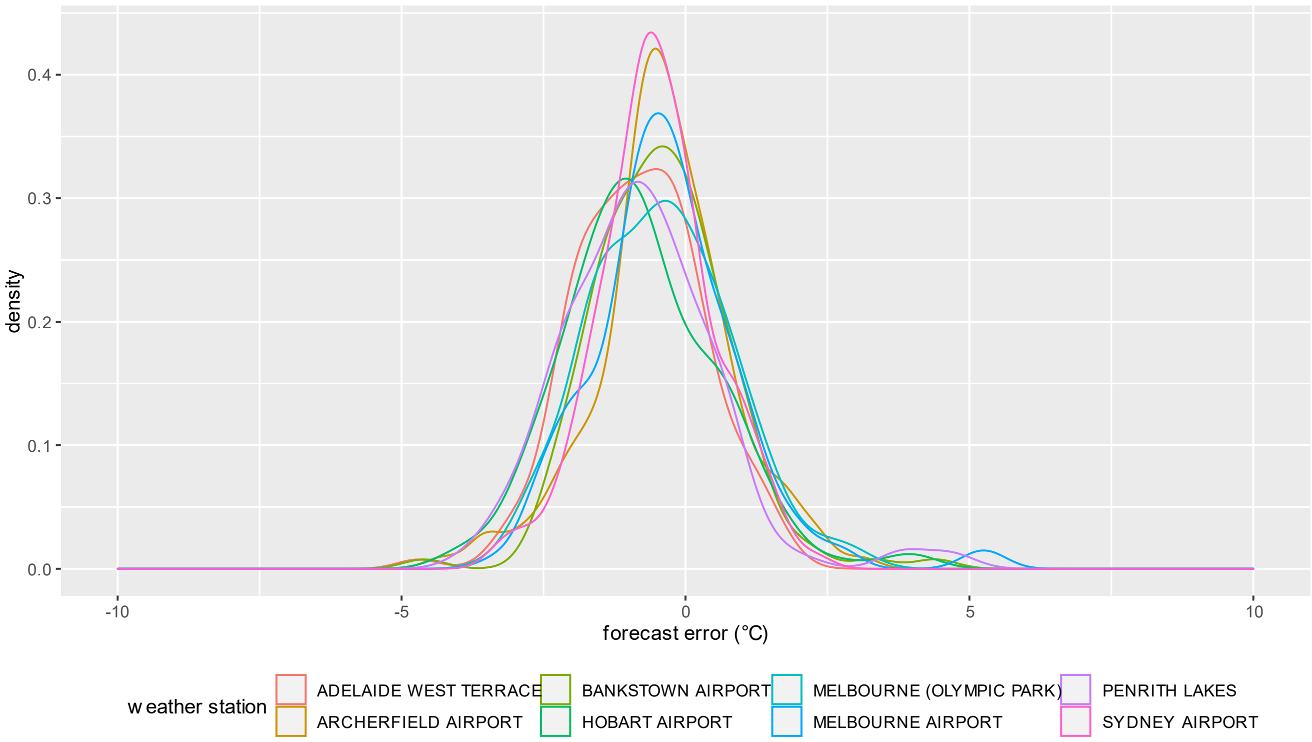


Figure 50 Melbourne (OP), top 10% temperatures, February and March 2022 including Provider D, all time horizons

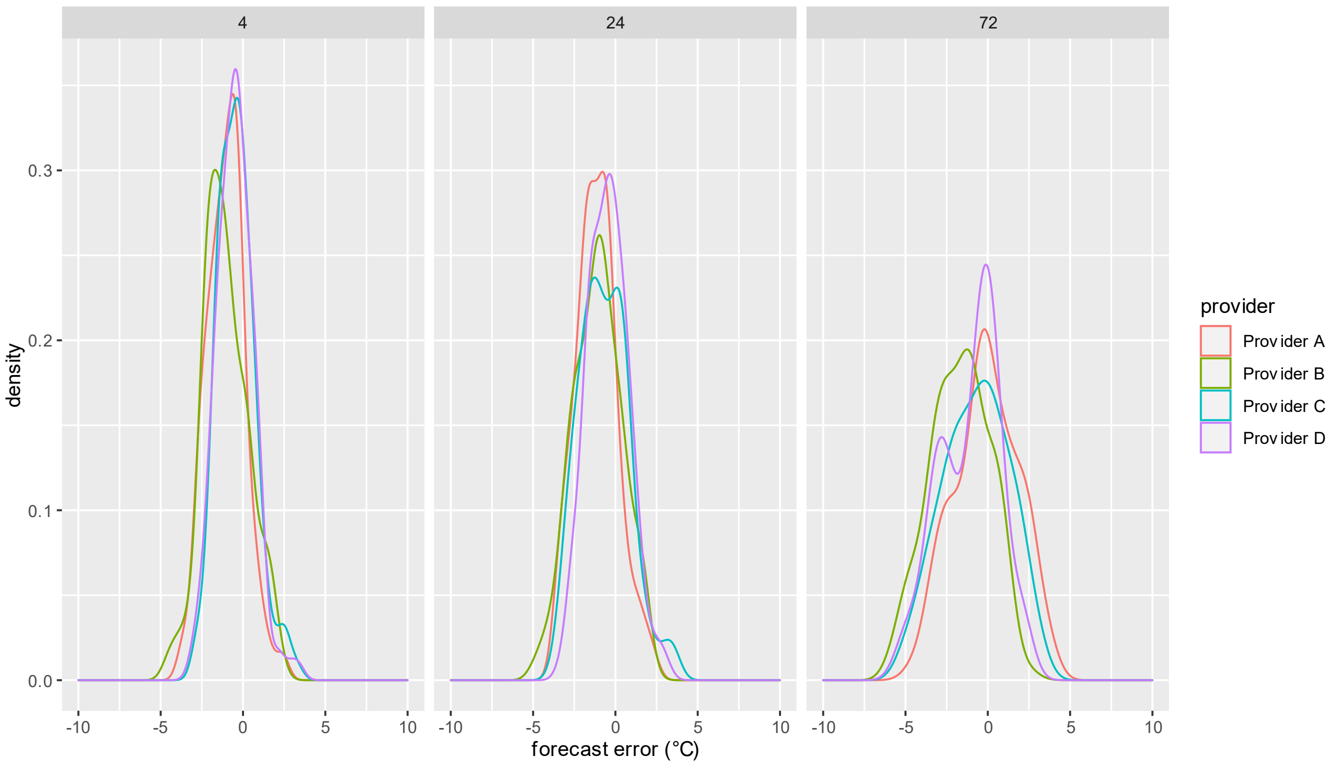


Figure 51 Hobart Airport, top 10% temperatures, February and March 2022 including Provider D, all time horizons