Temperature Forecast Analysis for Summer 2019-20

August 2020

A report assessing the forecast accuracy of AEMO's operational weather providers in the National Electricity Market from 1 December 2019 to 31 March 2020

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 2019-20 summer period.
- Give any intending weather providers information to assess the relative performance of their forecasts.
- Contribute to ongoing discussion and improvement within AEMO and the energy industry.

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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 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. 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 accuracy of AEMO's three weather service providers in the National Electricity Market (NEM) from 1 December 2019 to 31 March 2020. This biannual report follows the *Temperature Forecast Analysis for Summer 2018-19* and *Temperature Forecast Analysis for Winter 2019*. This report aims to highlight the differences in forecasting performance between summer 2018-19 and 2019-20, while also drawing new insights from summer 2019-20 performance.

The weather stations analysed in this report are Adelaide West Terrace (South Australia)[1], Archerfield (Queensland), Bankstown (New South Wales), Hobart Airport (AP) (Tasmania), Kent Town (South Australia), Melbourne Airport (AP) (Victoria), Melbourne Olympic Park (OP) (Victoria) and Penrith (New South Wales). These weather stations have the largest influence on demand forecasts for their respective NEM regions.

This report studies temperature forecast accuracy at the 72, 24, and 4-hour ahead (HA) rolling forecast horizons. To contextualise the forecasting performance results, reference is made to the temperature sensitivities of each NEM region as described in Section 2.

The key findings from the analysis were:

- Overall forecasting performance has improved since last summer. Providers B and C improved at all weather stations for at least two of the three assessed time horizons. Provider A improved overall forecast precision for all horizons at Kent Town, Melbourne AP and Melbourne OP but had mixed results elsewhere.
- Adelaide West Terrace had the lowest forecasting precision among all providers. Each provider had large under- and over-forecasting errors at this station.
- Provider A has ongoing forecast performance challenges at Hobart AP, where overall forecast performance did not improve, and accuracy remained poor, with median under-forecast error of 2.5^{o}C.
- Forecast improvements since last summer were not as consistent at high temperatures:
  - All providers had a performance decrease at Penrith and Bankstown, likely attributed to more challenging conditions this summer.
  - Providers A and C had a performance decrease at Kent Town. This was met with improved performance from Provider B.
  - Providers B and C tended to under-forecast 1-2^{o}C on average. Provider A tended to under-forecast on average, but to a lesser extent than Providers B and C. Under-forecasting was more prominent during summer 2019-20 for all providers.
  - Forecast performance was highest at Archerfield. However, for all providers, performance degraded for at least one of the three assessed time horizons compared to summer 2018-19.
- Comparing intraday performance reveals that:
  - All providers reduced their largest forecasting errors, which typically occured in the early afternoon. However, provider A showed the largest reduction in peak error.
  - Providers B and C improved their forecast performance the most at Hobart AP compared to summer 2018-19. Provider A errors remained high, especially overnight.
  - On the hottest days, Providers B and C had markedly worse performance at Bankstown AP compared to summer 2018-19. Provider A performed worse during summer 2019-20 on average at Bankstown AP but had lower error than any other provider in the early afternoon.

[1] Adelaide West Terrace was not included in previous reports. Analysis at this station has been included due to the decommissioning of Kent Town by the Bureau of Meteorology on 31 July 2020. AEMO have now introduced Adelaide West Terrace into demand forecasting models in place of Kent Town.

- Analysis of forecast performance in Victoria on 20 December 2019 reveals that all providers accurately forecast extreme temperatures up to 3 days ahead of widespread wind turbine de-rating and cut-out.

This analysis will be used by AEMO to aid operational decision-making and will be shared with weather providers to draw attention to potential areas of improvement. AEMO will continue to work with the weather forecasting industry on the key challenges identified in this report.

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 December 2019 to 31 March 2020[2]. This biannual report follows the *Temperature Forecast Analysis for Summer 2018-19* and *Temperature Forecast Analysis for Winter 2019*[3]. This report aims to highlight the differences in forecasting performance between summer 2018-19 and 2019-20, while also drawing new insight from summer 2019-20 performance.

This report is intended as a resource for weather service providers so they can benchmark their forecast performance against other providers and as a discussion and ongoing improvement piece within AEMO and the energy industry. It also includes a case study to highlight how temperature forecasts are linked to the operational challenges AEMO faced during the summer period.

2. Temperature sensitivity

This section aims to contextualise the forecasting performance results in Section 3. The performance of a temperature forecast must be understood with reference to the temperature sensitivity of electricity demand. That is, it is most important for providers to provide accurate and precise temperature forecasts when:

- Demand is high.
- Reserves are low.
- A small change in temperature results in a large change in demand.

These conditions are often met on hot summer days, meaning it is important to produce accurate and precise temperature forecasts on these days. In addition, electricity demand in each NEM state has different temperature sensitivity (Figure 1)[4].

Figure 1 illustrates that:

- At 30°C, an accurate temperature forecast for New South Wales is more critical than for Tasmania, for example.
- All states except Tasmania have notable temperature sensitivity on hot summer days, exceeding their temperature sensitivity on cool winter days.
- If the actual temperature is 35°C but the forecast was 30°C, the demand will be:
  - 1,800 MW higher than forecast in Queensland.
  - 1,700 MW higher than forecast in New South Wales.
  - 1,300 MW higher than forecast in Victoria.
  - 500 MW higher than forecast in South Australia.

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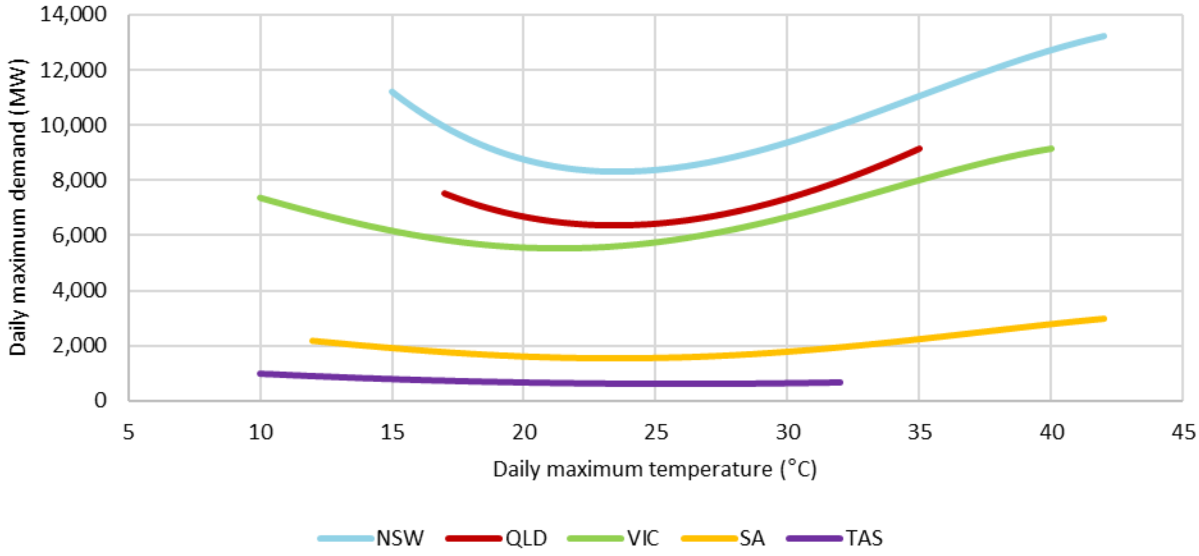
[2] All analysis refers to time in Australian Eastern Standard Time (AEST).

[3] Previously published reports under *Weather Forecasting* at https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/load-forecasting-in-pre-dispatch-and-stpasa

[4] Figure 1 and Figure 2 compare maximum daily maximum dry bulb temperature values with maximum daily native demand on weekdays (excluding public holidays) from 1 Jan 2017 to 31 Mar 2020. The temperature readings are taken from the primary weather station for demand forecasting in each state (New South Wales – Bankstown Airport, Queensland – Archerfield, Victoria – Melbourne Olympic Park, South Australia – Kent Town, Tasmania – Hobart Airport). Data points with few observations (i.e. very low and very high temperatures) were excluded to ensure reasonable curve fitting.

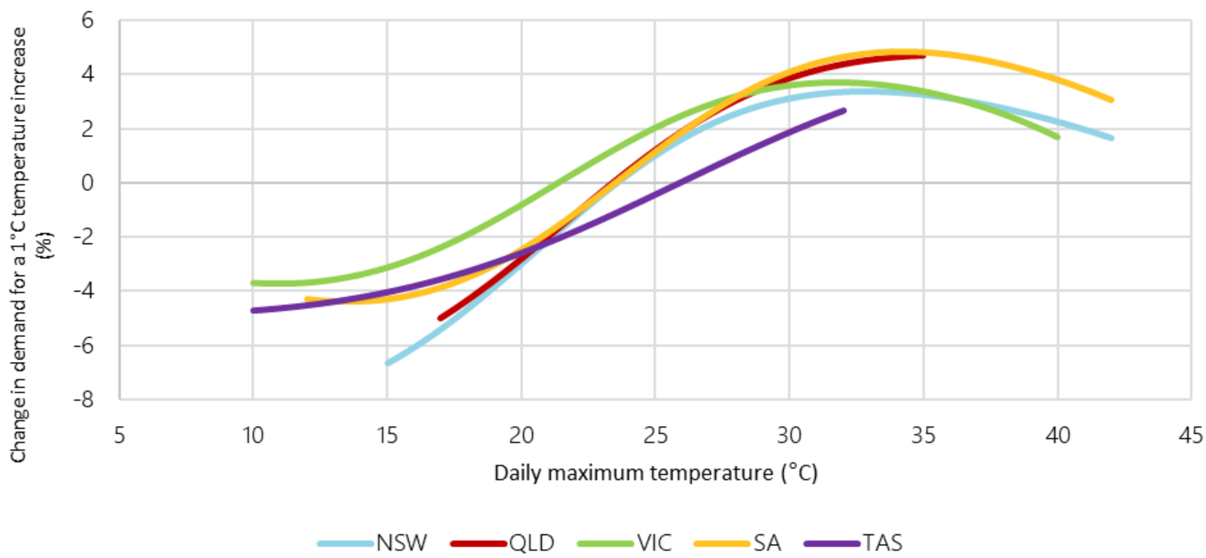
Figure 1 Weekday maximum daily demand (excluding major industrial loads) vs temperature in each NEM state



However, a 100 MW demand forecasting error in New South Wales does not create the same operational challenges as the same error in South Australia. Since each state has limited local generation and interconnector capacity, percentage changes in demand must be understood in conjunction with absolute demand changes. Figure 2 illustrates the percentage change in demand if the actual temperature is 1°C higher than the forecast temperature. Key findings from Figure 2 include:

- Most states have the highest temperature sensitivity at 32°C to 35°C during summer. This makes temperature forecasts critical at or above these temperatures, because demand is both high and sensitive.
- South Australia and Queensland have the highest temperature sensitivity at up to 5% per 1°C during summer.
- Even considering proportionality, Tasmania demand has comparatively low temperature sensitivity.
- Towards 40°C, demand sensitivity reduces as most cooling devices that can be switched on, are switched on by this stage. Accurate temperature forecasting at these temperatures is still critical because demands are very high (as shown in Figure 1).

Figure 2 Percentage change of demand of each NEM state with a 1°C under-forecasting error



3. Summer forecast performance

This section contains a selection of insights into hourly temperature forecasting performance for summer 2019-20 in the NEM. Results supporting major comparisons between summer 2018-19 and 2019-20 are included in the main report, and a full set of results is in appendices A1 and A2.

This report studies temperature forecast performance at the 72, 24, and 4-hour ahead (HA) rolling forecast horizons.

Many of the results in this section and in Appendix A1 are displayed as error density plots, which 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 less than the actual temperature).
- The y-axis shows error density. This reflects the relative rate of occurrence of a forecast error. For each forecast error, the error density will be between 0 and 1, and the area under each curve equates to 1.
- In general, the height of the error density peak captures the level of forecast precision, and the positioning of the peak with respect to a forecast error of zero captures the forecast accuracy. The higher the peak, the greater the precision and the smaller the expected deviation from the average level of error. The further the peak is from zero error, the lower the accuracy, and the larger the tendency for over- or under-forecasting on average.

Appendix A2 contains intraday mean absolute error (MAE) profiles for every weather station by provider. Forecasts are provided for each hour of the day.

3.1 Insights by weather station

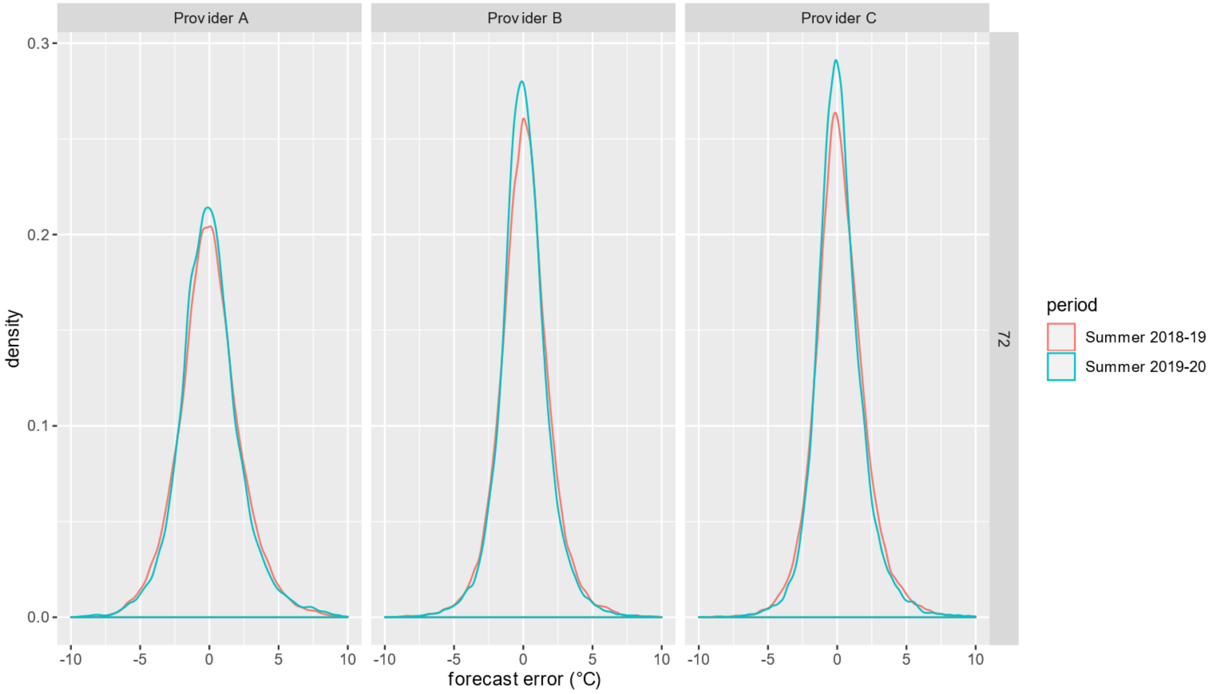
Overall forecasting performance has generally improved since last summer

Summer 2019-20 was Australia's second hottest on record, surpassed only by summer 2018-19, with 50th percentile temperatures 1-1.5°C lower at all studied weather stations this summer compared to last. Despite this, Bankstown Airport, Penrith Lakes and Hobart Airport all broke maximum temperature records, with new records standing at 47°C, 48.9°C and 41.4°C respectively. Adelaide West Terrace also saw its highest daily minimum temperature since 1939, at 33.6°C.

These temperature records, combined with bushfire activity affecting transmission and generation infrastructure, and smoke haze impacting solar generation and causing behavioural changes in electricity consumption, meant that accurate temperature forecasts were critical to the ongoing secure supply of energy.

Figure 3 shows the 72-HA error distributions for each provider across all studied weather stations comparing summer 2018-19 and 2019-20. At a high level this shows that forecasting performance either improved or remained consistent at this horizon. This is representative of the overall improvements also observed for the 4- and 24-HA horizons.

Figure 3 Summer performance comparison (2018-19 and 2019-20), all weather stations, 72-HA horizon



For all providers, performance improvements were mainly due to increased precision. Average forecast biases and large under- or over-forecasting was still observed, and at some stations was larger than summer 2018-19.

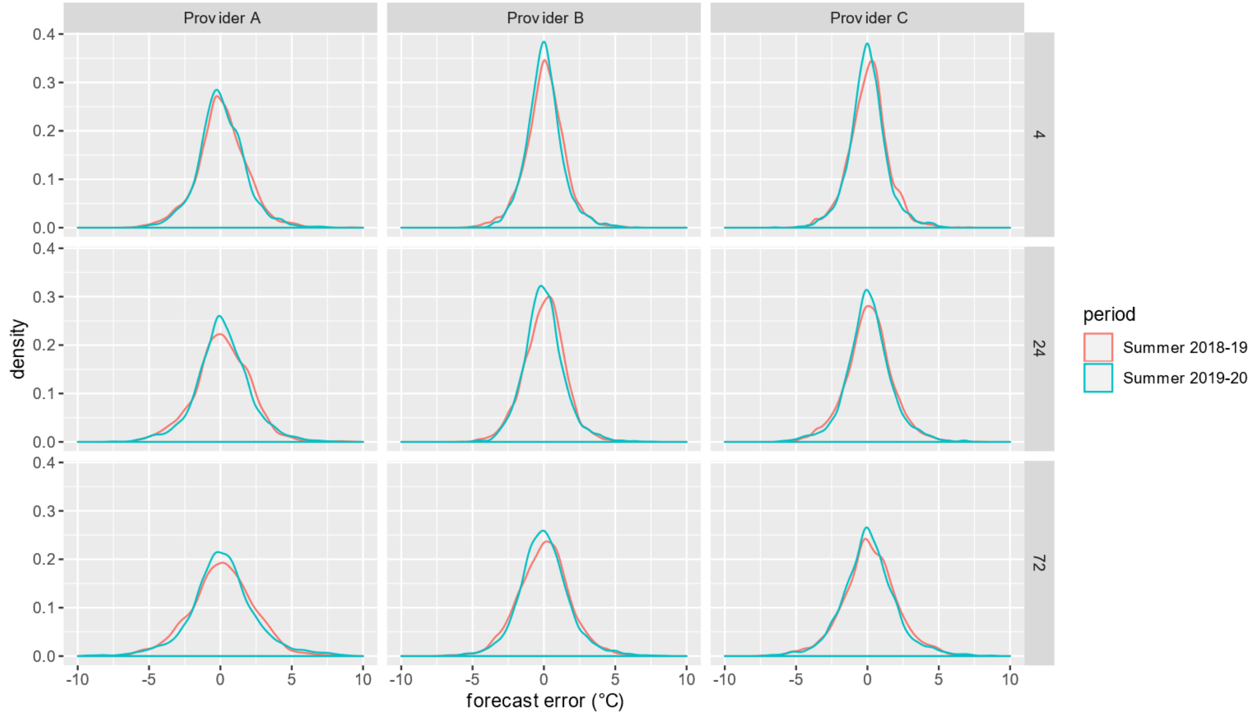
Providers B and C forecast performance improved at all weather stations for at least two of the three assessed time horizons compared to summer 2018-19:

- 72-HA performance improved at all stations except for Archerfield which remained relatively consistent.
- 24-HA performance either improved, most notably at Bankstown, Hobart, and Kent Town, or remained consistent. Additionally, differences in provider performance identified in summer 2018-19 reduced, particularly at Bankstown and Melbourne Olympic Park (OP).
- Provider C improved performance at the 4-HA horizon at all weather stations.

Provider A improved forecast precision for all horizons at Kent Town, Melbourne AP and Melbourne OP but had mixed results elsewhere. Overall, Provider A was the lowest performing provider, consistent with last summer, however average performance did improve for each forecast horizon.

Forecast performance improved for all providers and horizons at Kent Town and Melbourne AP, and either improved or remained consistent at Bankstown and Melbourne OP. Figure 4 shows the performance improvements at Kent Town between summer 2018-19 and 2019-20, which represents the general improvement trend.

Figure 4 Kent Town, all providers, all summer comparison 2018-19 and 2019-20, 4, 24, and 72-HA



Forecast improvements since last summer were not as consistent at high temperatures

Forecast performance of the top 10% of observed temperatures varied between stations relative to summer 2019-20[5]. Compared with last summer at high temperatures:

- Providers B and C tended to under-forecast 1-2^{0}C on average. Provider A tended to under-forecast on average, but to a lesser extent than Providers B and C. Under-forecasting was more prominent during summer 2019-20 on average.
- Forecast performance was highest at Archerfield. However, for all providers, performance degraded for at least one of the three assessed time horizons compared to summer 2018-19.

High temperature forecast performance generally improved or remained consistent at Hobart Airport, Melbourne OP and Melbourne AP for all providers. Provider B improved the most overall relative to last summer, either improving or remaining consistent at all horizons at Kent Town, Melbourne OP and Hobart Airport.

The New South Wales stations, Bankstown and Penrith, were more challenging to forecast this summer, which could be attributed to extreme heat, bushfire activity and smoke haze in the state.

Figure 5 and 6 show that all providers had performance decreases at these stations for at least two horizons compared to summer 2018-19. These figures also highlight the tendency for Providers B and C to under-forecast high temperatures and that this tendency increased during summer 2019-20.

[5] In the *Temperature Forecast Analysis for Summer 2018-19*, high temperatures were defined as the top 5% of temperatures at each station. This has been changed to the top 10% of temperatures to increase sample size and produce more reasonable and comparable error distributions.

Figure 5 Bankstown, all providers, 2018-19 & 2019-20, top 10% of temperatures, 4, 24, and 72-HA

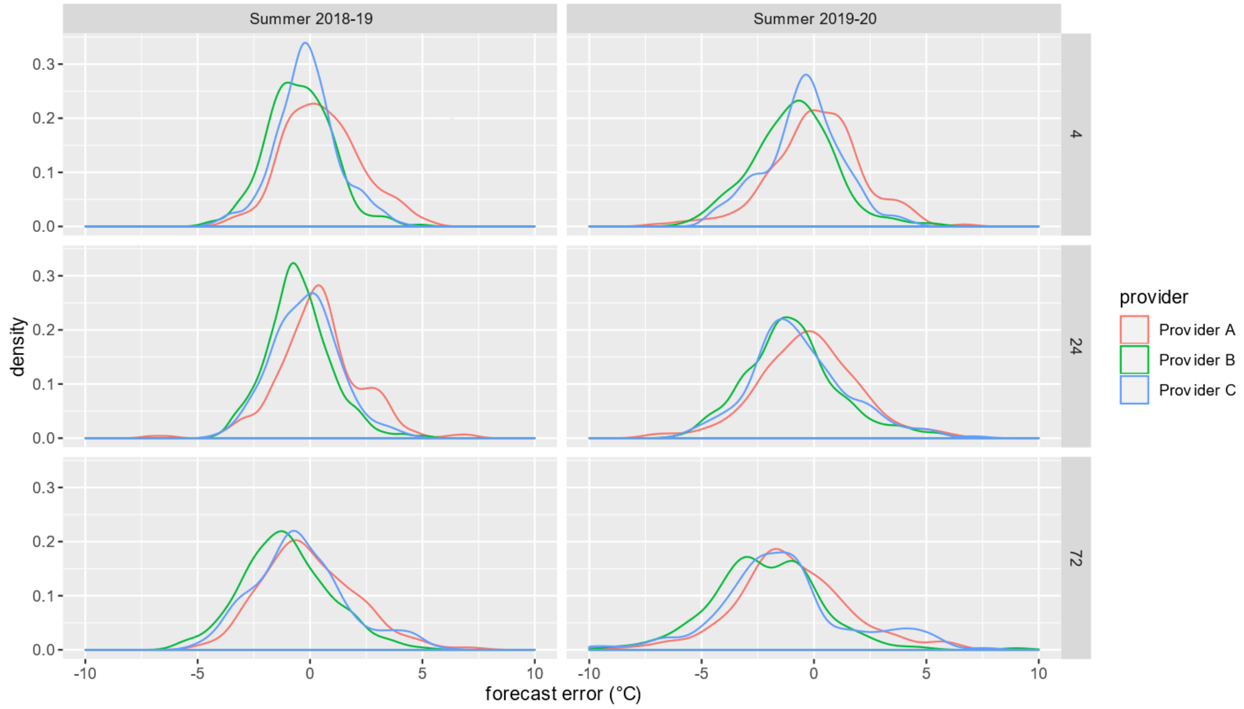
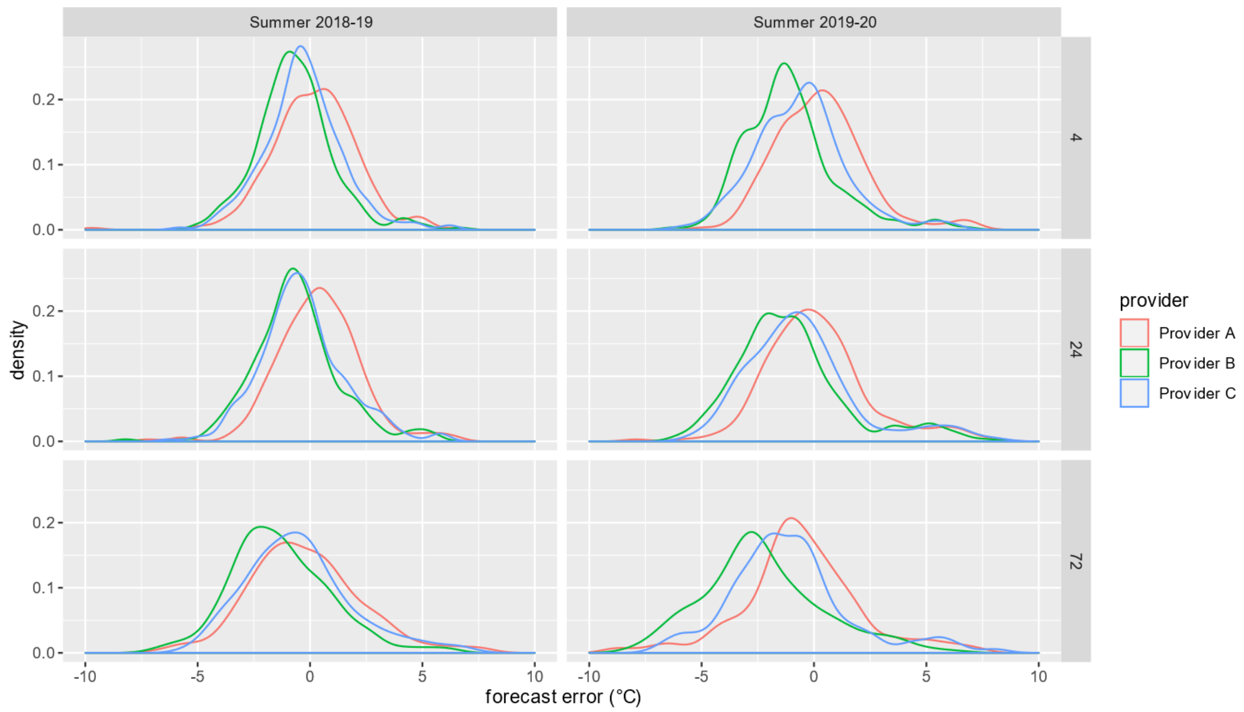


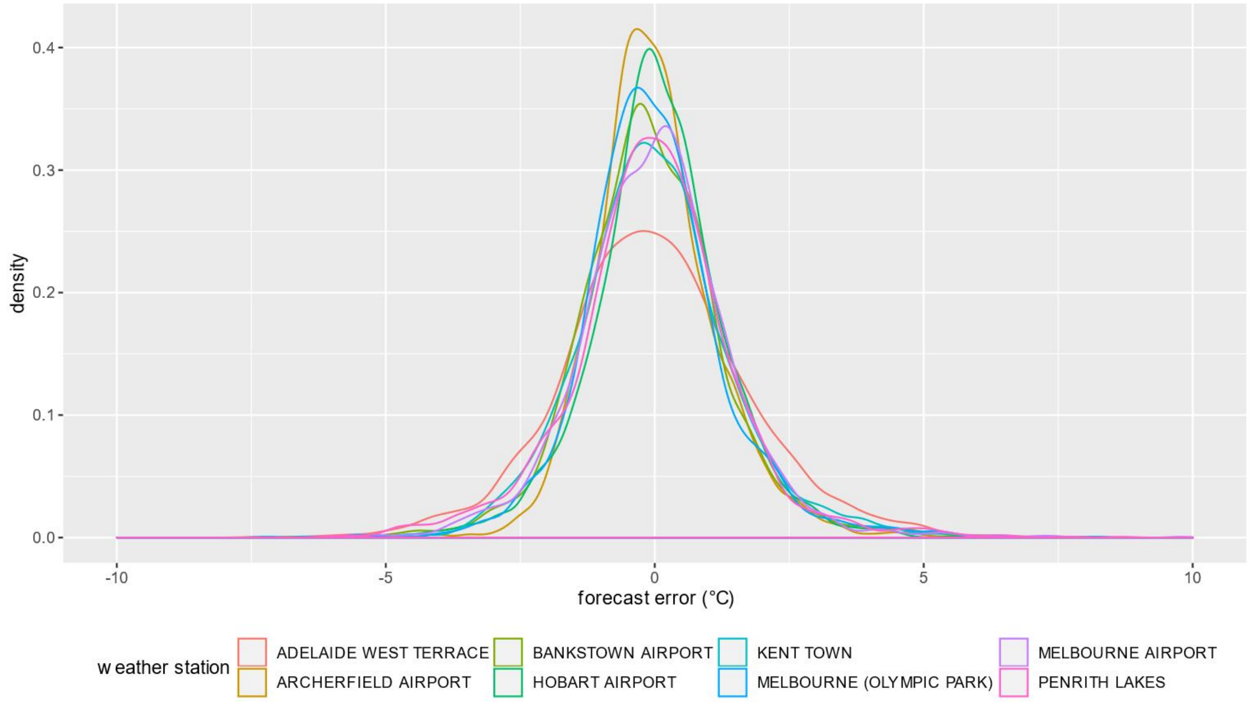
Figure 6 Penrith, all providers, 2018-19 & 2019-20, top 10% of temperatures, 4, 24, and 72-HA



West Terrace had the lowest forecasting precision among all providers

Adelaide West Terrace was forecast with the lowest precision among all providers and weather stations in summer 2019-20. This is demonstrated in Figure 7, which shows the error distribution for all weather stations for Provider B. This comparison is similar for Providers A and C which shows West Terrace performance marred by large under- and over-forecasting errors.

Figure 7 All weather stations, Provider B, summer 2019-20, 24-HA



Performance at West Terrace was worse than at Kent Town in summer 2019-20. As shown in Figure 8 and Figure 9, Providers A and B had notably less precise and accurate forecasts at West Terrace compared to Kent Town. Provider C performed better and was comparatively strong at 4-HA, however, was slightly less precise at the 24- and 72-HA time horizons compared to Kent Town.

Figure 8 West Terrace, summer 2019-20, 4, 24, and 72-HA time horizons

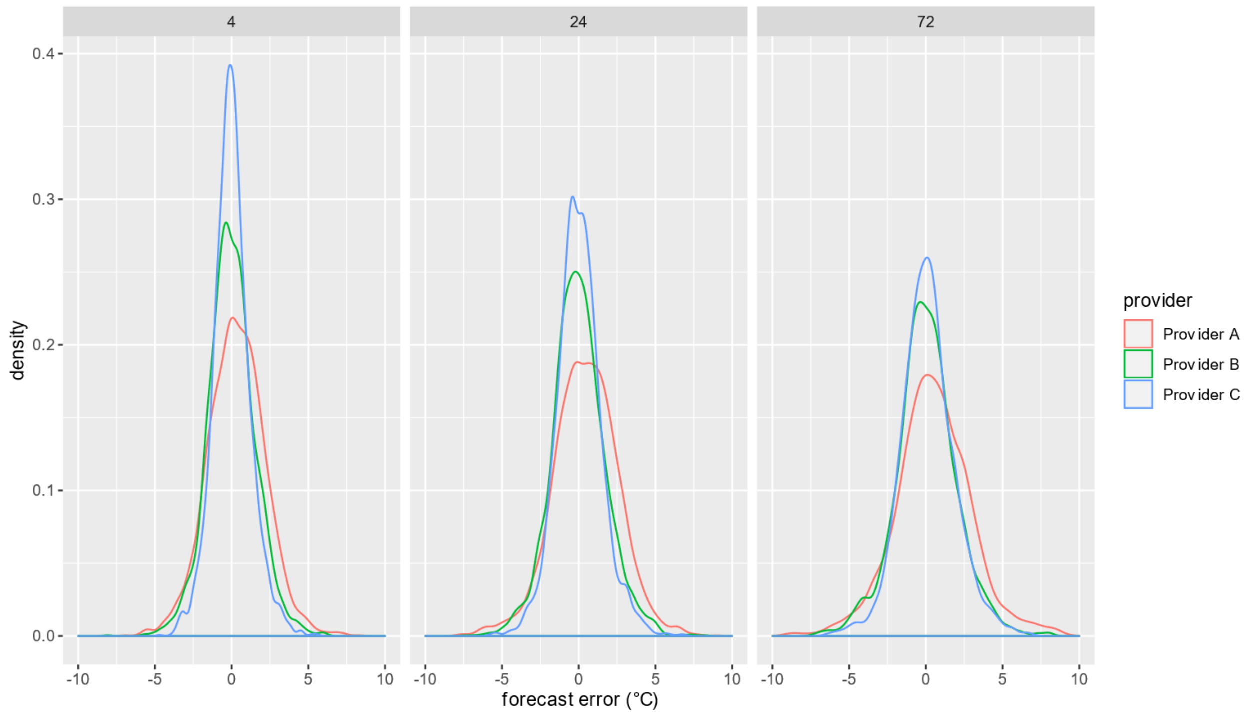
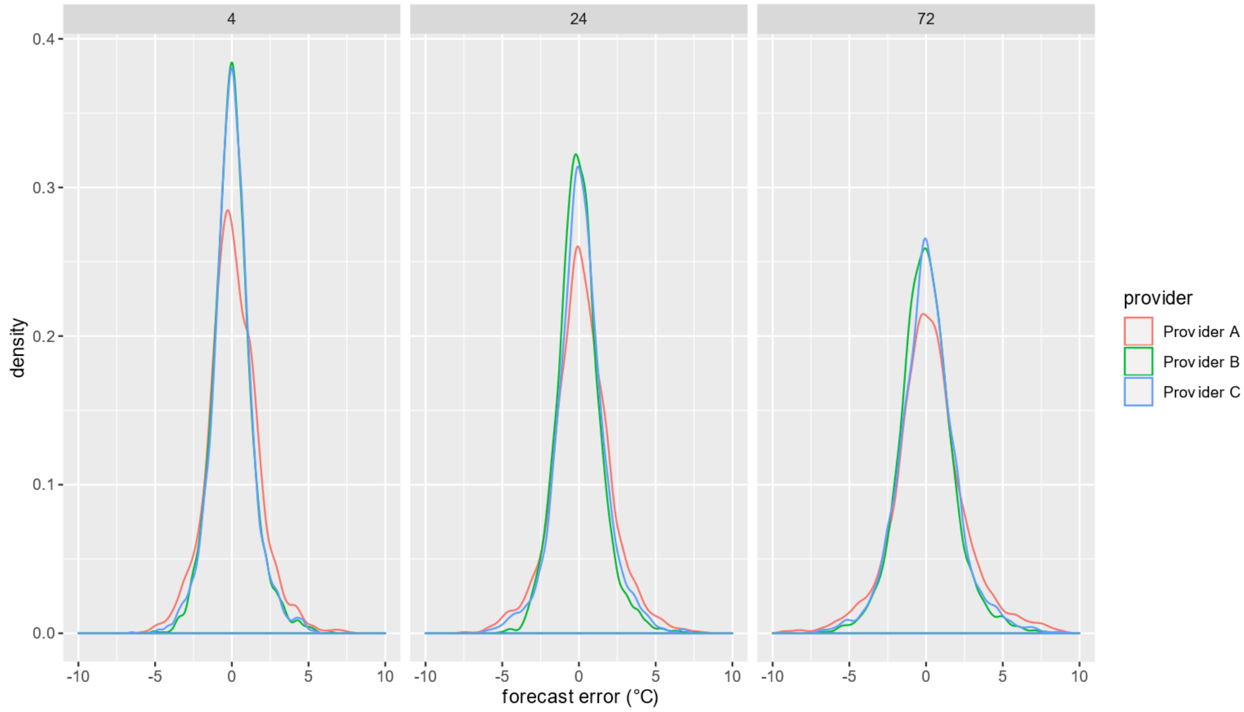


Figure 9 Kent Town, summer 2019-20, 4, 24, and 72-HA time horizons



Compared to summer 2018-19 at the 24-HA horizon, forecast performance decreased for Provider A, and remained consistent for Providers B and C.

On July 31 2020, Kent Town weather station was decommissioned. AEMO is now using West Terrace as the primary weather station to forecast demand in South Australia. Weather stations in urban areas such as Kent Town better capture the heat island effect and thus are better suited to demand forecasting.

Ongoing performance improvements at West Terrace are particularly important given the high temperature sensitivity of South Australian demand, as explored in Section 2. That is, small changes in temperature forecasts can lead to large demand changes, especially on hot days. Although Section 2 explores the temperature sensitivity for Kent Town, similar results are anticipated for West Terrace.

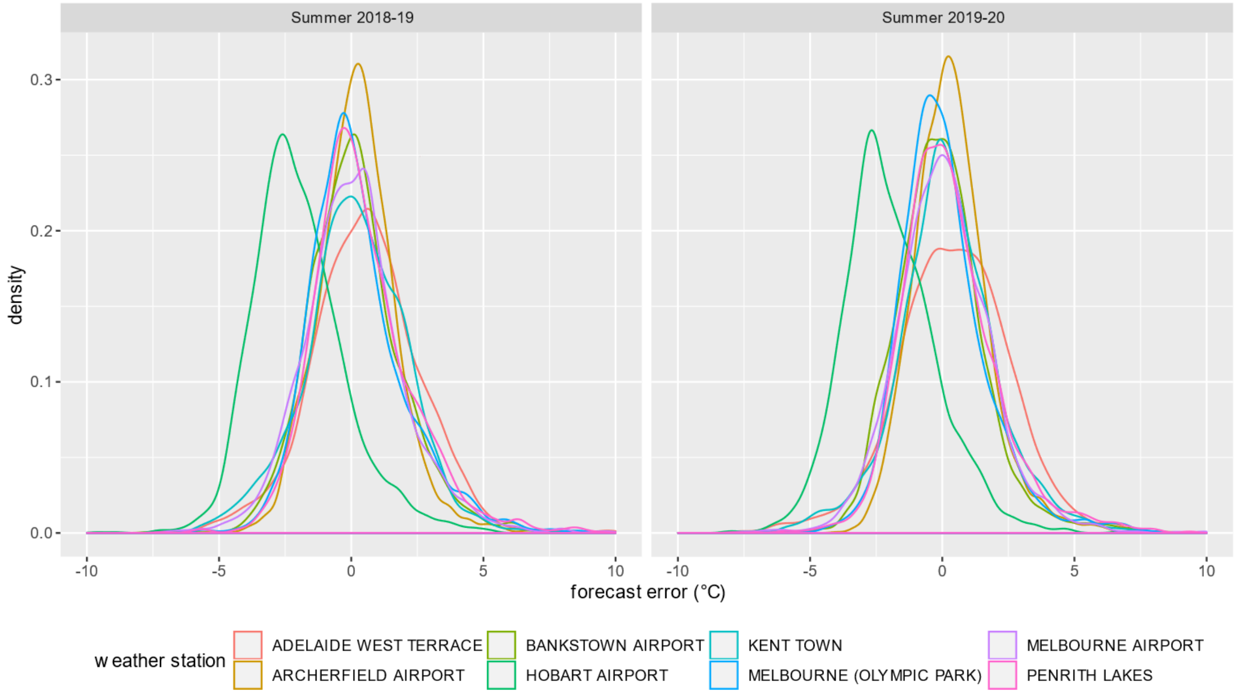
3.2 Insights by provider

Provider A has ongoing performance challenges at Hobart Airport

Provider A had similar forecast performance at Hobart Airport in summer 2019-20 and summer 2018-19. Provider A's accuracy was lower than any provider at any station with the median forecast approximately 2.5°C under-forecast during summer 2019-20.

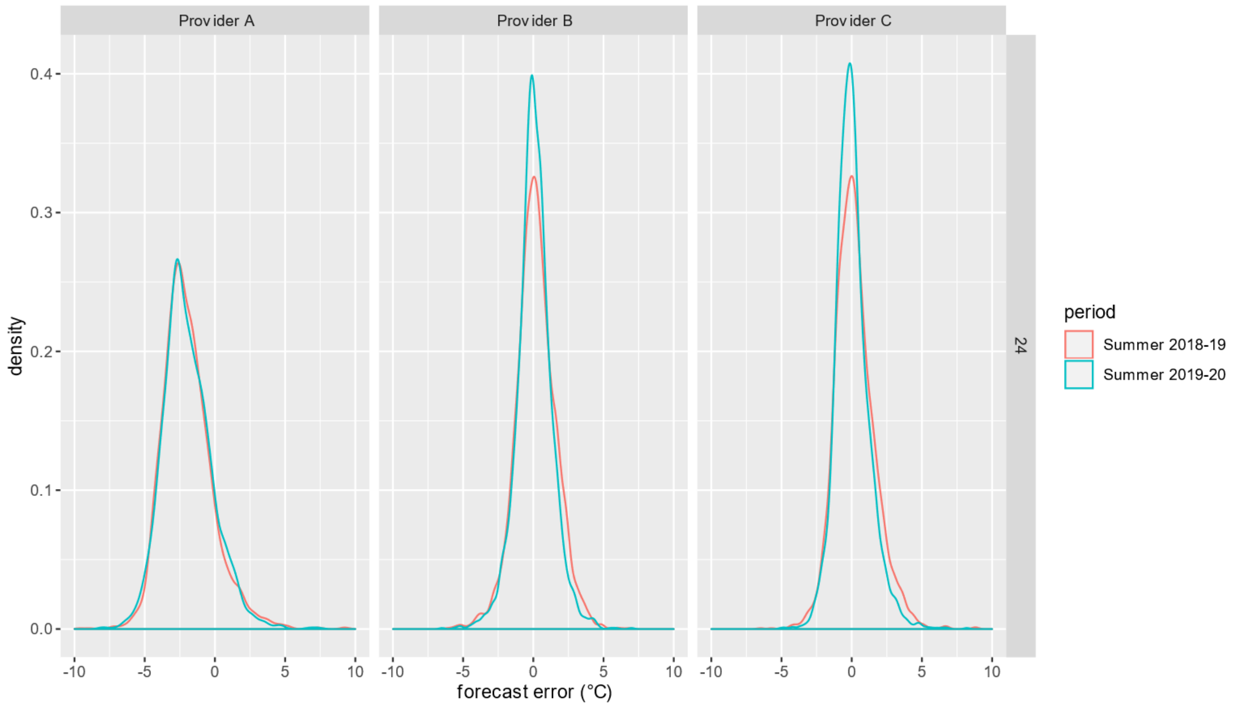
Figure 10 shows the comparative performance of Provider A at all stations in summer 2018-19 and 2019-20.

Figure 10 All weather stations, Provider A, summer comparison 2018-19 and 2019-20, 24-HA



Provider A's performance at Hobart Airport compares with a significant increase in performance by Providers B and C during summer 2019-20 at the 24-HA horizon, as shown in Figure 11.

Figure 11 Hobart Airport, all providers, all summer comparison 2018-19 and 2019-20, 24-HA



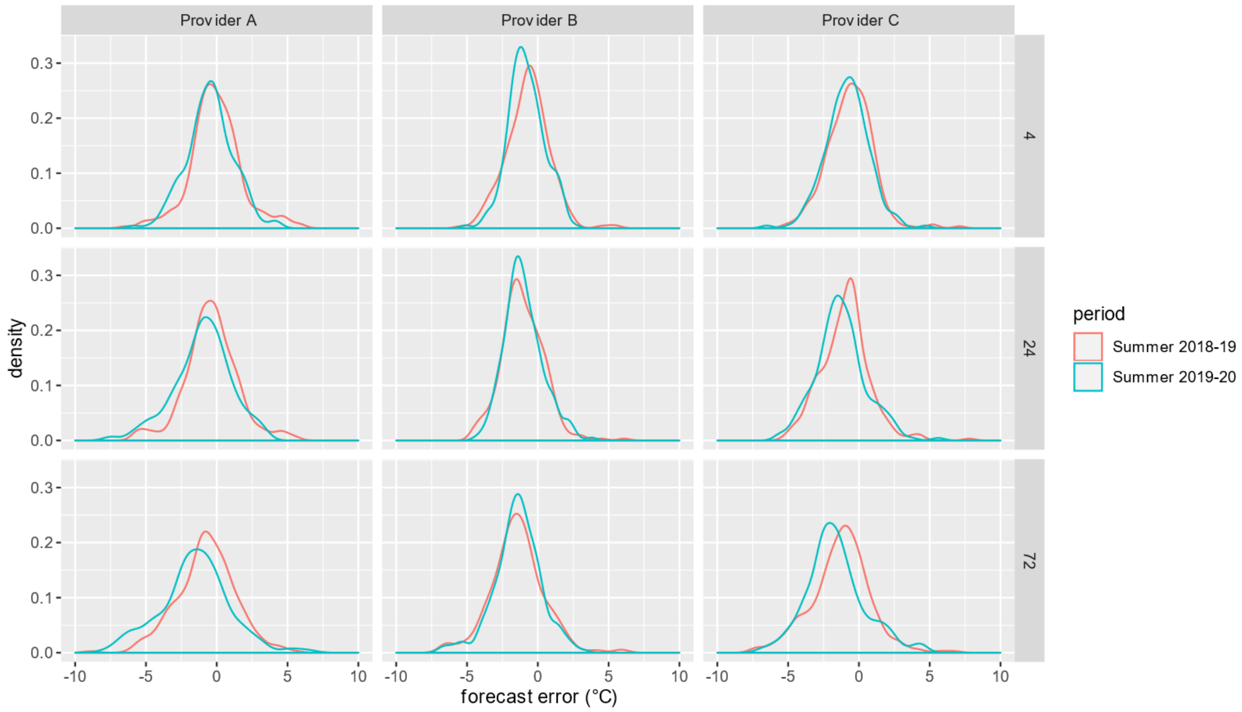
Although Provider A had the lowest forecasting performance at Hobart Airport, Tasmania has low temperature sensitivity during summer periods as described in Section 2. Therefore, accurate weather forecasting at Hobart Airport is not as critical to demand forecasting as other weather stations in the NEM during summer.

Provider A and C had a performance decrease at Kent Town at high temperatures

High temperatures were milder at Kent Town during summer 2019-20, with a 10th percentile threshold 1.5°C lower than the previous summer. Contrary to an overall performance increase, the performance of forecasting the top 10% of temperatures at Kent Town decreased for Providers A and C compared to summer 2018-19. Forecast performance either worsened, with under-forecasting more prominent, or remained approximately consistent at all forecast horizons.

This was met with a general increase in performance by Provider B, as shown in Figure 12. This divergence in performance reduced consensus between Providers B and C and made demand forecasting more challenging at high temperatures during summer 2019-20 in South Australia.

Figure 12 Kent Town, all providers, 2018-19 & 2019-20, top 10% of temperatures, 4, 24, and 72-HA



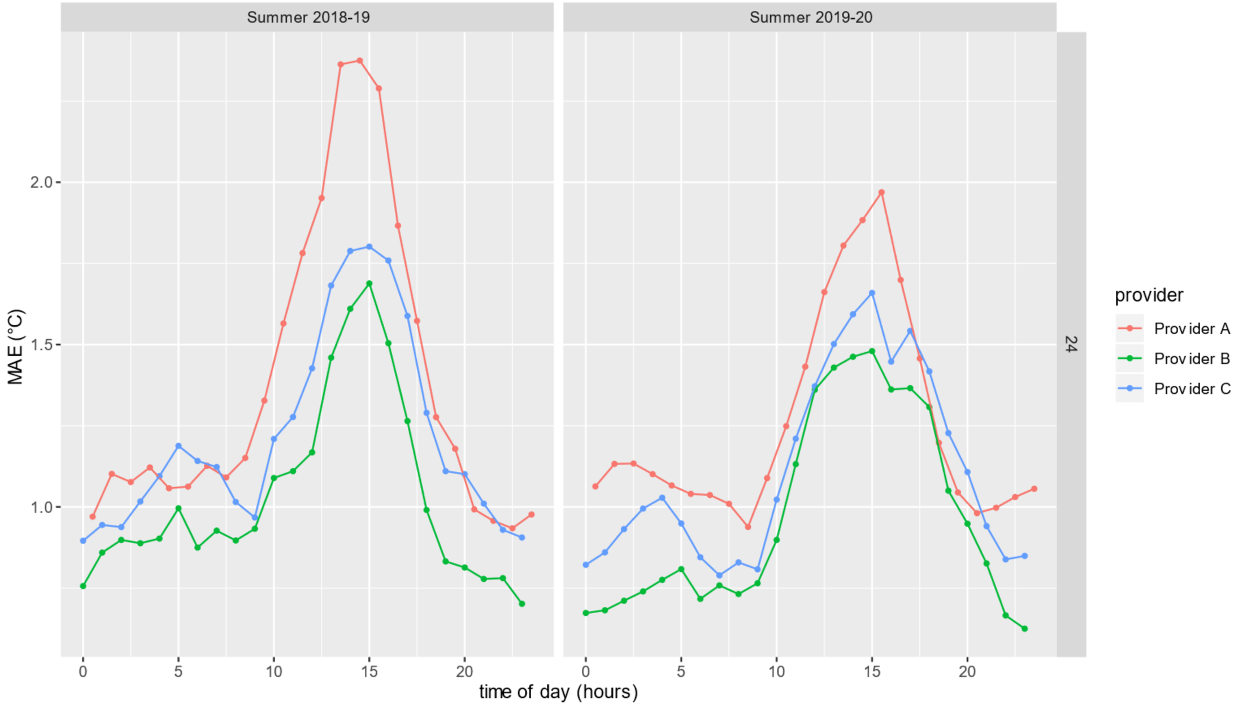
3.3 Intraday insights

Provider A intraday peak errors reduced significantly this summer

All providers tended to have the largest errors in the early afternoon. In summer, this usually aligns with daily maximum temperature. During this time the grid is in a state of flux, with solar PV ramping down and demand ramping up. It is therefore important that accurate afternoon temperature forecasts are being fed into the demand forecasting models.

While Providers B and C experienced some peak error reductions, Provider A had the most significant peak reductions. Figure 13 shows the comparison of intraday forecasting errors at Melbourne OP for summer 2018-19 and 2019-20 at the 24-HA horizon. This is representative of the improvement trend at all stations and horizons, except for Archerfield and Hobart AP. Errors at other times of the day for Provider A typically reduced, but to a lesser extent.

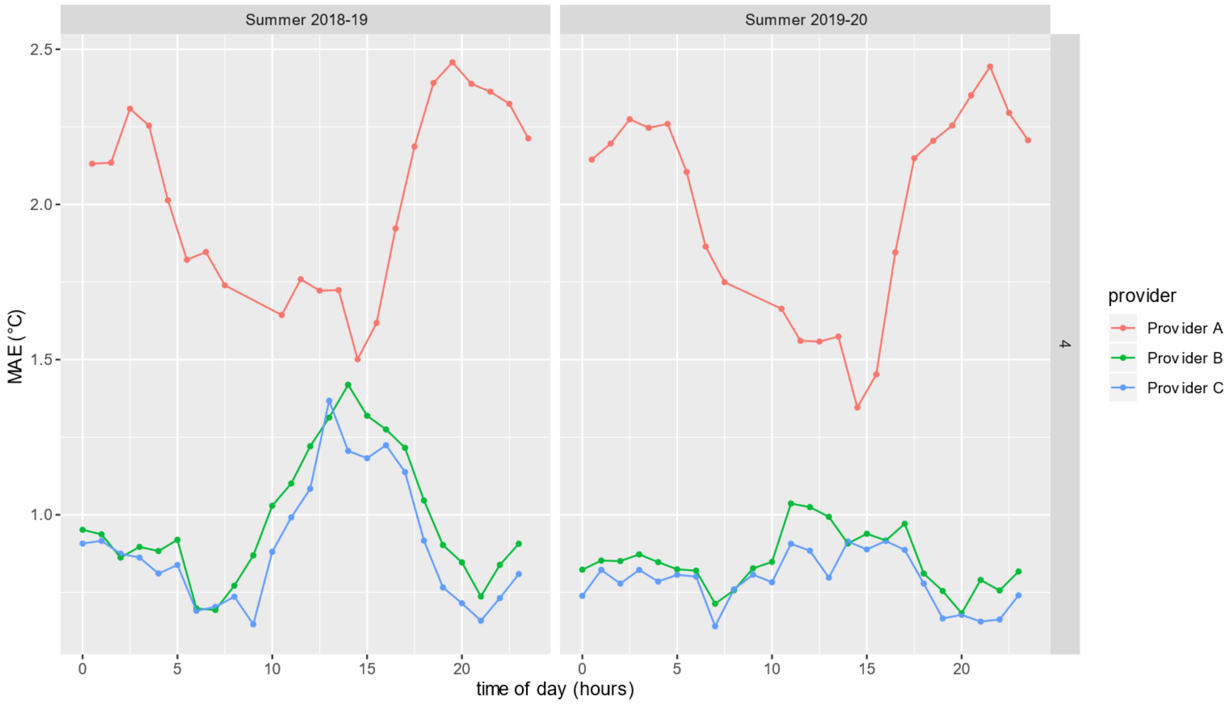
Figure 13 Melbourne OP, all providers, MAE intraday profiles, all summer 2018-19 and 2019-20, 24-HA



Providers B and C improved for Hobart Airport and provider A's highest errors remain overnight

As with Provider A, Providers B and C reduced their largest intraday forecasting errors at several stations, the most notable being Hobart AP, as shown in Figure 14.

Figure 14 Hobart AP, all providers, MAE intraday profiles, all summer 2018-19 and 2019-20, 4-HA



For the 4- and 24-HA horizons during summer 2019-20, errors were consistent throughout the day, whereas during summer 2018-19, errors were elevated at approximately 1500 hrs. At 1500 hrs for the 4-HA interval, the average error for Providers B and C was below 1°C during summer 2019-20.

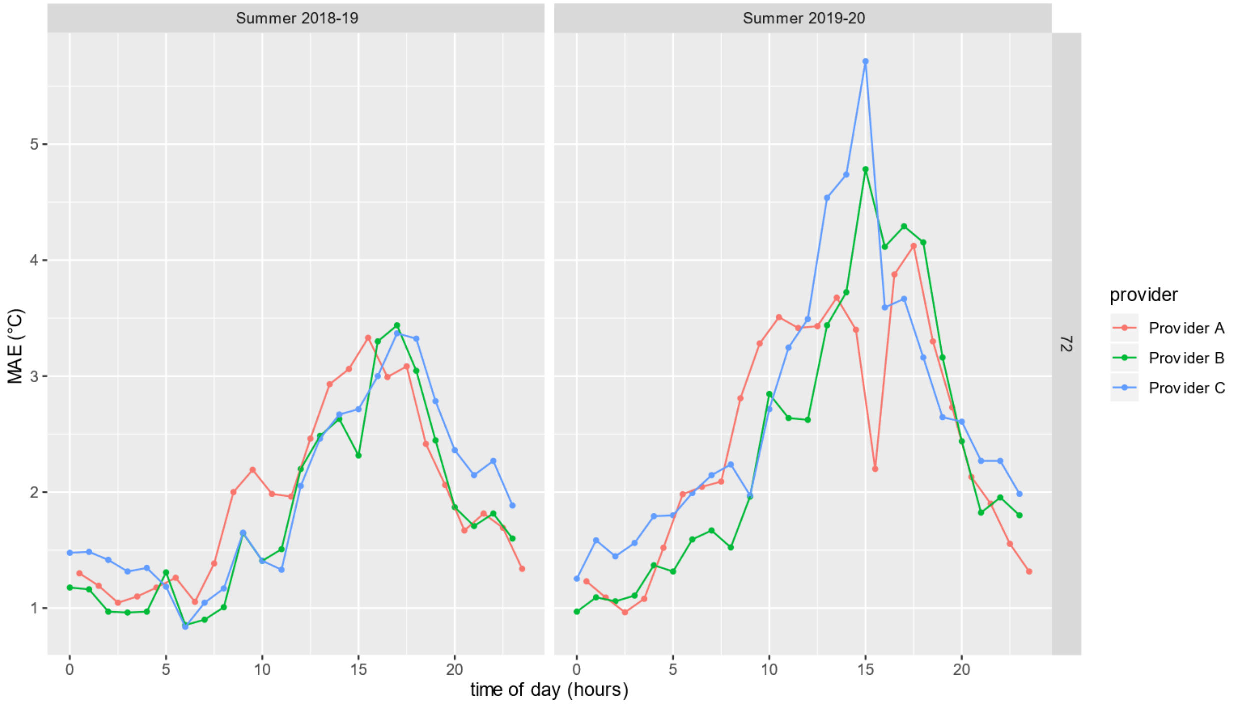
At Hobart AP, Provider A's largest errors occurred overnight, at over 2°C on average at the 4-HA horizon. This is the only example where a provider has higher errors overnight than during the daytime. Daytime performance at Hobart AP between providers is comparable, especially at high temperatures.

Performance suffered on the hottest days in Bankstown

On the hottest days, Providers B and C had markedly worse performance at Bankstown AP compared to summer 2018-19. Most of this degradation occurred in the 72-HA horizon where Providers B and C average errors reached ~5°C, as shown in Figure 15.

Provider A performed worse during summer 2019-20 on average compared to Providers B and C, but there are examples where it outperformed Providers B and C this year, and its own results last year. For example, during the top 10% of hot days, at the 72-HA horizon at 1500 hrs, Provider A error reduced by 1.2°C at Bankstown, as shown in Figure 15. For the same interval and forecast horizon, Provider B error increased by 1.4°C, and Provider C error increased by 2.6°C.

Figure 15 Bankstown, all providers, MAE intraday profiles, top 10% hot days 2018-19 and 2019-20, 72-HA



4. Case study: Victoria, 20 December 2019

On Friday 20 December 2019, AEMO declared an actual Lack of Reserve 2 (LOR2) condition in Victoria without it first being forecast in the Pre-Dispatch Projected Assessment of System Adequacy (PD PASA)[6]. The reserve condition was predominately due to a high demand forecast as well as high temperature de-rating and cut-out of wind generators affecting wind farms across the region.

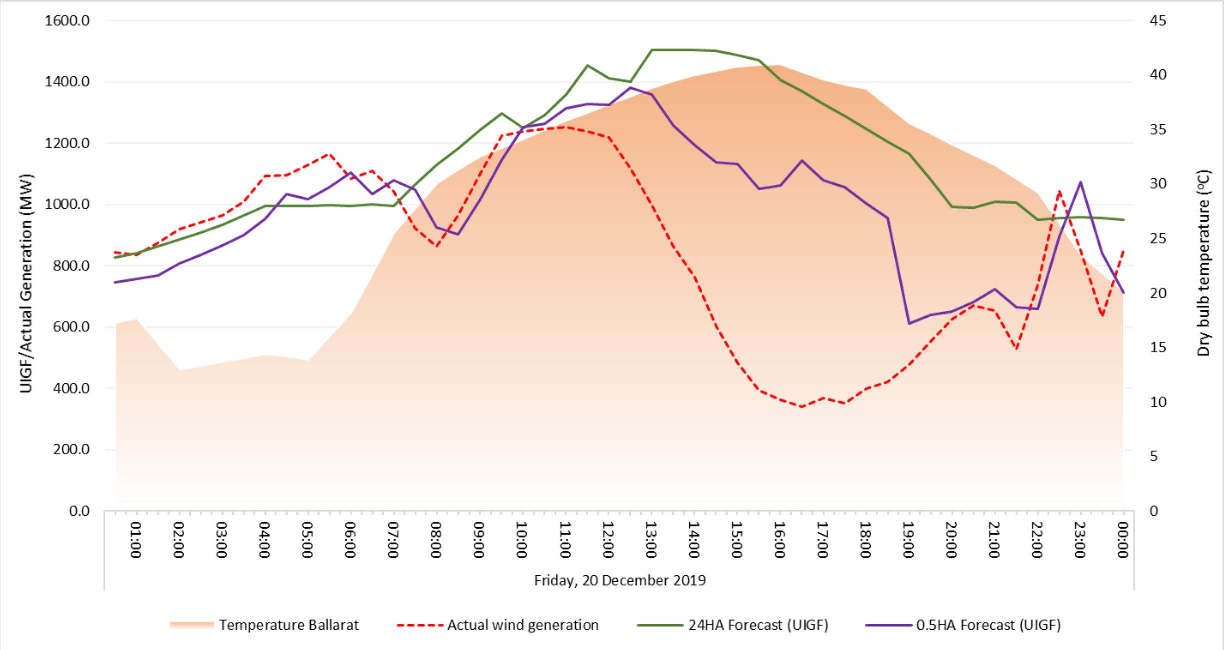
Day-ahead forecasts indicated very hot and windy conditions:

- Temperatures exceeding 40°C were forecast by all weather providers at Melbourne OP, Melbourne AP, and Ballarat.
- Unconstrained Intermittent Generator Forecast (UIGF) for Victorian wind generation indicated a maximum of 1,500 MW, approximately 70% of capacity at the time, and 1,250 MW during time of peak demand.

Actual temperatures peaked in Melbourne at 1700 hrs, reaching 43.9°C at Melbourne AP and 43.2°C at Melbourne OP. West of Melbourne, the temperature at Ballarat reached 41°C at 1600 hrs, and Mildura in Victoria's North-West reached 47°C.

The extreme temperatures significantly affected the performance of wind farms. Figure 16 shows the aggregate UIGF for Victorian wind farms for the 24-HA and 0.5-HA rolling forecast horizons against actual generation and temperature at Ballarat, which is located near many of the wind farms in Victoria. This event is discussed in AEMO's 2019-20 NEM *Summer Operations Review Report*[7].

Figure 16 Aggregate UIGF and actual wind generation in Victoria, Friday 20 December 2019



[6] Details of LOR2 declaration found in the NEM *Lack of Reserve Framework Report for Quarter 4 2019*, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/lor-framework-quarterly-reports/2019/nem-lack-of-reserve-framework-report---quarter-ending-31-december-2019.pdf?la=en&hash=BF0BA3C7CE7689E65E181AE83C96D4E9.

[7] See section 3.4.3 of AEMO's Summer Operations Review Report: https://aemo.com.au/-/media/files/electricity/nem/system-operations/summer-operations/2019-20/summer-2019-20-nem-operations-review.pdf?la=en

The UIGF is produced using wind farm availability and localised gridded weather forecasts. The observed differences between UIGF and actual generation were too significant to be attributed to weather variability, with wind speeds reasonably constant, and were predominantly due to availability, submitted by market participants, not reflecting high-temperature de-rating and cut-out. The errors were large even at near-term forecast horizons:

- Errors exceeded 1,000 MW between 1500 hrs and 1630 hrs for the rolling 24-HA horizon.
- Errors exceeded 650MW between 1500 hrs and 1730 hrs for the rolling 0.5-HA horizon.

This resulted in an over-estimate of available reserves compared to real-time dispatch. The time of minimum reserve aligned with maximum temperature and minimum wind generation. The UIGF 30-minutes ahead of this interval was over-forecast 700 MW. The error in forecast reserve resulted in an actual LOR2 condition being declared without first being forecast.

Weather provider performance

The accuracy of temperature forecasts was particularly important for electricity demand forecasting and for signalling the risk of high-temperature derating and cut out ahead of time.

Figure 17 illustrates that all providers performed very well at Melbourne AP. All providers forecast morning temperatures and temperatures after 1200 hrs accurately, particularly for horizons less than 48-HA. Forecasting the step change in temperature at approximately 1000 hrs was challenging for all providers – this additional heat will have translated to an increase in demand. The day-ahead forecast for all providers was very good, particularly Provider C at temperatures greater than 40°C.

Due to its vicinity to the major load centre, observations at Melbourne weather stations are highly indicative of Victorian demand. Accurate temperature forecasts, like those provided for this day, will always increase the accuracy of demand forecasts. The observed peak demand of 9,249 MW was forecast within 1 MW of error in the day-ahead forecast. A high degree of accuracy was important to ensure the demand side of the reserve equation was as accurate as possible and helped capture risk on this day.

Figure 17 Forecast temperatures against actual temperature observations (black dashed line) for each provider on Victoria 20 December 2020 at Melbourne Airport

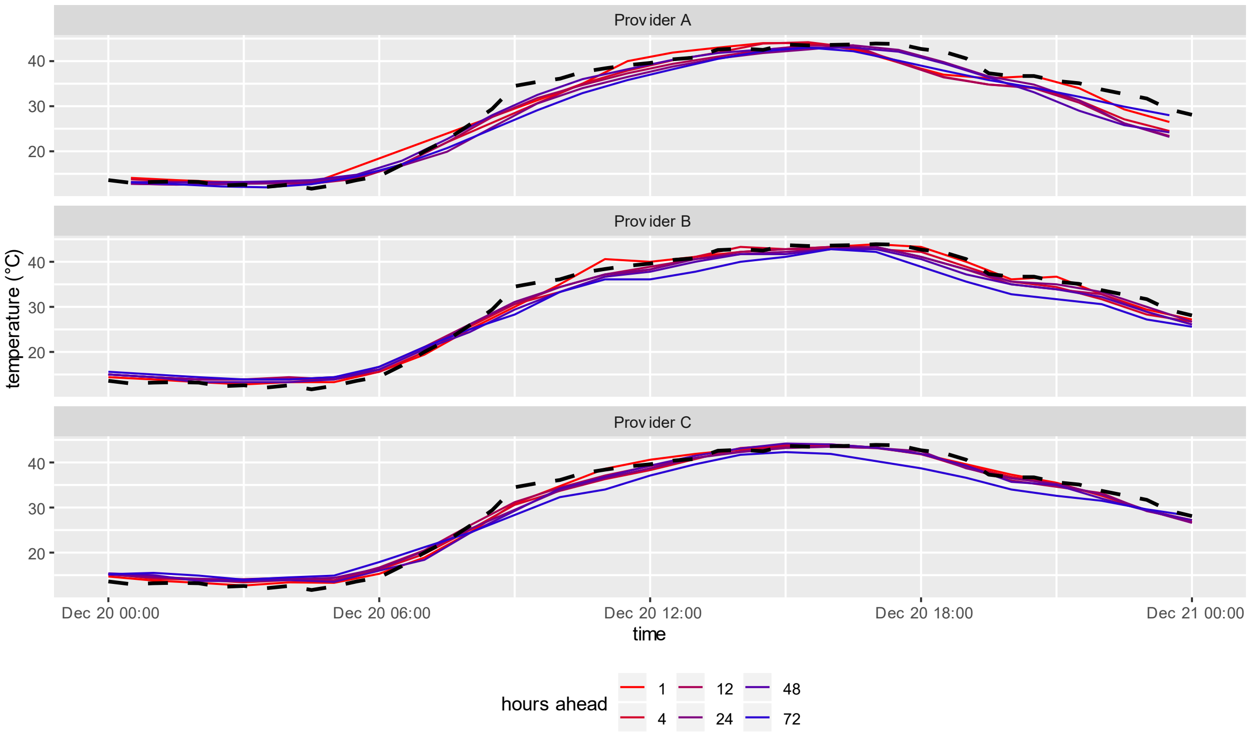
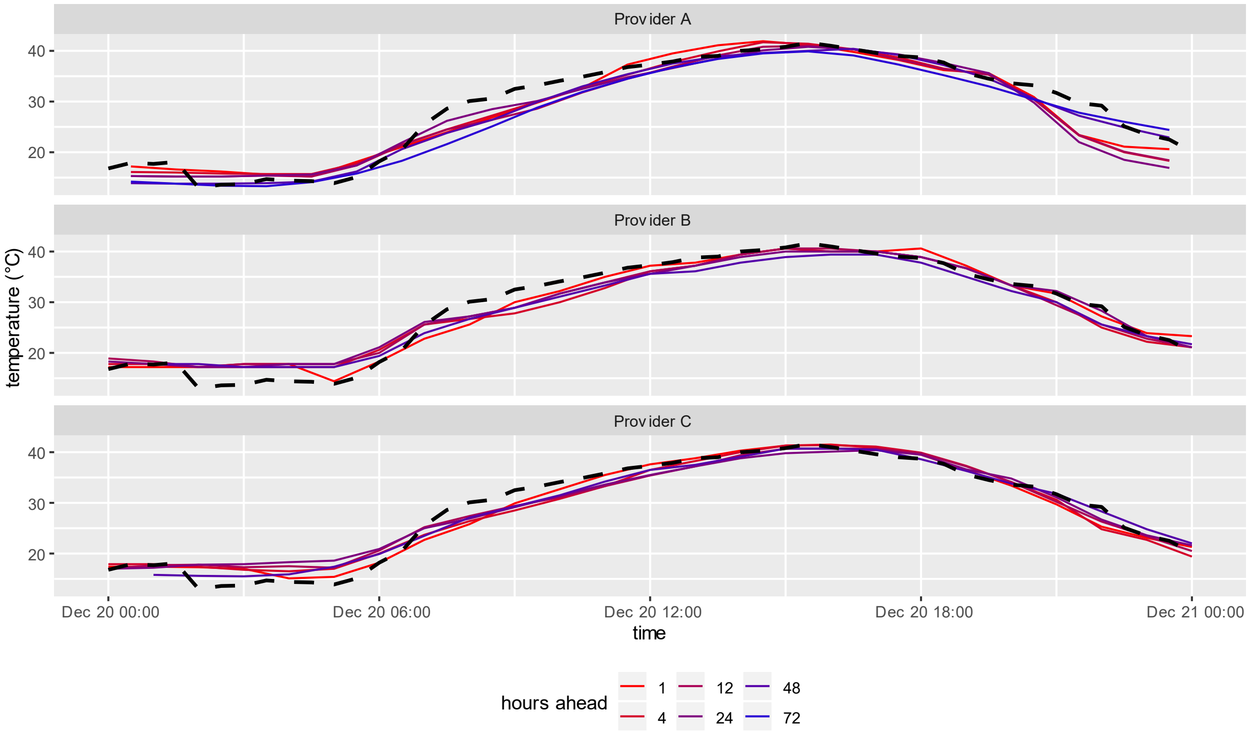


Figure 18 shows that all providers forecast Ballarat temperatures reasonably well at all forecast horizons. All providers were accurate in forecasting the time and magnitude of peak temperature even at the 72-HA horizon. The period between 0700 hrs and 1200 hrs where temperature ramped to a maximum, and heat built quickly, was under-forecast by all providers.

Considering how extreme the eventual temperatures were in the Ballarat region, these were high quality forecasts which accurately communicated the risk of potential de-rating and cut-out up to three days ahead.

Figure 18 Forecast temperatures against actual temperature observations (black dashed line) for each provider on Victoria 20 December 2020 at Ballarat



5. Conclusions

The results presented in this report supplement the findings of the summer 2018-19 and winter 2019 forecast analysis, and AEMO will use them to aid operational forecasting and decision-making. This analysis will be shared with our current weather service providers to draw attention to their potential areas of improvement and provide information to intending weather service providers. In addition, the report aims to contribute to ongoing discussion and improvement within AEMO and the energy industry.

The key findings from the analysis were:

- Overall forecasting performance has generally improved since last summer.
- Adelaide West Terrace had the lowest forecasting precision among all providers.
- Provider A has ongoing performance issues at Hobart Airport.
- Penrith and Bankstown saw a general performance decrease at high temperatures, likely attributed to more challenging conditions this summer.
- Providers A and C had a performance decrease at Kent Town at high temperatures. This was met with an increase in performance from Provider B.
- All providers signalled adequate risk of high temperature derating and cut out in Victoria on 20 December 2019.

In 2020, AEMO is continuing to work with the weather forecasting industry to ensure weather forecast tools are developed for the purposes of energy forecasting. In addition, AEMO is:

- Working with Solcast on the ARENA-funded Nowcasting project, to test improvements to near-term weather forecasts in the 0-6 hour ahead horizon[8].
- Working with the renewable energy industry to improve the management of intermittent generation de-rating and cut-out during extreme weather conditions[9]. AEMO is updating its generator reference temperature procedure ahead of summer 2020-21 to better capture the risk of these events.

[8] See AEMO's media release on the ARENA funded Nowcasting project here: https://aemo.com.au/news/solcast-nowcasting-project

[9] See section 9.2.3 of AEMO's Summer Operations Review Report: https://aemo.com.au/-/media/files/electricity/nem/system-operations/summer-operations/2019-20/summer-2019-20-nem-operations-review.pdf?la=en

A1. Error density plots

A1.1 Station comparison by provider

Figure 19 All weather stations, Provider A, all summer intervals 2019-20, 24-HA time horizon

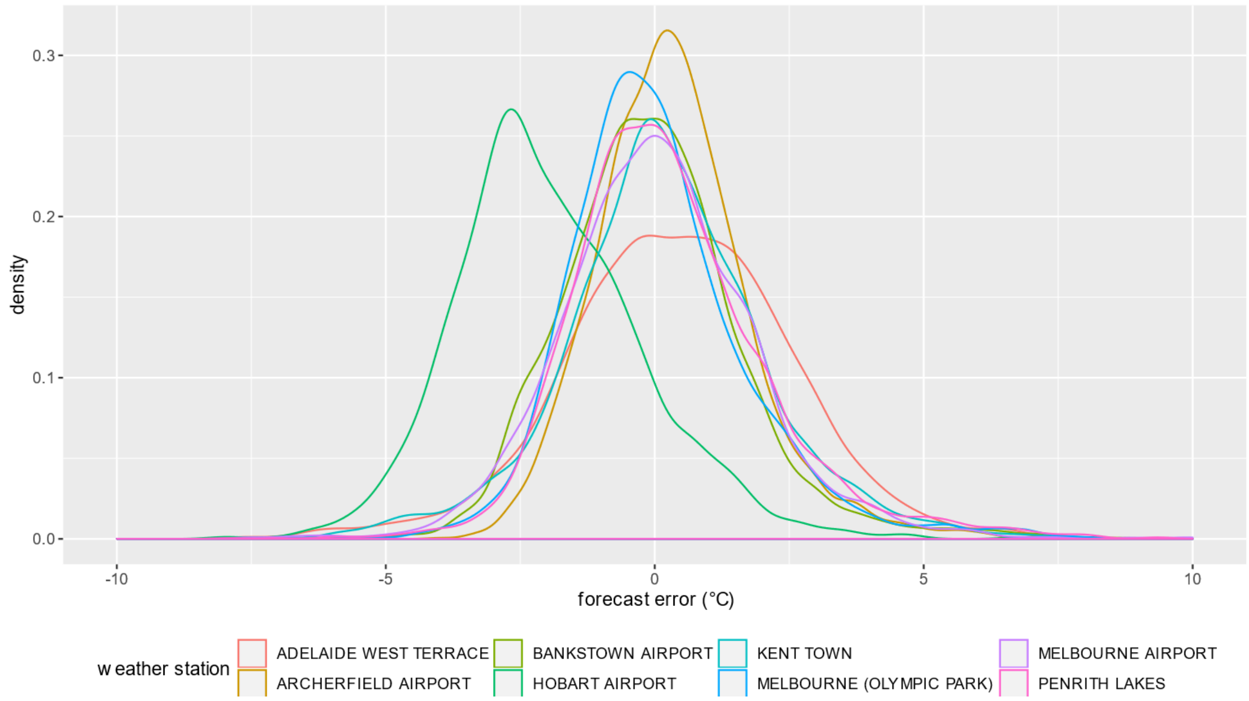


Figure 20 All weather stations, Provider A, top 10% of temperatures 2019-20, 24-HA time horizon

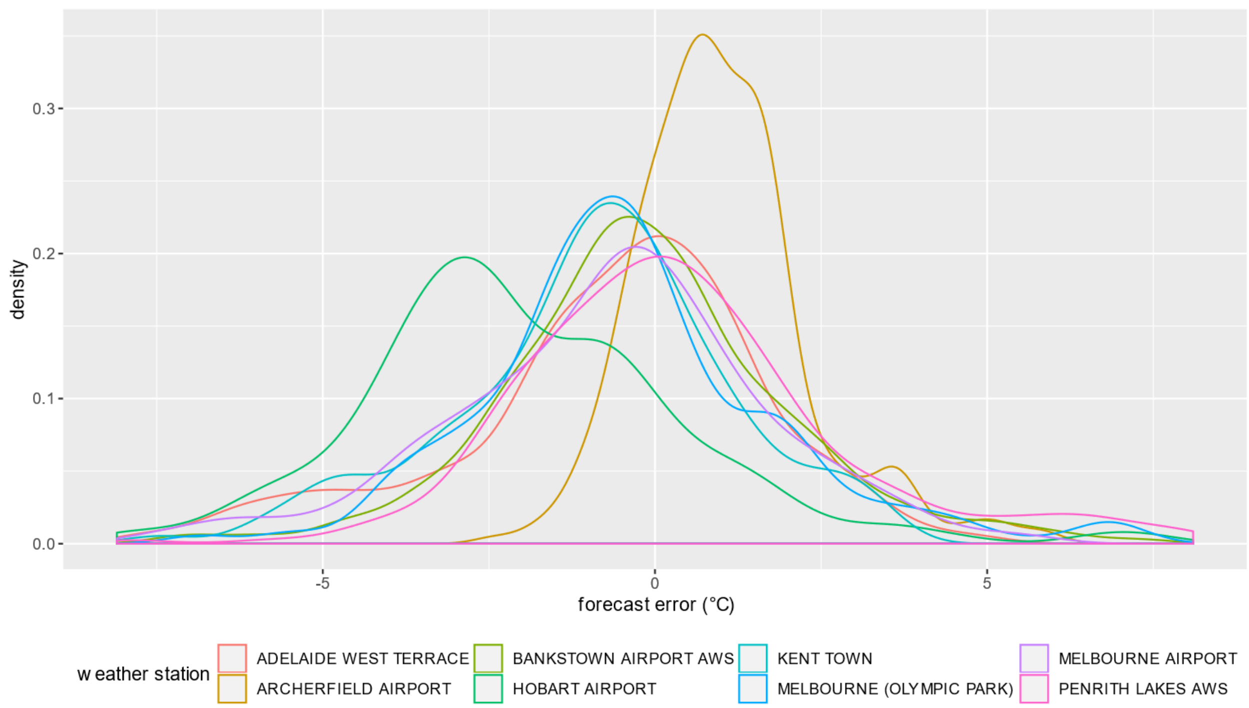


Figure 21 All weather stations, Provider B, all summer intervals 2019-20, 24-HA time horizon

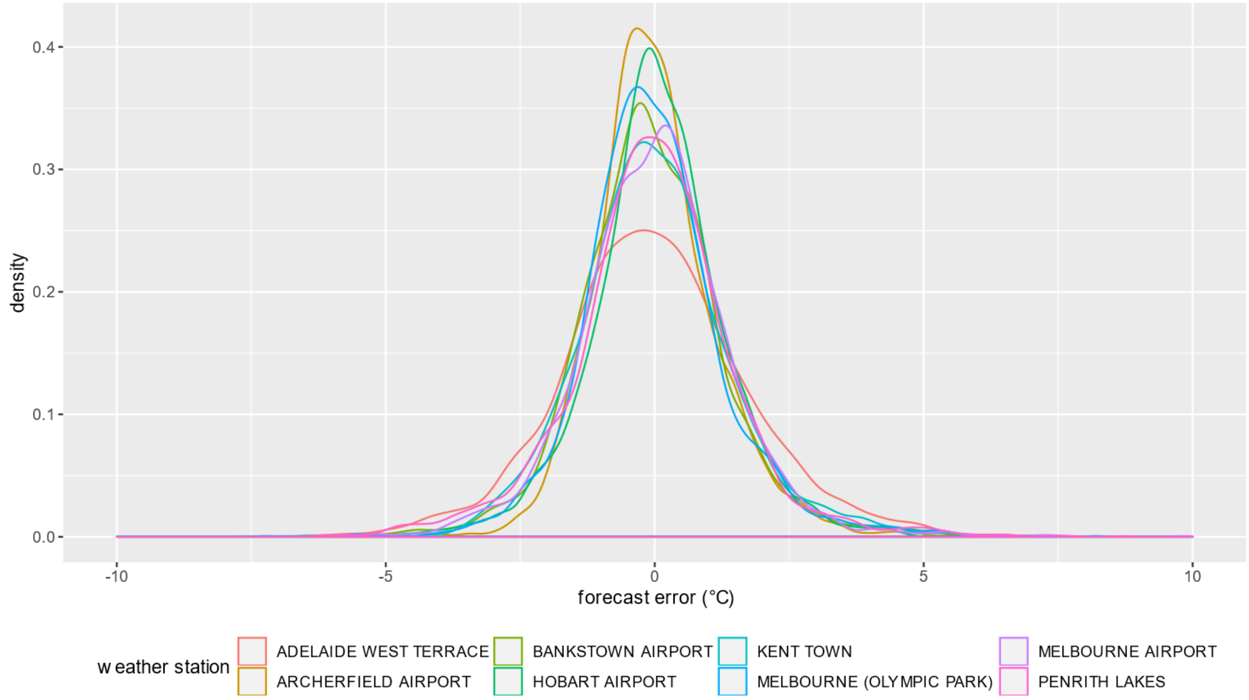


Figure 22 All weather stations, Provider B, top 10% of temperatures 2019-20, 24-HA time horizon

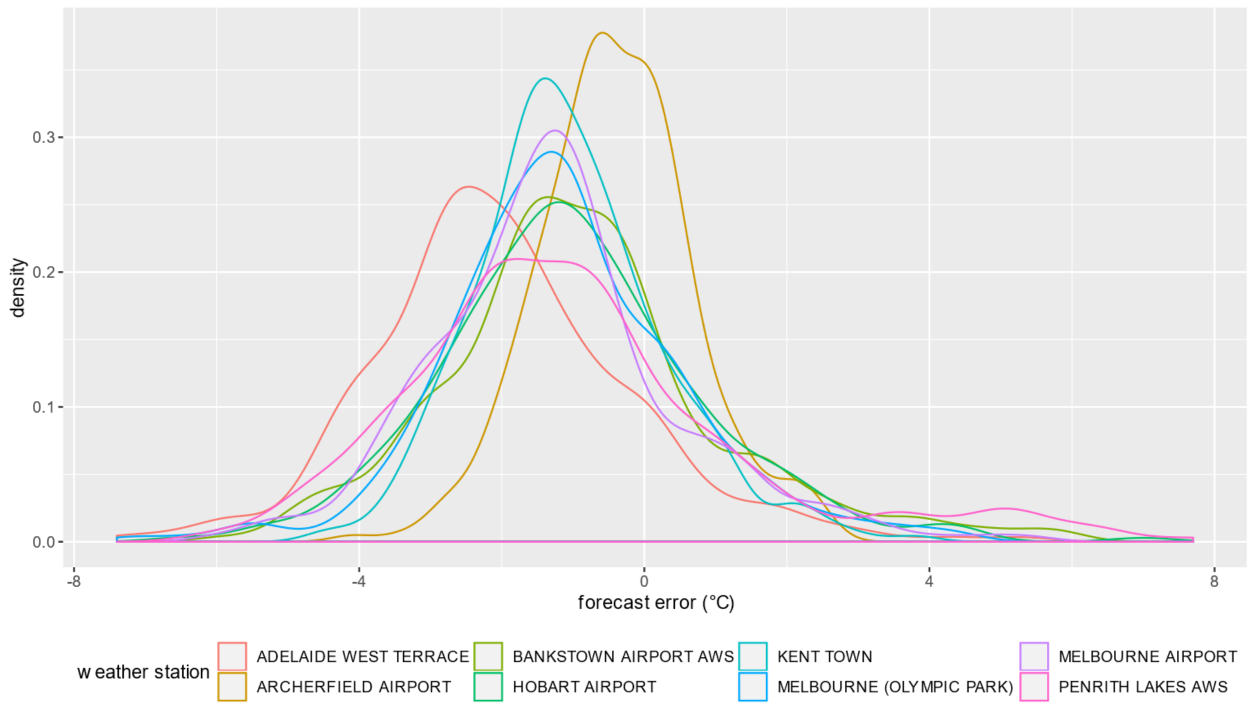


Figure 23 All weather stations, Provider C, all summer intervals 2019-20, 24-HA time horizon

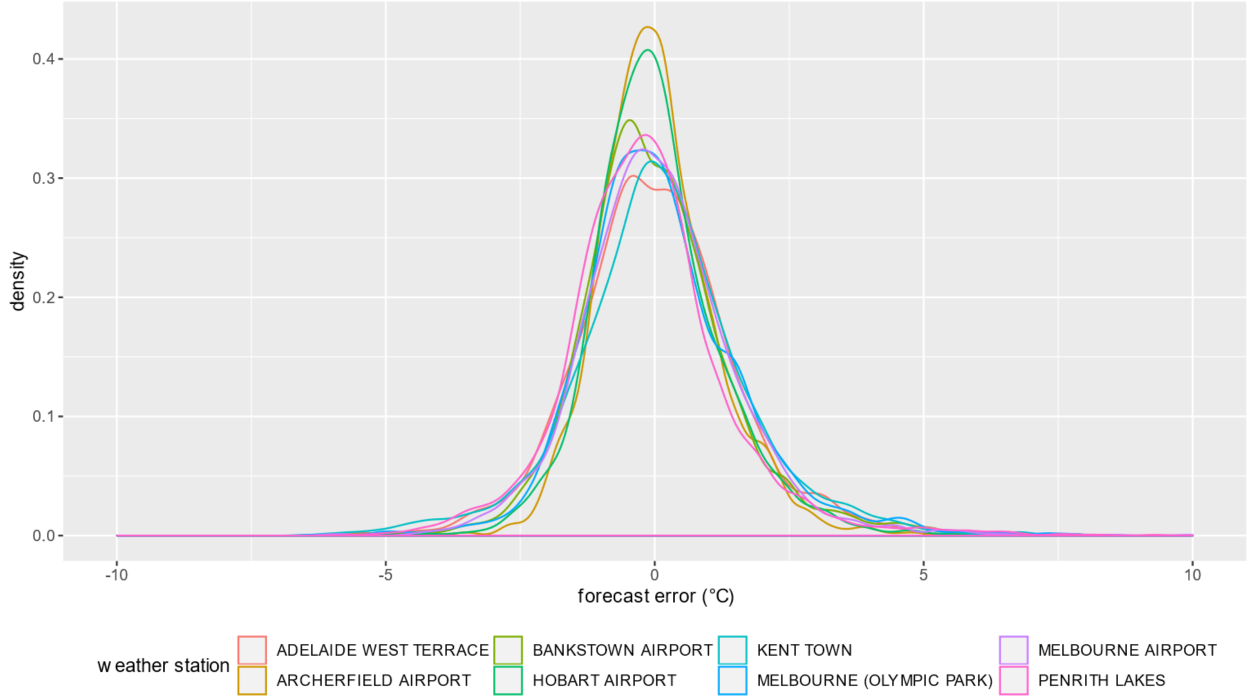
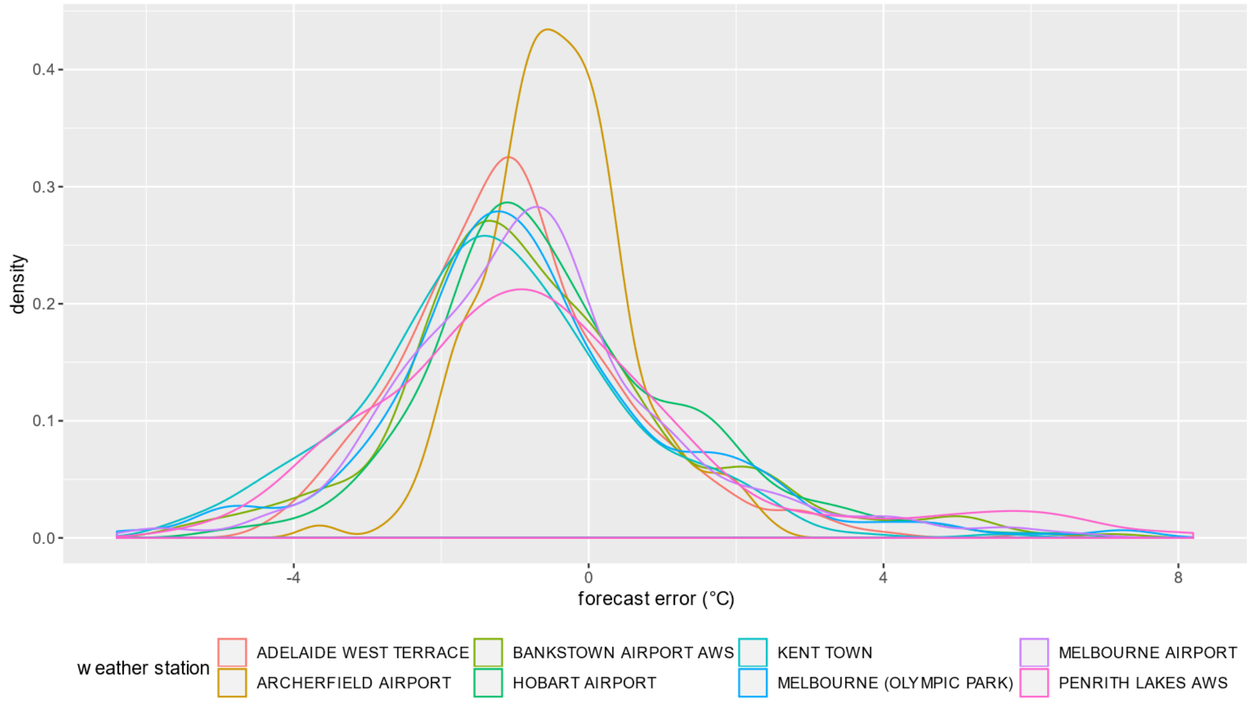


Figure 24 All weather stations, Provider C, top 10% of temperatures 2019-20, 24-HA time horizon



A1.2 Provider comparison by station

Figure 25 Adelaide West Terrace, all providers, all summer 2019-20, 4-, 24-, and 72-HA

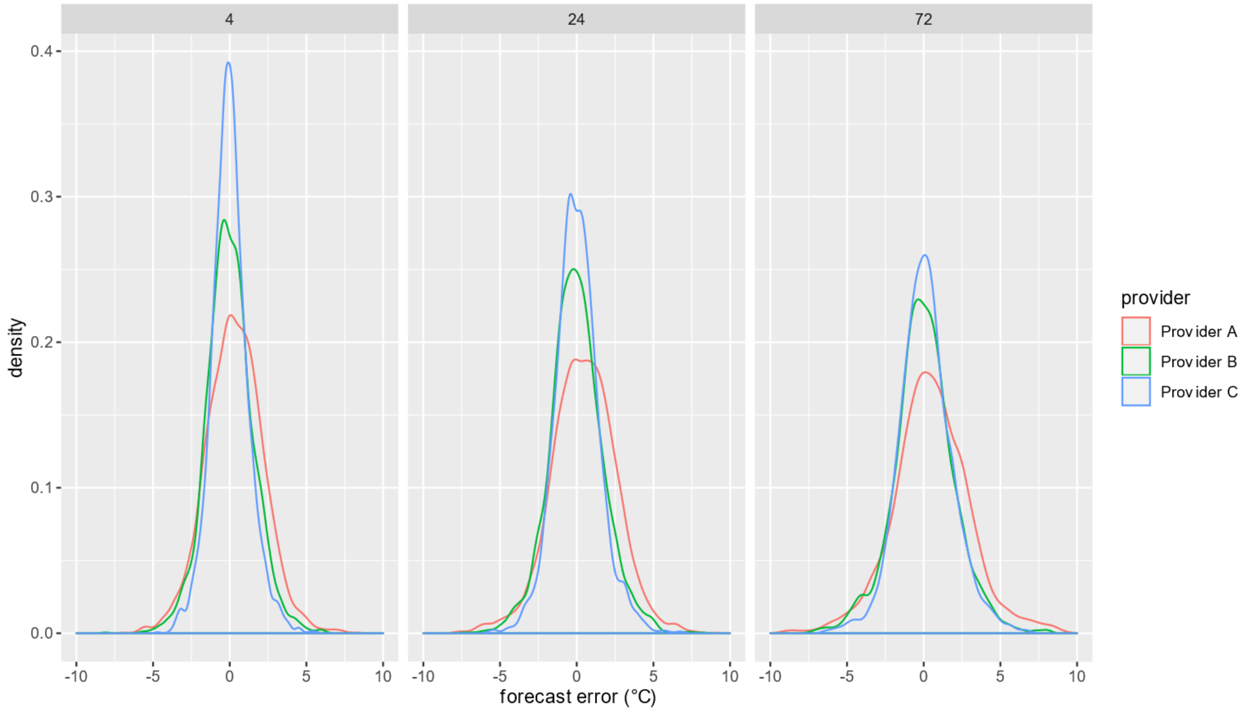


Figure 26 Adelaide West Terrace, all providers, top 10% temperatures summer 2019-20, 4-, 24-, and 72-HA

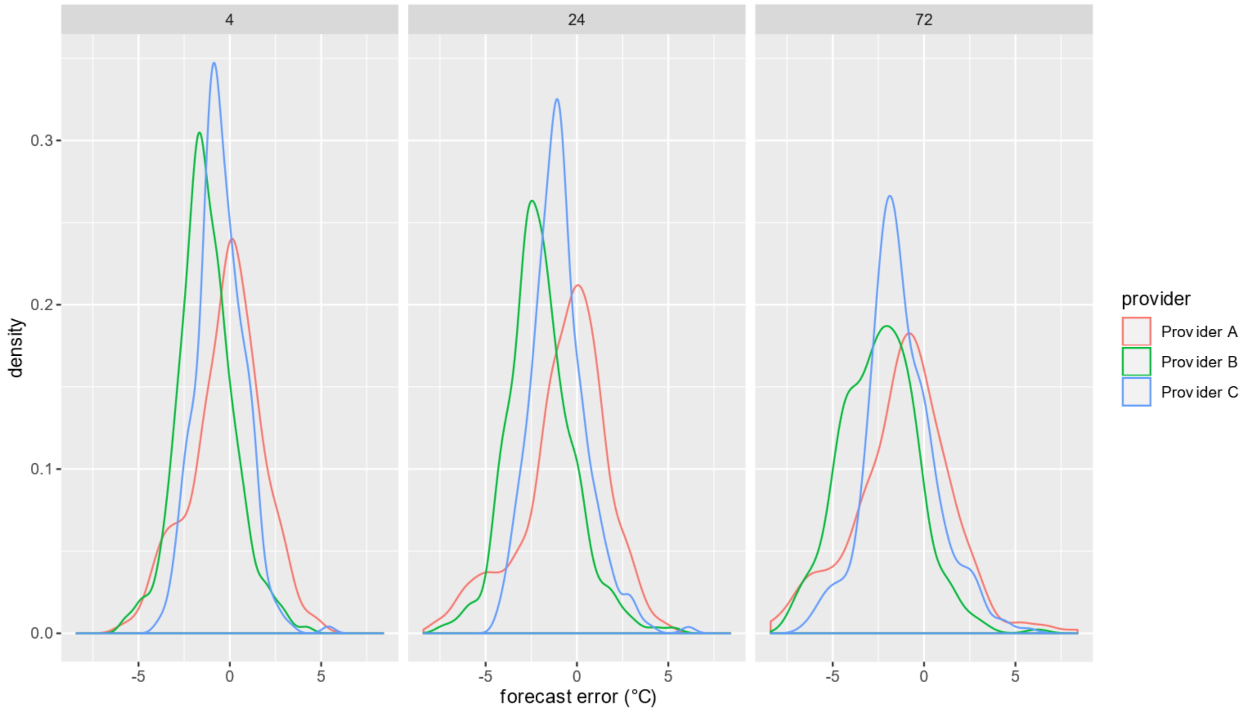


Figure 27 Archerfield, all providers, all summer 2019-20, 4-, 24-, and 72-HA

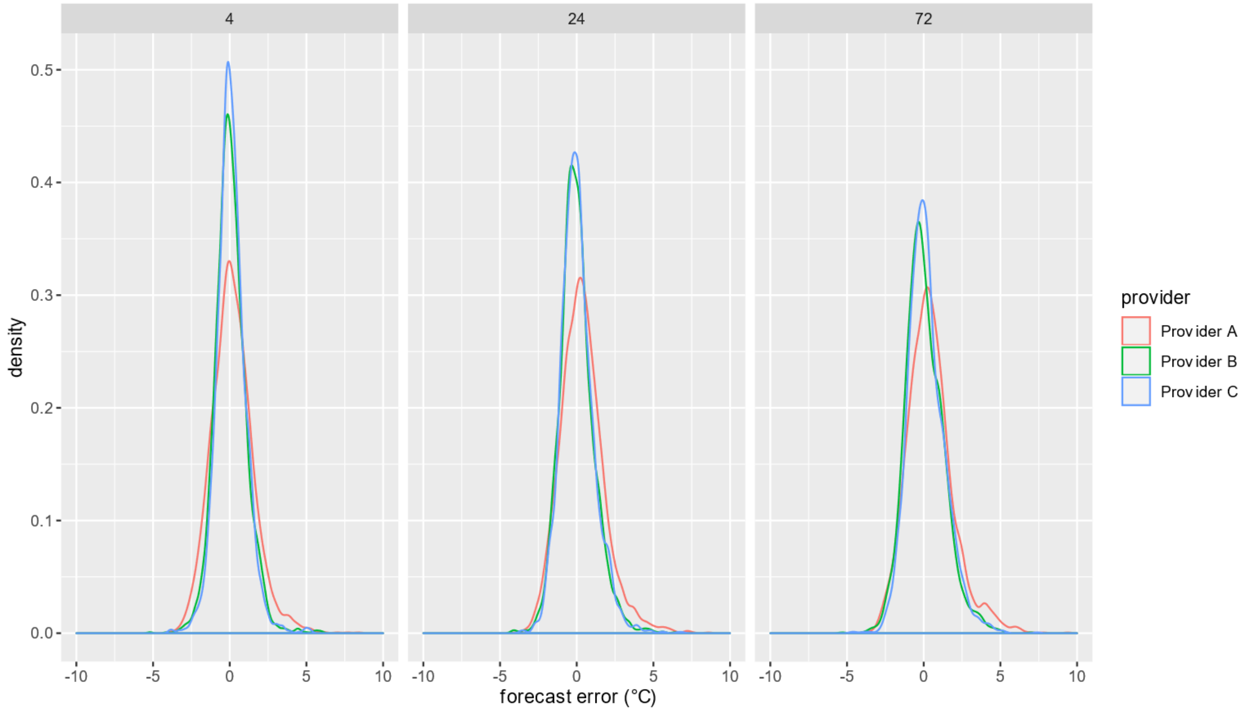


Figure 28 Archerfield, all providers, top 10% temperatures summer 2019-20, 4-, 24-, and 72-HA

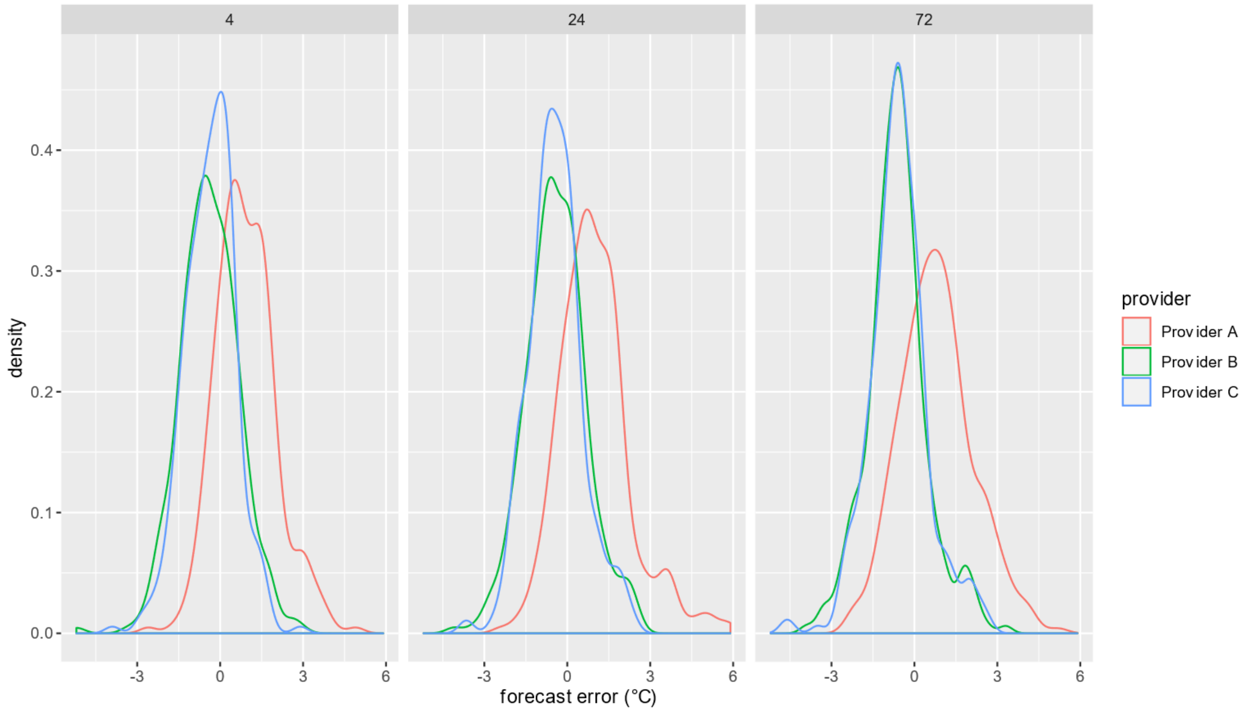


Figure 29 Bankstown Airport, all providers, all summer 2019-20, 4-, 24-, and 72-HA

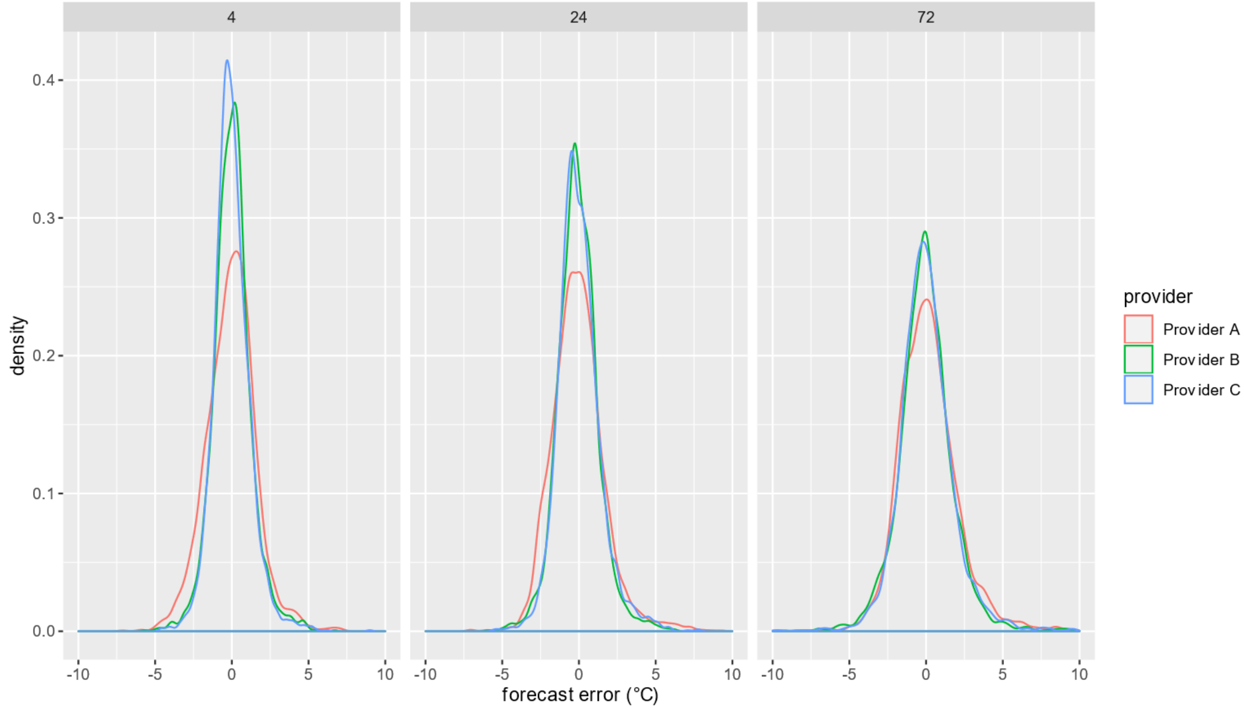


Figure 30 Bankstown Airport, all providers, top 10% temperatures summer 2019-20, 4-, 24-, and 72-HA

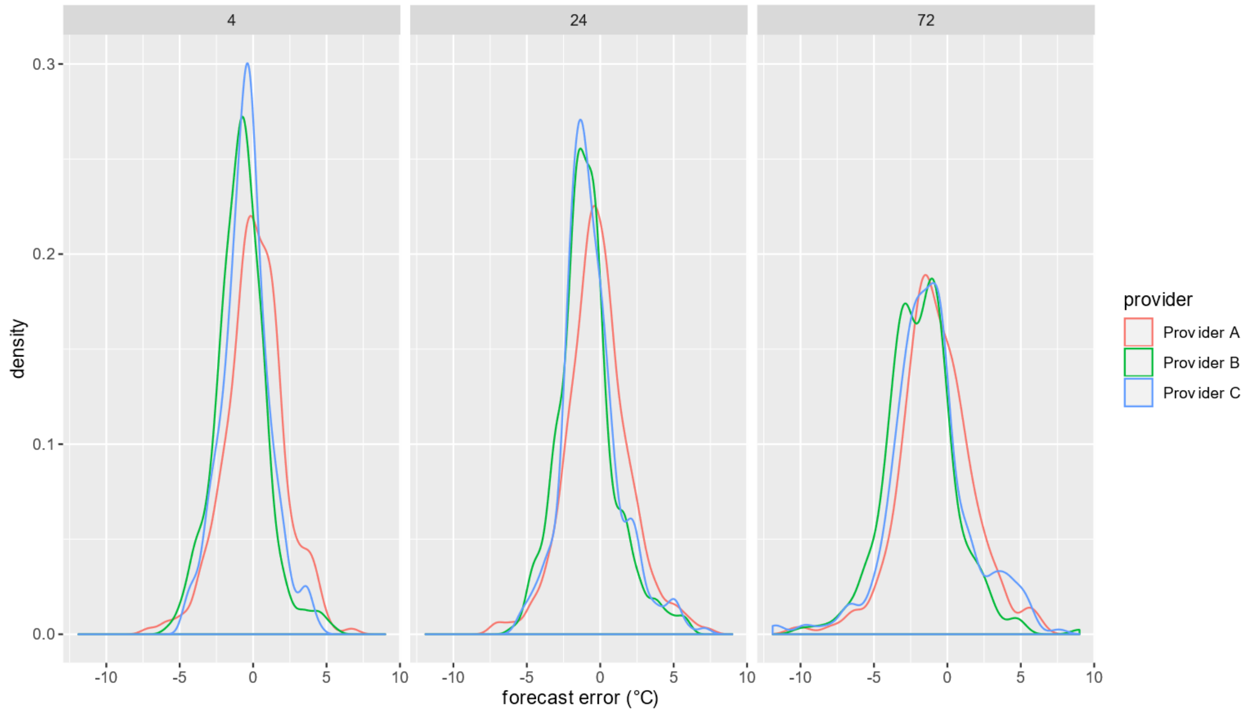


Figure 31 Hobart Airport, all providers, all summer 2019-20, 4-, 24-, and 72-HA

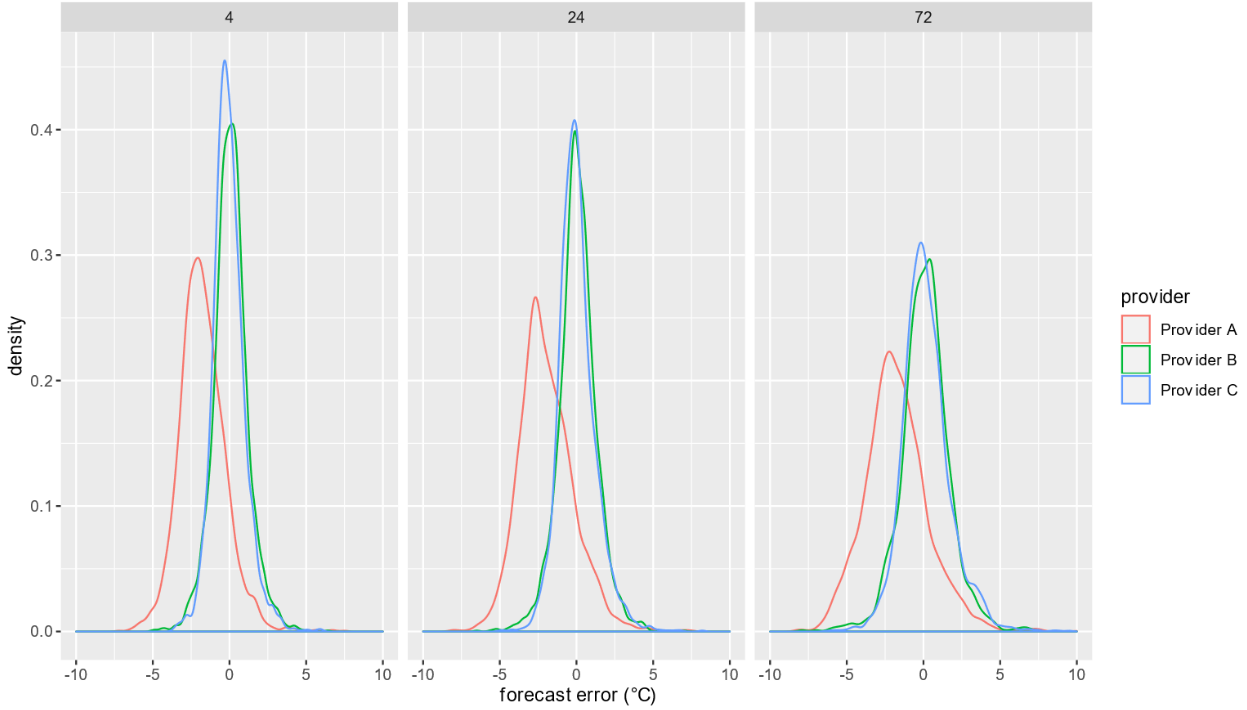


Figure 32 Hobart Airport, all providers, top 10% temperatures summer 2019-20, 4-, 24-, and 72-HA

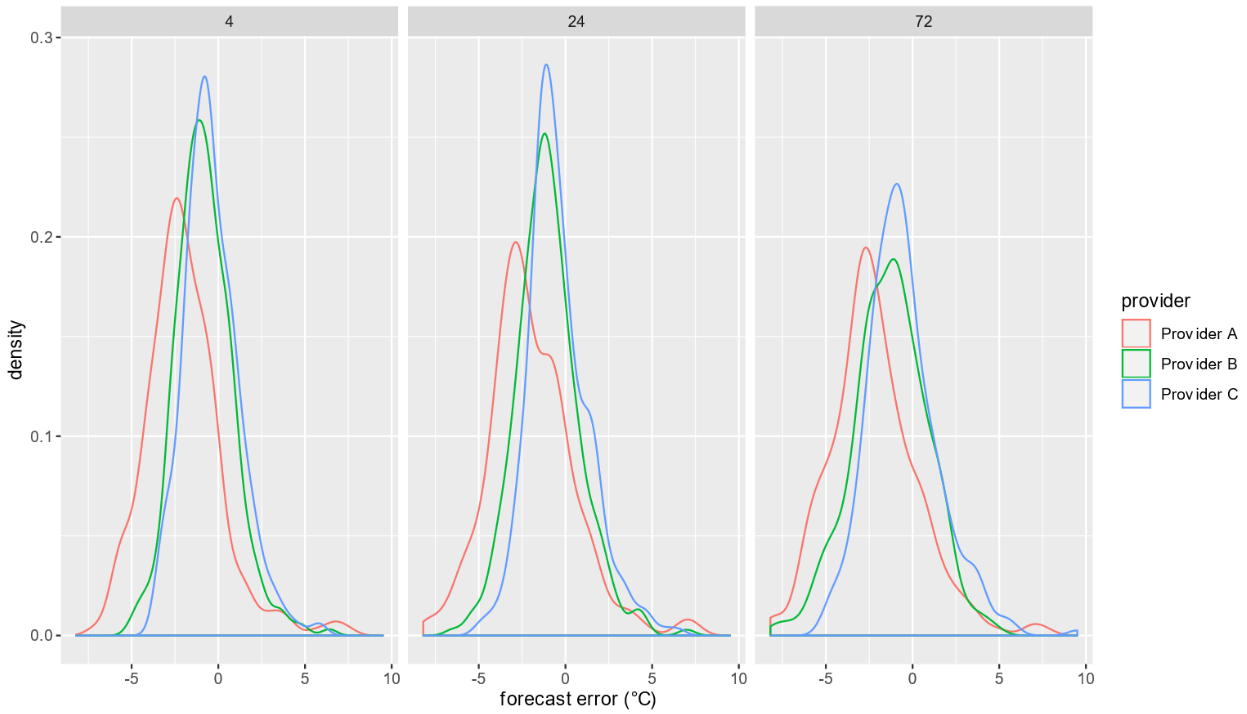


Figure 33 Kent Town, all providers, all summer 2019-20, 4-, 24-, and 72-HA

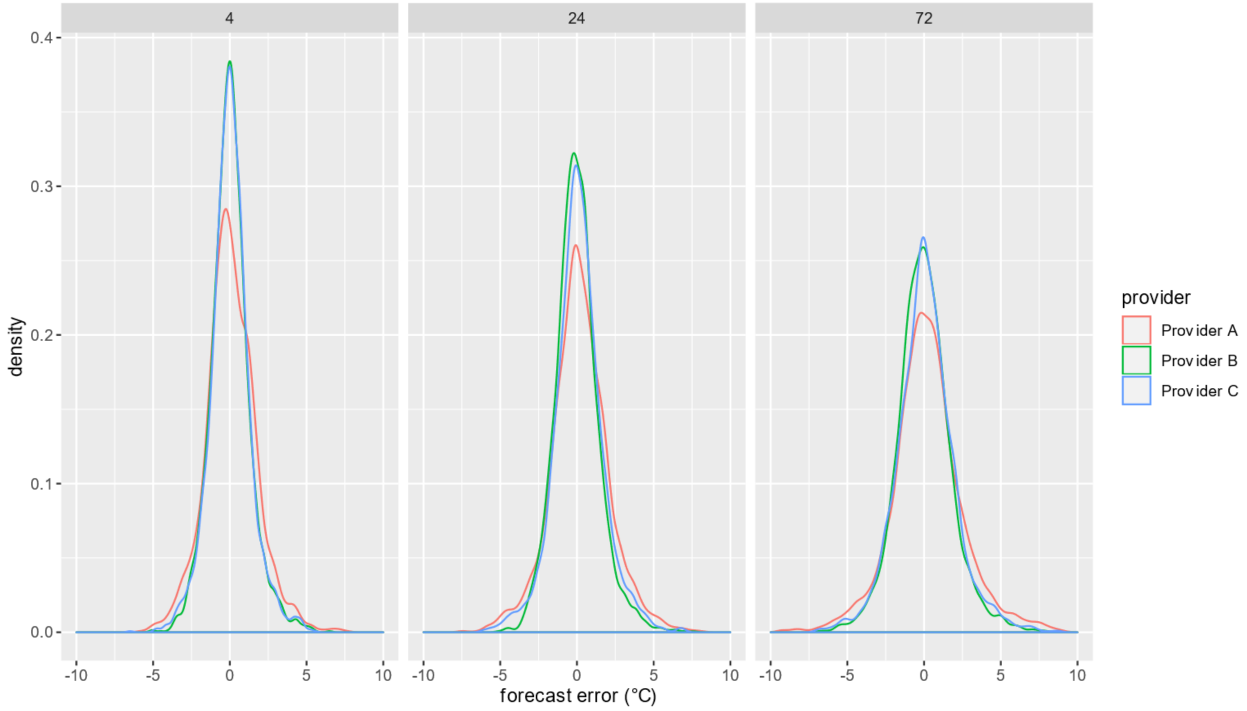


Figure 34 Kent Town, all providers, top 10% temperatures summer 2019-20, 4-, 24-, and 72-HA

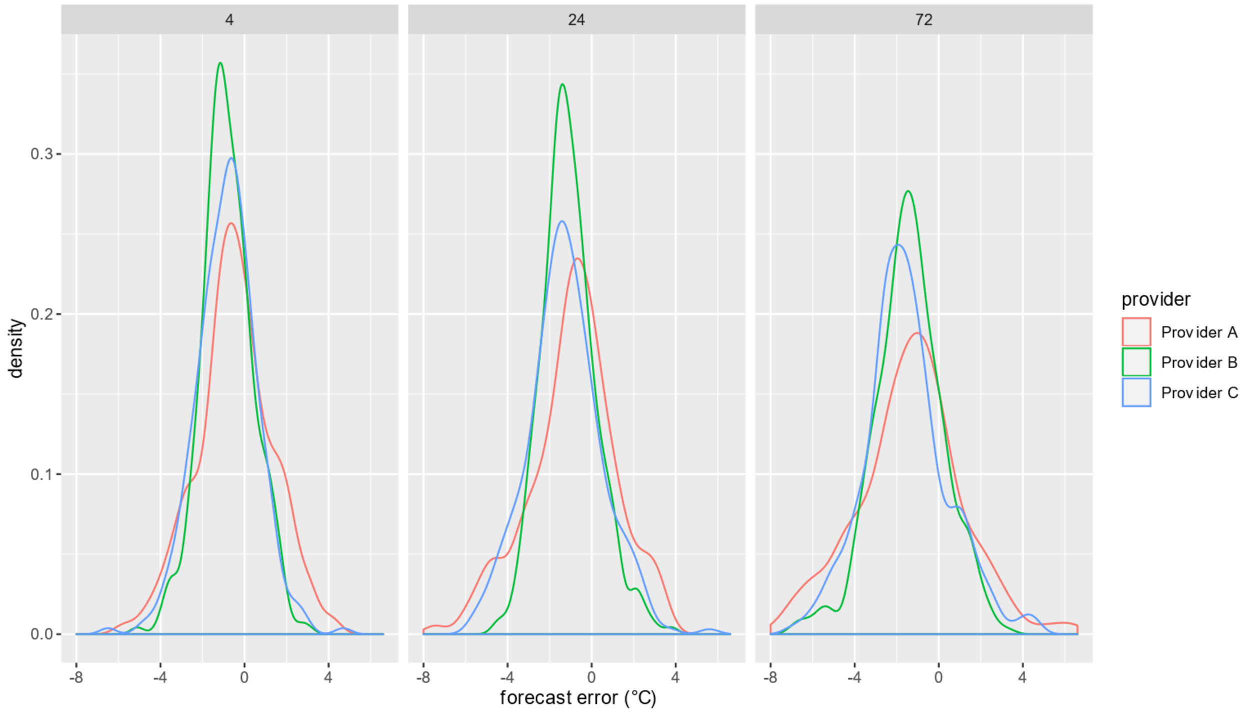


Figure 35 Melbourne OP, all providers, all summer 2019-20, 4-, 24-, and 72-HA

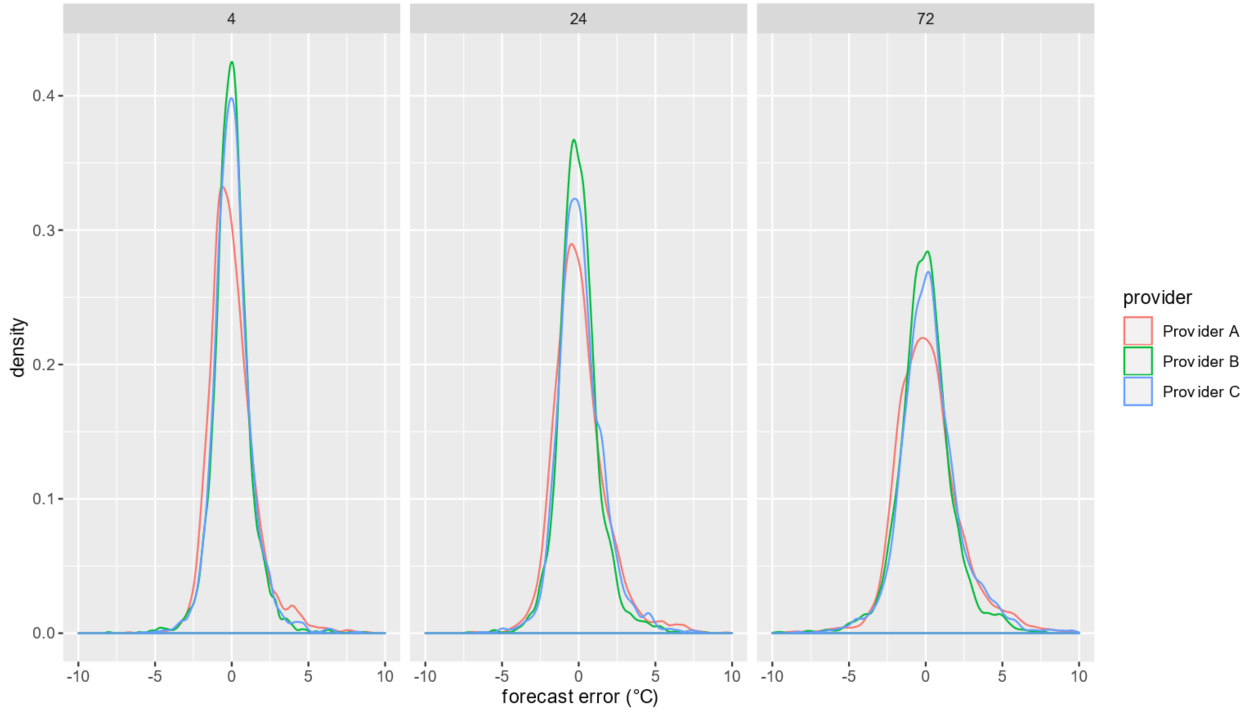


Figure 36 Melbourne OP, all providers, top 10% temperatures summer 2019-20, 4-, 24-, and 72-HA

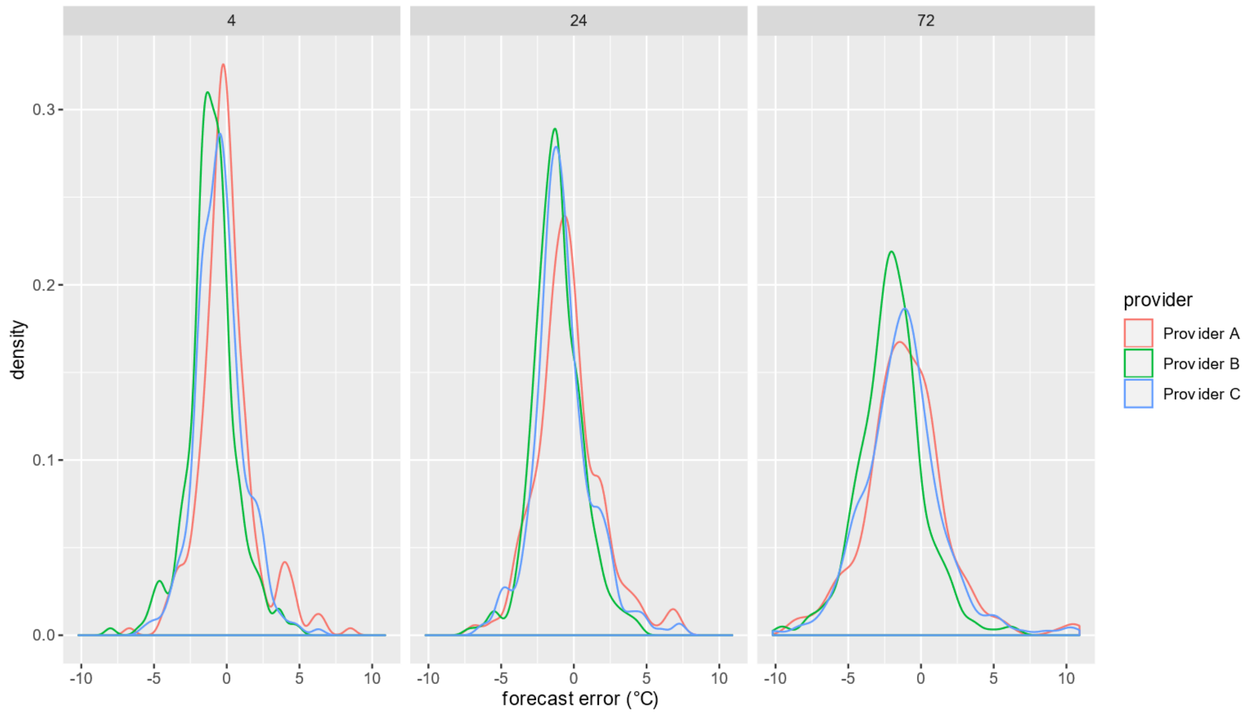


Figure 37 Melbourne AP, all providers, all summer 2019-20, 4-, 24-, and 72-HA

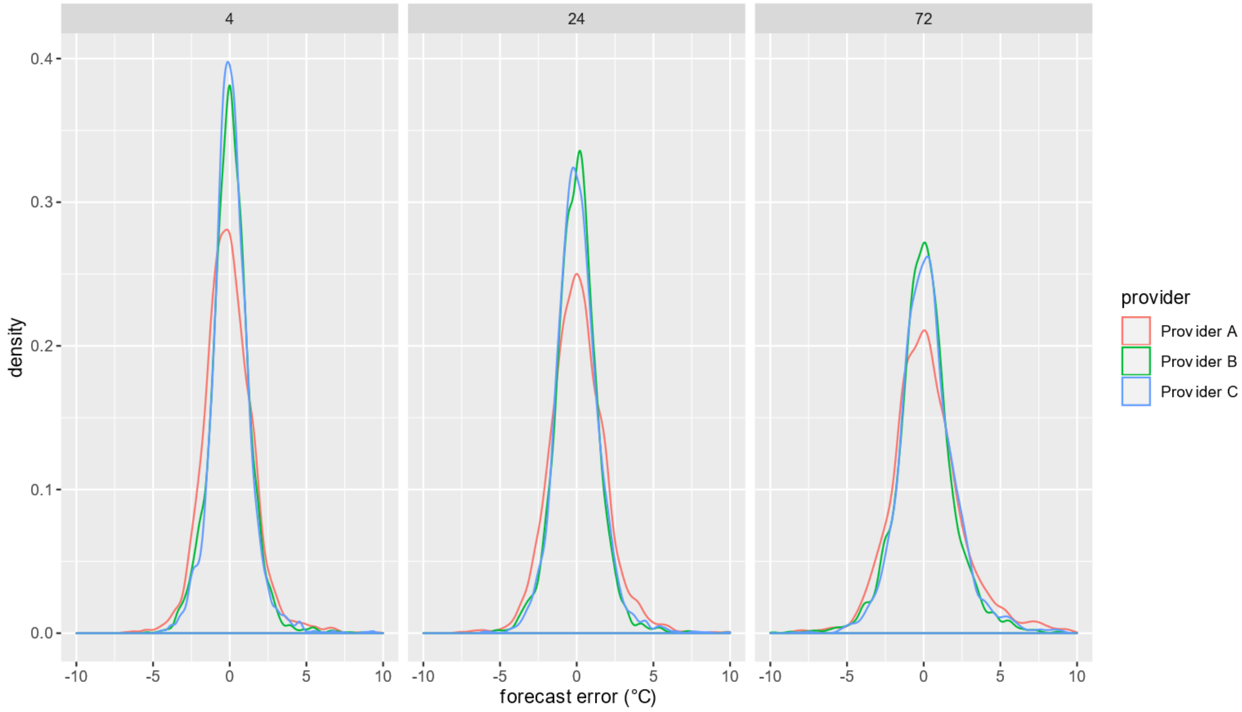


Figure 38 Melbourne AP, all providers, top 10% temperatures summer 2019-20, 4-, 24-, and 72-HA

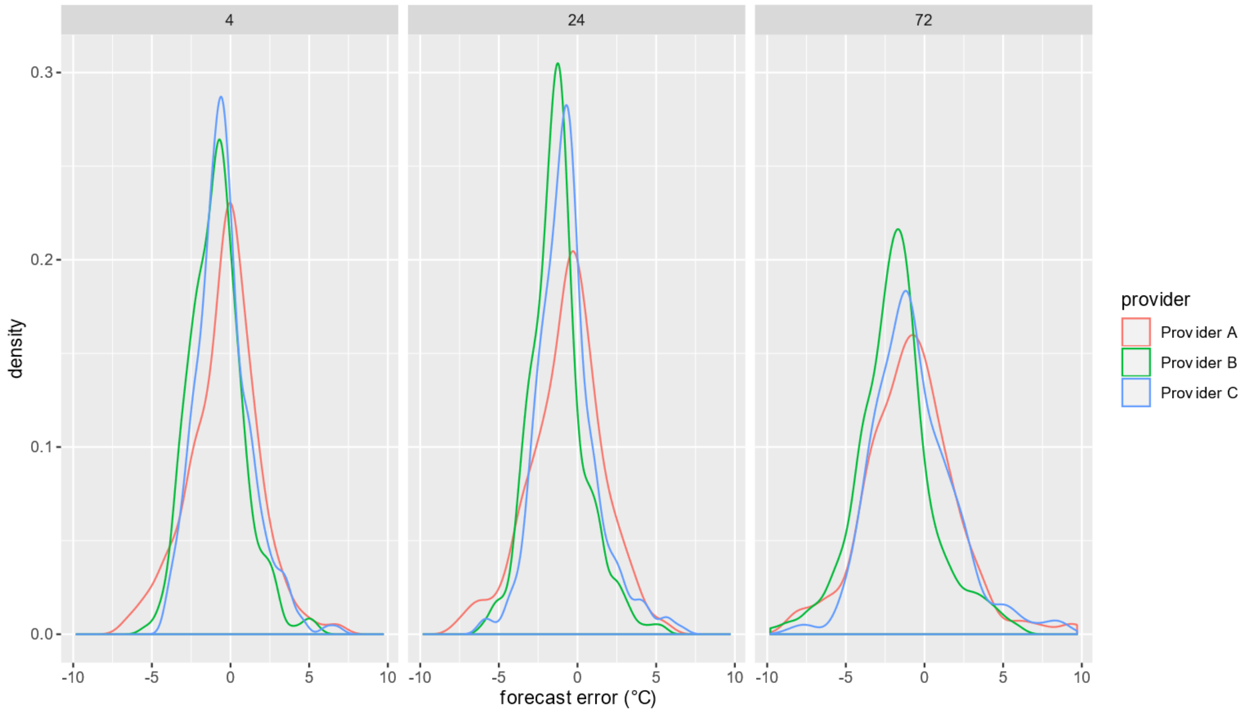


Figure 39 Penrith Lakes, all providers, all summer 2019-20, 4-, 24-, and 72-HA

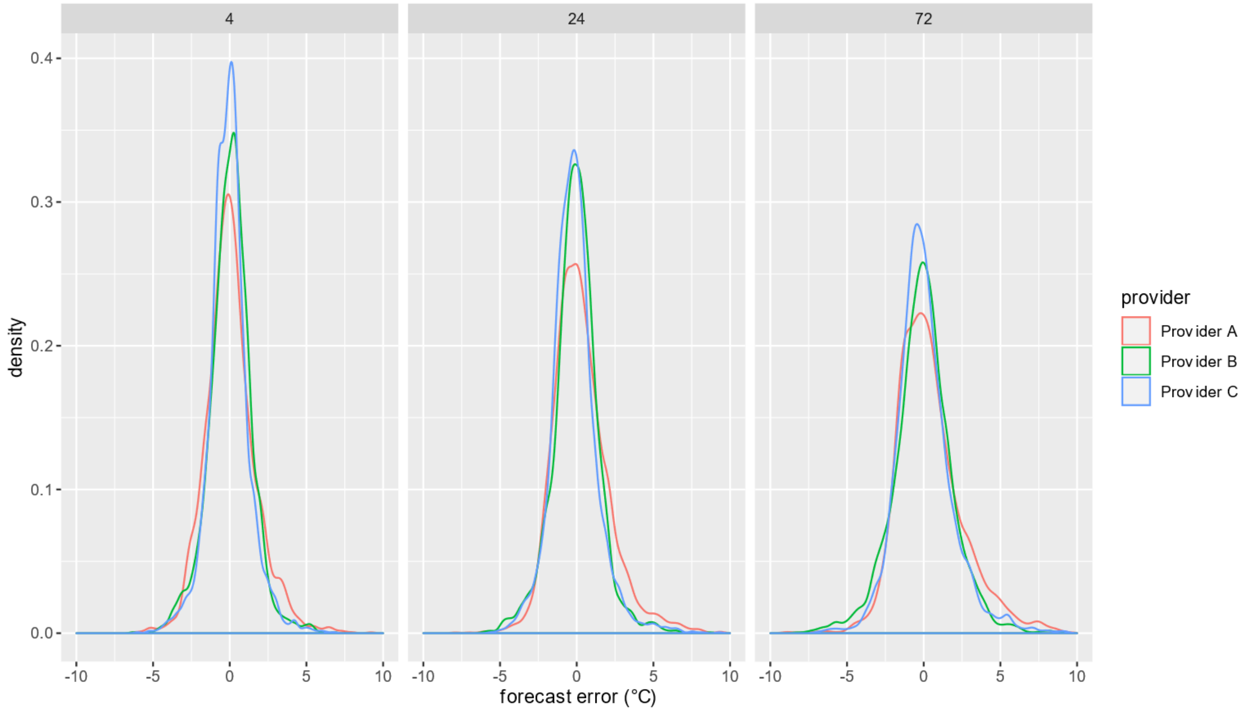
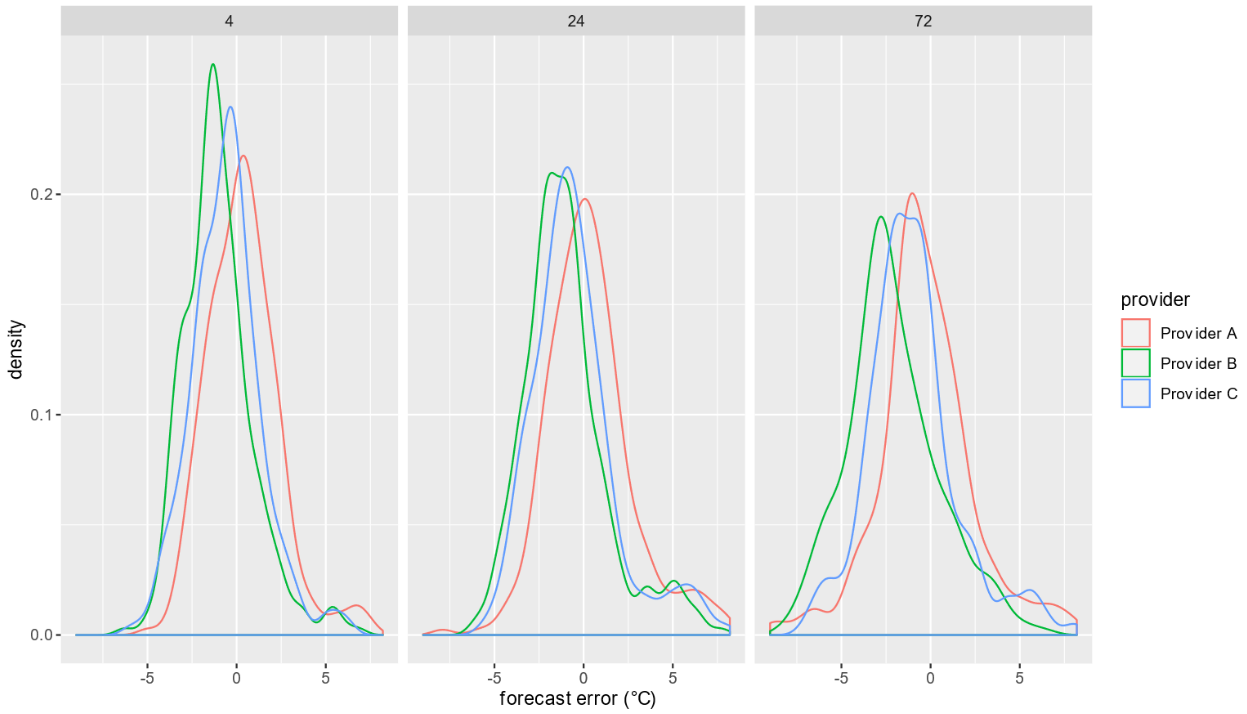


Figure 40 Penrith Lakes, all providers, top 10% temperatures summer 2019-20, 4-, 24-, and 72-HA



A2. Intraday MAE profiles

Figure 41 Adelaide West Terrace, intraday MAE profile, all providers, summer 2019-20

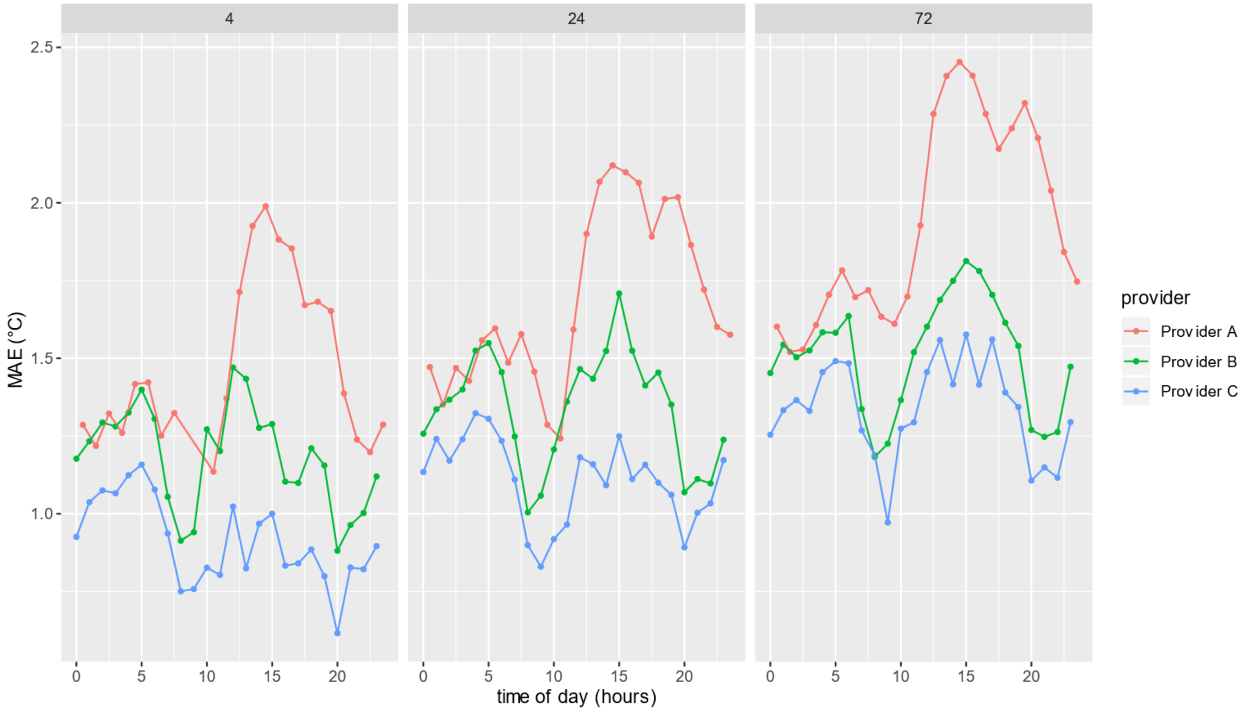


Figure 42 Adelaide West Terrace, intraday MAE profile, all providers, top 10% hottest days summer 2019-20

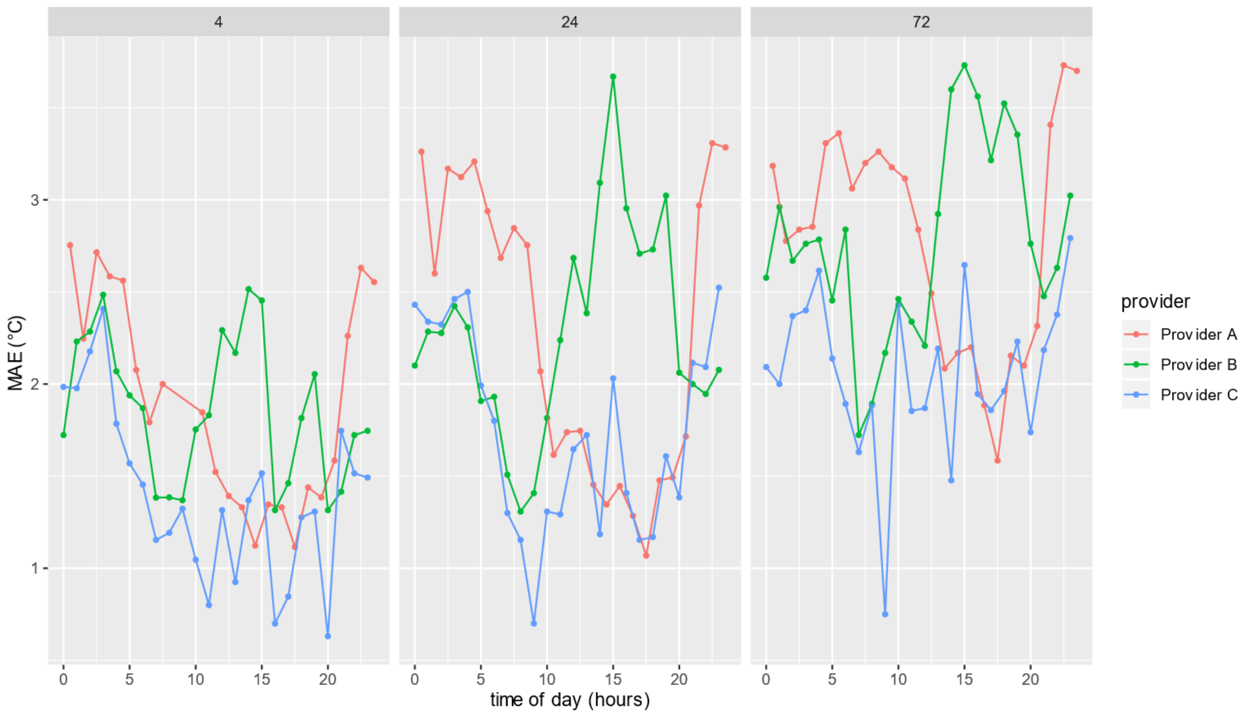


Figure 43 Archerfield, intraday MAE profile, all providers, summer 2019-20

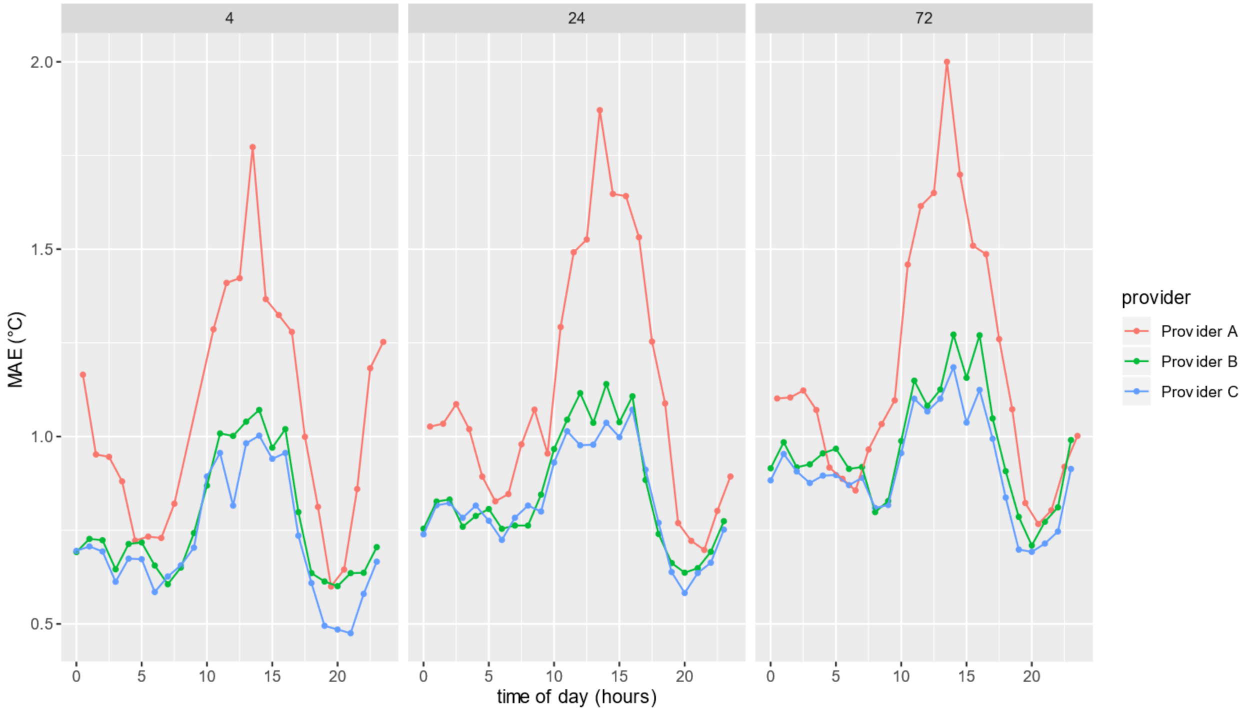


Figure 44 Archerfield, intraday MAE profile, all providers, top 10% hottest days summer 2019-20

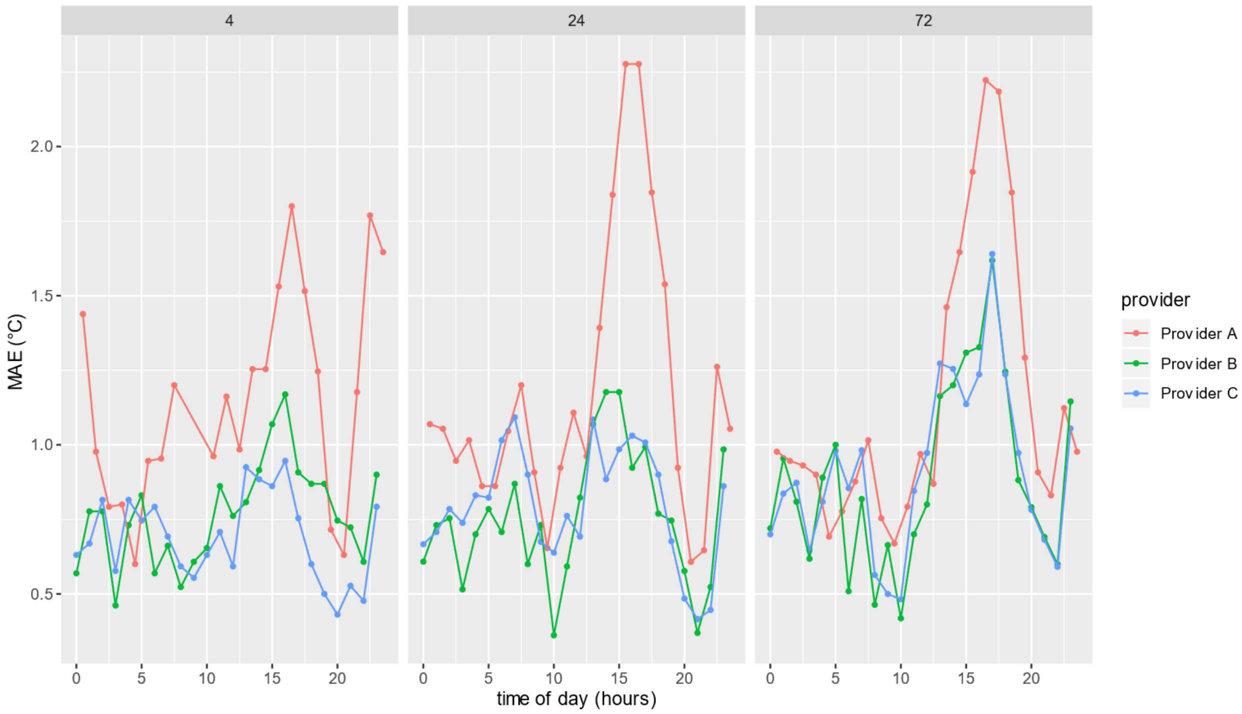


Figure 45 Bankstown, intraday MAE profile, all providers, summer 2019-20

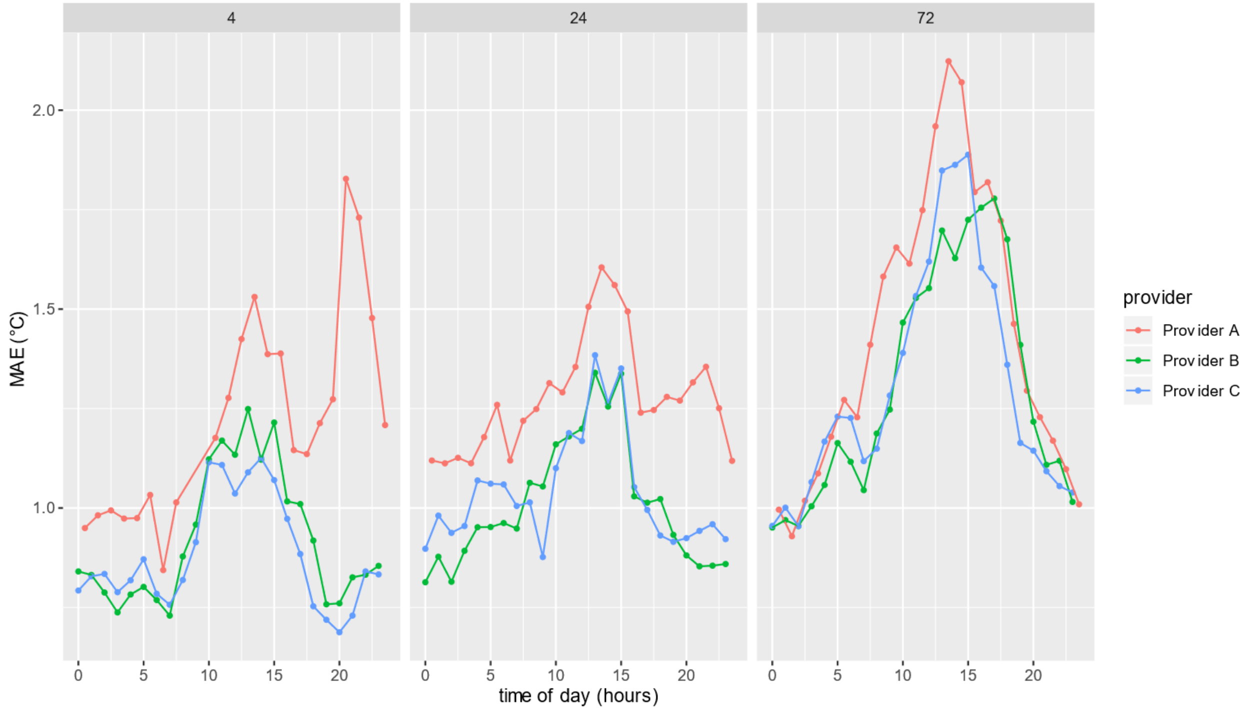


Figure 46 Bankstown, intraday MAE profile, all providers, top 10% hottest days summer 2019-20

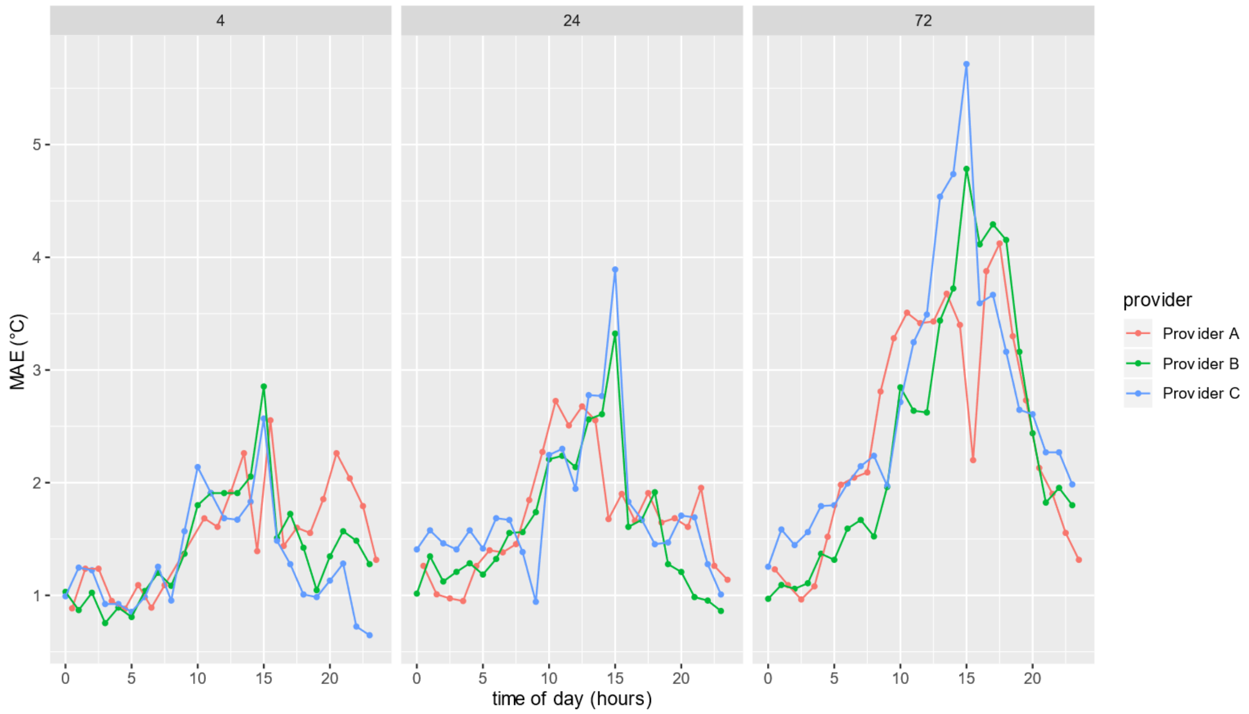


Figure 47 Hobart Airport, intraday MAE profile, all providers, summer 2019-20

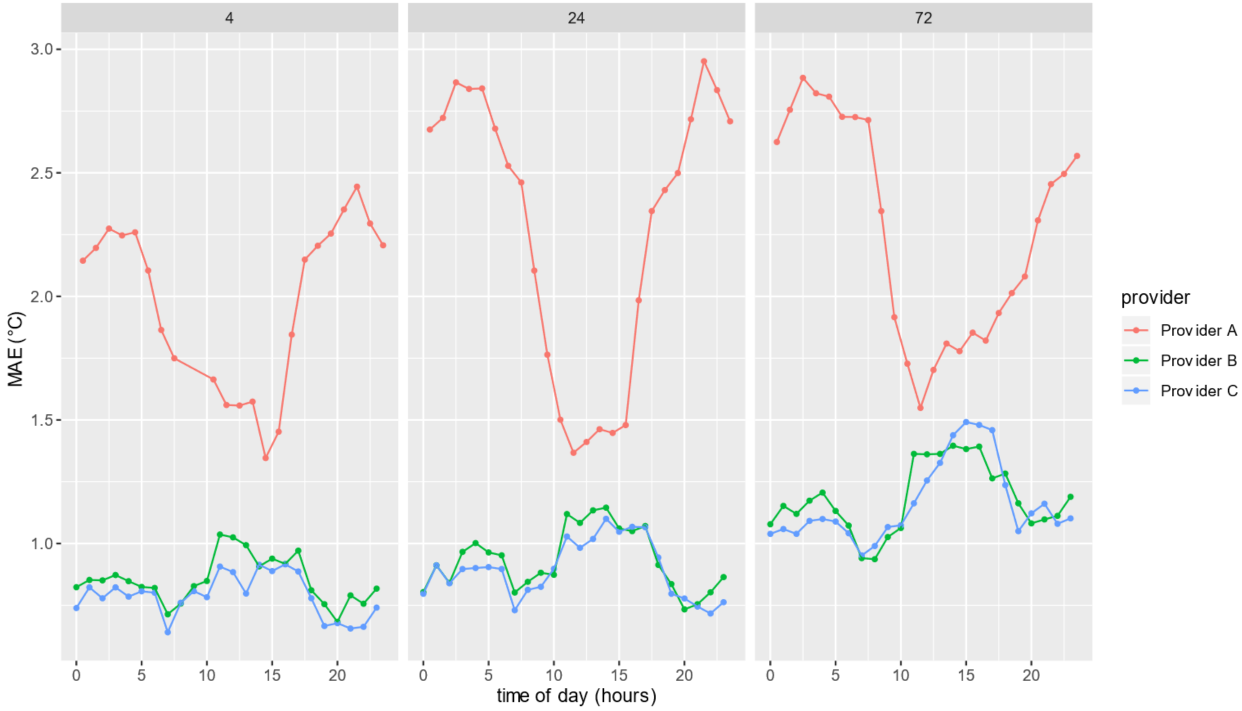


Figure 48 Hobart Airport, intraday MAE profile, all providers, top 10% hottest days summer 2019-20

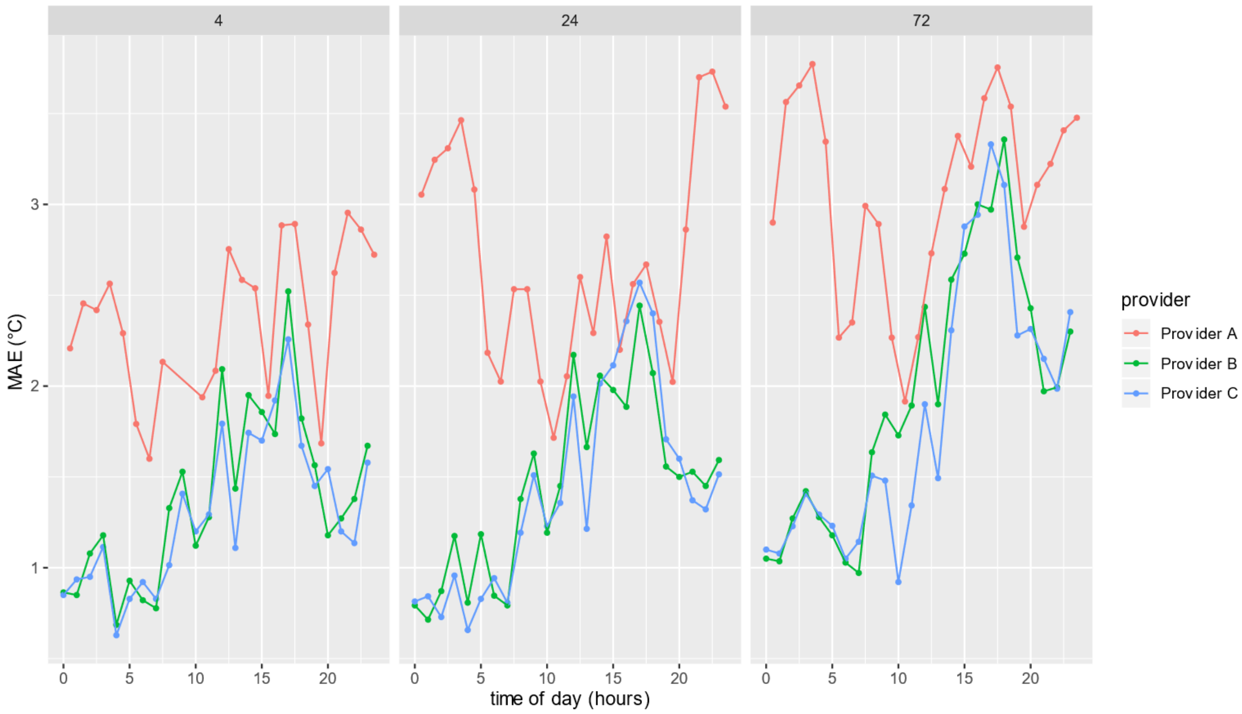


Figure 49 Kent Town, intraday MAE profile, all providers, summer 2019-20

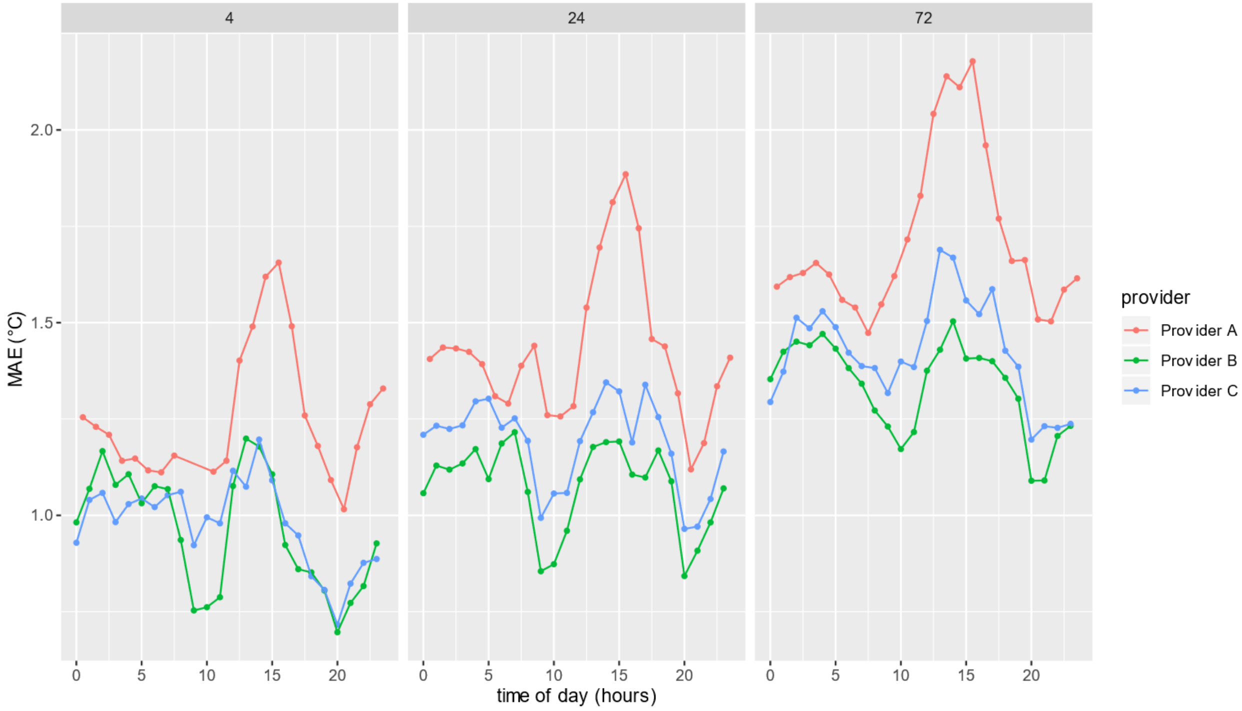


Figure 50 Kent Town, intraday MAE profile, all providers, top 10% hottest days summer 2019-20

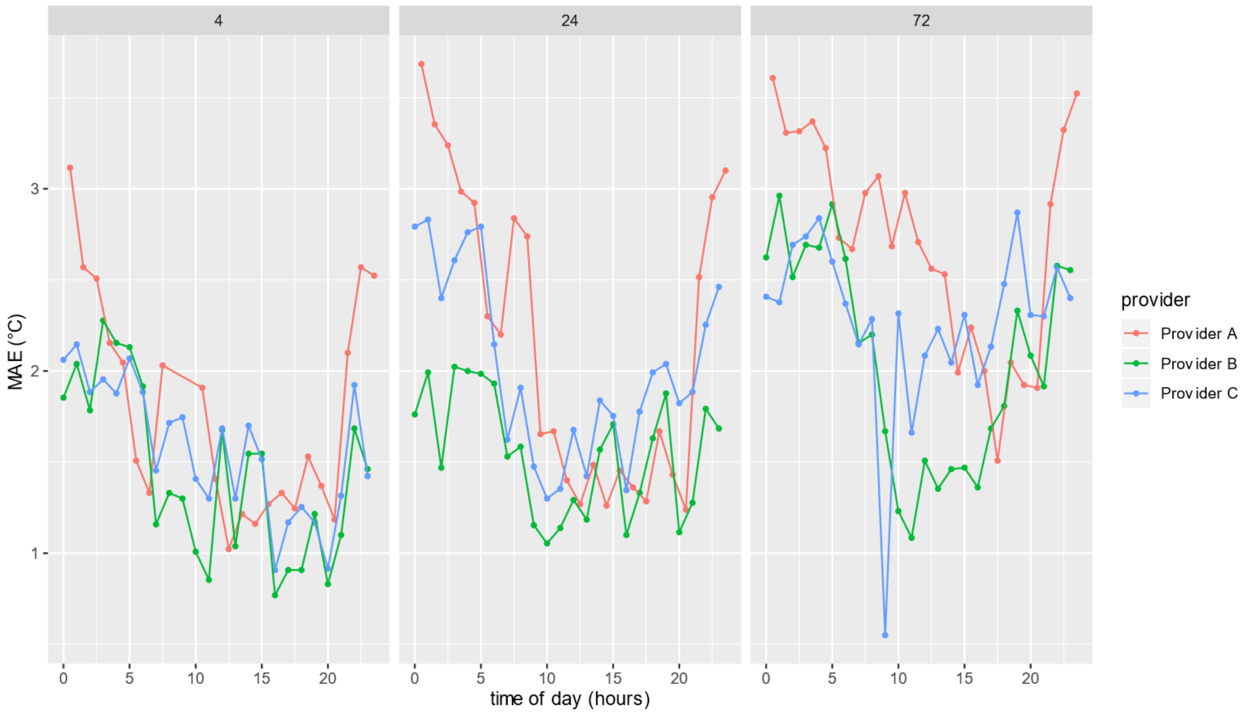


Figure 51 Melbourne OP, intraday MAE profile, all providers, summer 2019-20

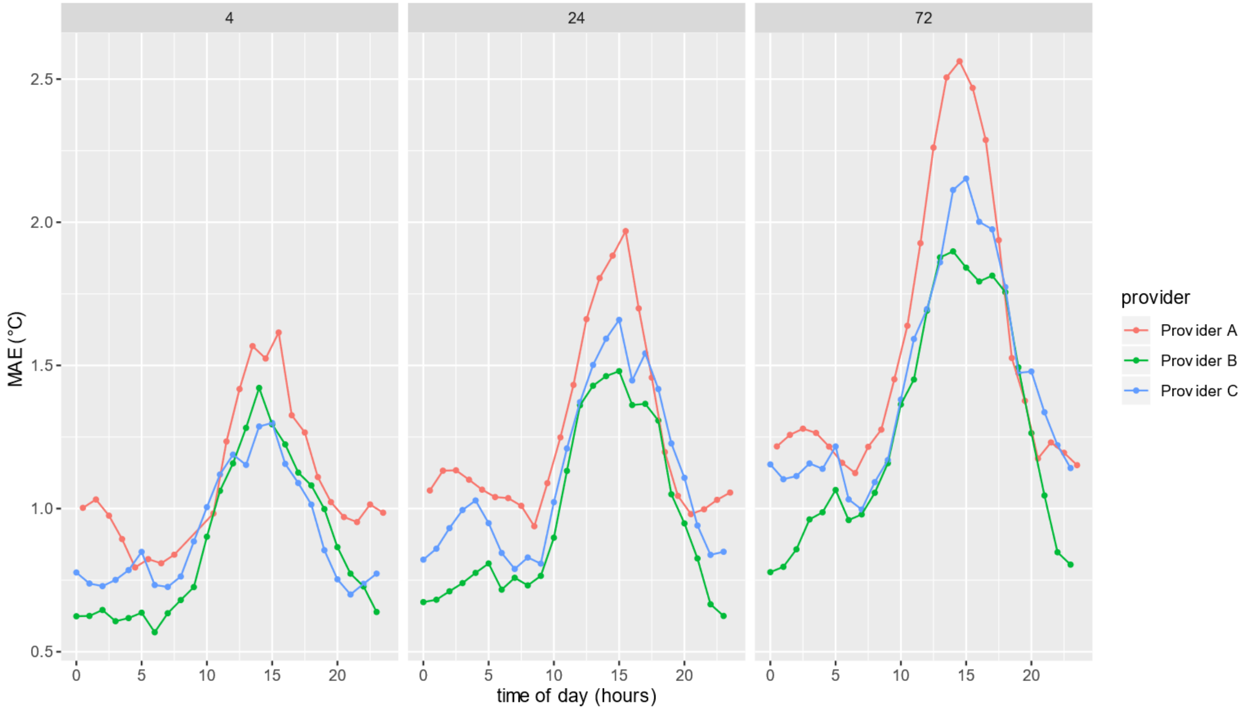


Figure 52 Melbourne OP, intraday MAE profile, all providers, top 10% hottest days summer 2019-20

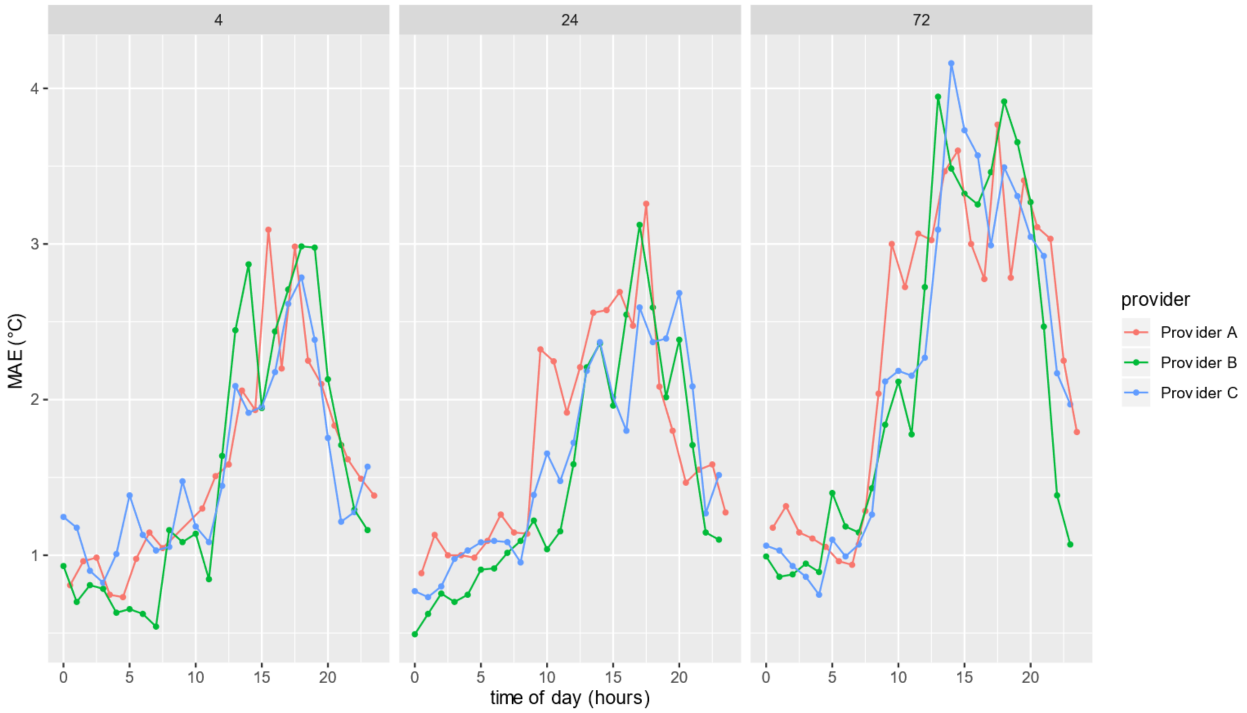


Figure 53 Melbourne AP, intraday MAE profile, all providers, summer 2019-20

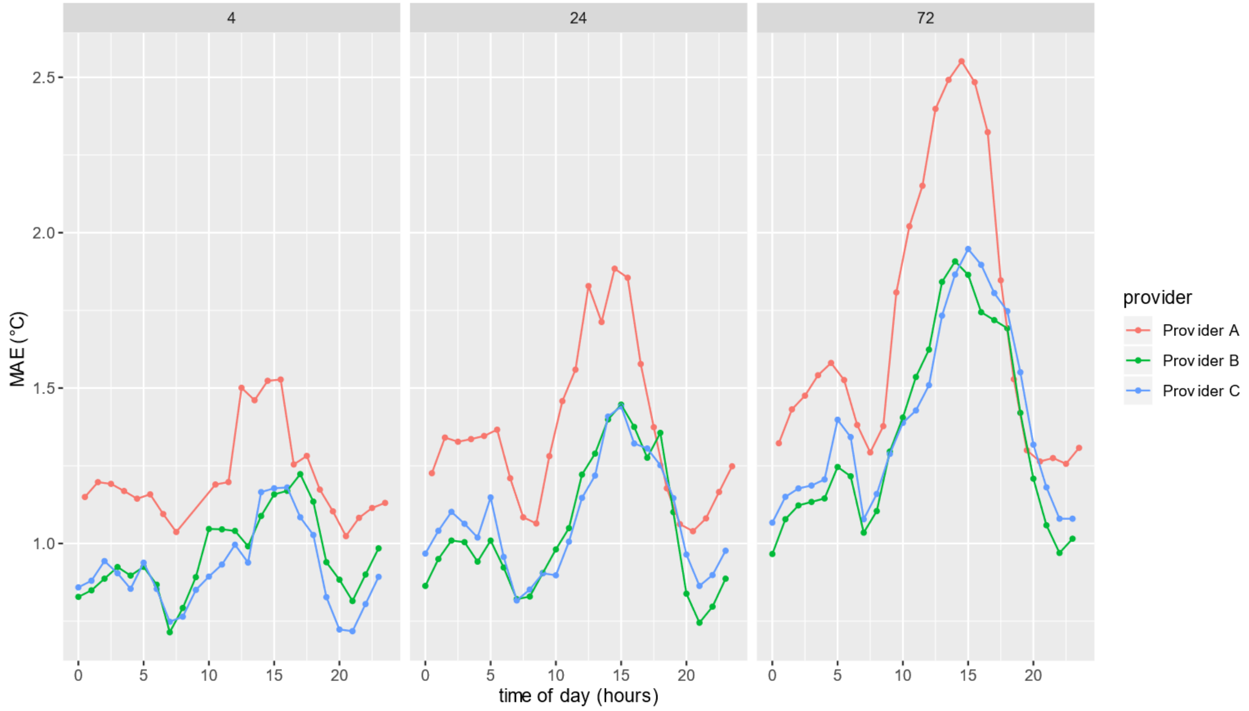


Figure 54 Melbourne AP, intraday MAE profile, all providers, top 10% hottest days summer 2019-20

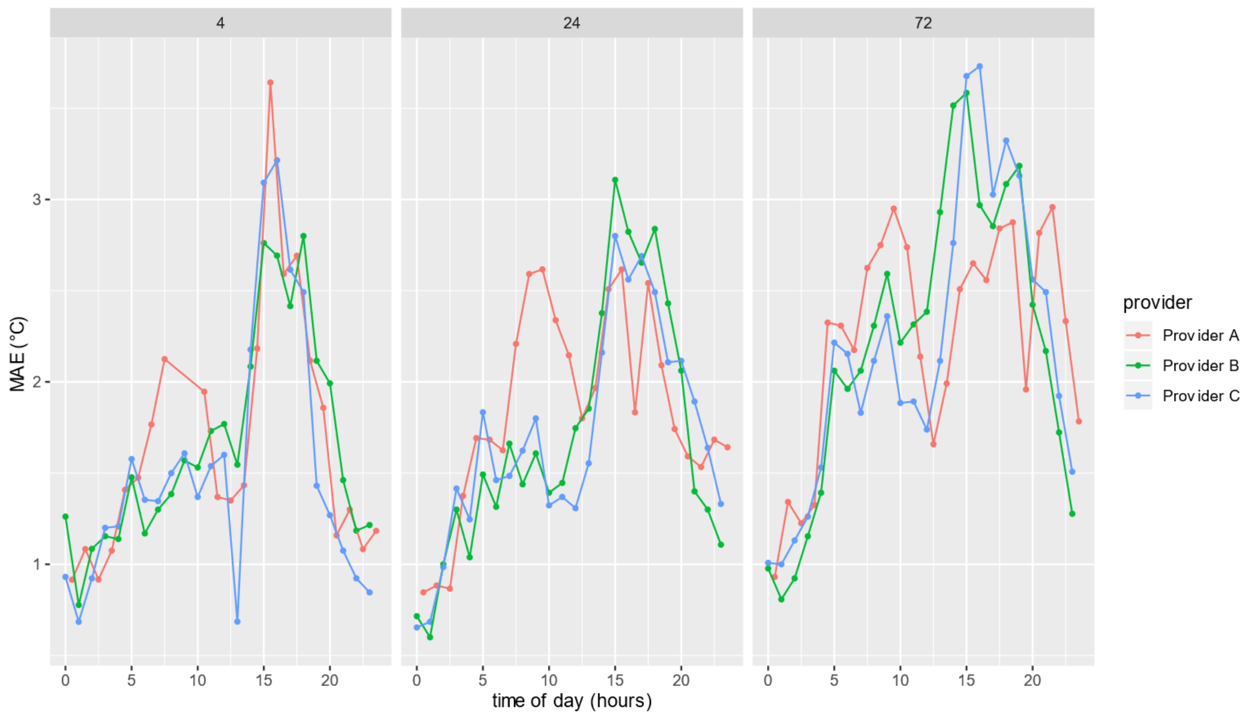


Figure 55 Penrith, intraday MAE profile, all providers, summer 2019-20

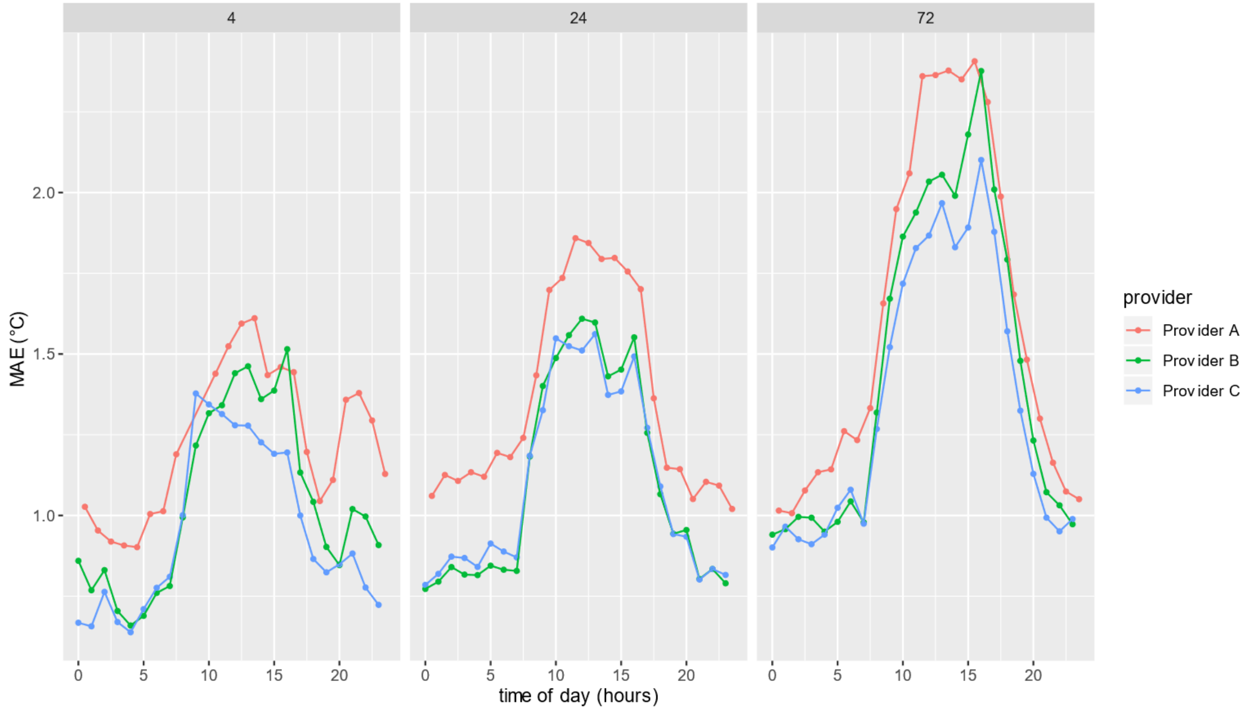


Figure 56 Penrith, intraday MAE profile, all providers, top 10% hottest days summer 2019-20