Supplementary Material for: "The impact of sea breezes on offshore wind energy resources in Australia"

Contents:

S1.Comparison of sea breeze front days with previous studies

In this section, sea breeze front (SBF) days are defined for three regions over 1979–2024, following the methods outlined in Section 2.2 of the main text. The seasonal cycle of SBF days in these regions are then compared with the results of three previous studies on sea breeze occurrences in Australia, for the purposes of evaluating the accuracy of the sea breeze identification methods used in the main text. The three regions (and studies) are the southeast of the Australian state of Queensland near the city of Brisbane (Soderholm et al., 2017), the southwest of Australia near the city of Perth (Masselink and Pattiaratchi, 2001) and near the city of Adelaide in the Australian state of South Australia (Pazandeh Masouleh et al., 2016). The seasonal cycle from each of the three previous studies are approximately reproduced here, by manually extracting data from the relevant figures of each paper.

In the current study, SBF days are counted for each region by considering the occurrence of a sea breeze object in a broad coastal area (see shaded area in Figure S1), and compared with results from previous studies based on point observations within that area (see orange crosses in Figure S1). This discrepancy between area and point definitions is due to the characterisation of the sea breeze as a frontal object in the current paper, with the broader circulation around that front impacting local conditions away from the front. The number of sea breeze objects is sensitive to the size of the coastal area chosen, although the shape of the seasonal cycle remains consistent for any reasonably sized region (not shown). The size of the coastal areas shown in Figure S1 were subjectively chosen based on the expected area for which a detected sea breeze object could impact local surface conditions, as well as the agreement between the subsequent SBF counts with the previous results shown.

Figure S1 shows that the monthly distribution of mean SBF days per month in southeast Queensland agrees very well with the results from Figure 2b of Soderholm et al. (2017). This includes both the number of SBF days per month and the shape of the seasonal cycle, with a peak of 14–15 days per month during October–November (Austral Spring), and a minimum of around 3.5 days per month during June (Austral Winter). Sea breeze days are defined by Soderholm et al. (2017) at the Archerfield automatic weather station (indicated in Figure S1) over an 18-year period (1997–2014), based on a local observed increase in wind speed and relative humidity, and a change in wind direction.

The seasonal cycle of mean SBF days per month in Perth broadly follows the results from Figure 4a of Masselink and Pattiaratchi (2001), shown in Figure S1. However, there are a larger number of SBF days identified per month from January–March (around 23–25) compared with the previous study (around 16–20), and fewer days per month from June–November. The peak of SBF days is also shifted to January (25 days per month), compared with December in previous study (23 days per month). Both the SBF days and previous study indicate a minimum during June, although with fewer SBF days per month (6) compared with the previous study (10). Masselink and Pattiaratchi (2001) identify sea breeze days using weather station observations at Perth Airport (indicated in Figure S1) from 1949–1997, using wind speed and direction only. Therefore, there is potential for large-scale changes in wind speed and direction to be falsely identified by sea breezes in that study, especially during the cool-season when synoptic-scale cold fronts can frequently impact the Perth region. It is acknowledged in that study that "the sea breeze selection algorithm works extremely well for the summer wind data, but is slightly less successful in identifying sea breezes during the winter".

The seasonal cycle is also broadly similar between the SBF days and results from Figure 4 of Pazandeh Ma-

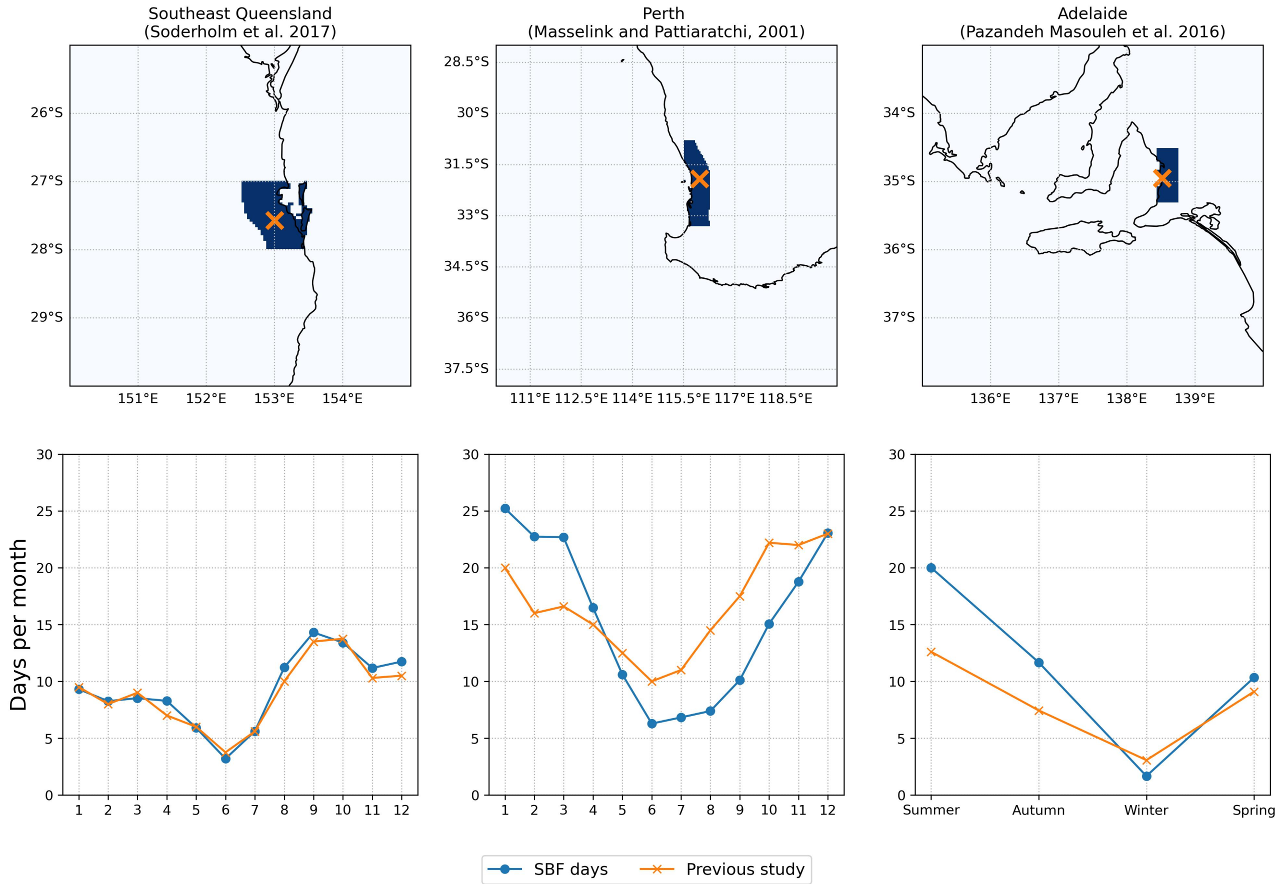

Figure S1: (bottom panels) Comparison between the (blue circles) seasonal cycle of sea breeze front (SBF) days, using methods described in Sections 2.1 and 2.2 of the main text, and (orange crosses) three previous studies for (left) southeast Queensland, (centre) the city of Perth and (right) the city of Adelaide. In each of the top panels, the areas used to define SBF days are shown with blue shading, while the locations of weather stations used to define sea breeze days in each of the previous studies are indicated with an orange cross.

souleh et al. (2016) for the city of Adelaide, shown in Figure S1. In that study, results are reported as the median sea breeze days per season, and are converted here to median days per month within each season by dividing by three. The median number of SBF days per season are very similar to the previous study for the Austral Winter (June–August) and Spring (September–November), although a larger number of SBF days per month are observed during Summer (December–February, 20 compared with 12.5) and Autumn (March–May, 12 compared with 7.5). Pazandeh Masouleh et al. (2016) identify sea breeze days using wind speed and direction data from the Adelaide Airport weather station, over a period of 1955–2008, constrained to days with a climatologically average land-sea temperature contrast above 0 °C, as well as days without a strong offshore wind observed by radiosonde. The observations used include 3-hourly surface wind observations and 12-hourly radiosonde data, and the study notes that "the (method) is likely to underestimate the frequency of sea breeze days as some potential sea breeze days with shorter duration might not be detected". This could contribute to the lower sea breeze days per month in that study compared with the SBF days used here.

In summary, the SBF days for three selected regions broadly agree with three different previous studies for each region, in terms of the approximate magnitude and shape of the seasonal cycle. This provides confidence that the sea breeze identification methods and SBF days used in the main text are able to accurately represent the observed variability in sea breeze days around Australia. There are also some differences between the seasonal cycle in SBF days and previous studies for Perth and Adelaide. Some differences are to be expected given the very different methods used between those previous studies (based on station wind data) and the current study (based on moisture frontogenesis from atmospheric model data).

S2: Average daily profile of surface air temperature on sea breeze front days and other days

Figure S2 shows the average daily profile of surface air temperature for each coastal land region, adjacent to each offshore wind area during the summer. Daily profiles are shown separately for days with a sea breeze front (SBF) identified in the same area, and other days. Figure S2 demonstrates that on SBF days, air temperatures over the land tend to be higher, providing enhanced sea breeze forcing and regional cooling demand (see main text).

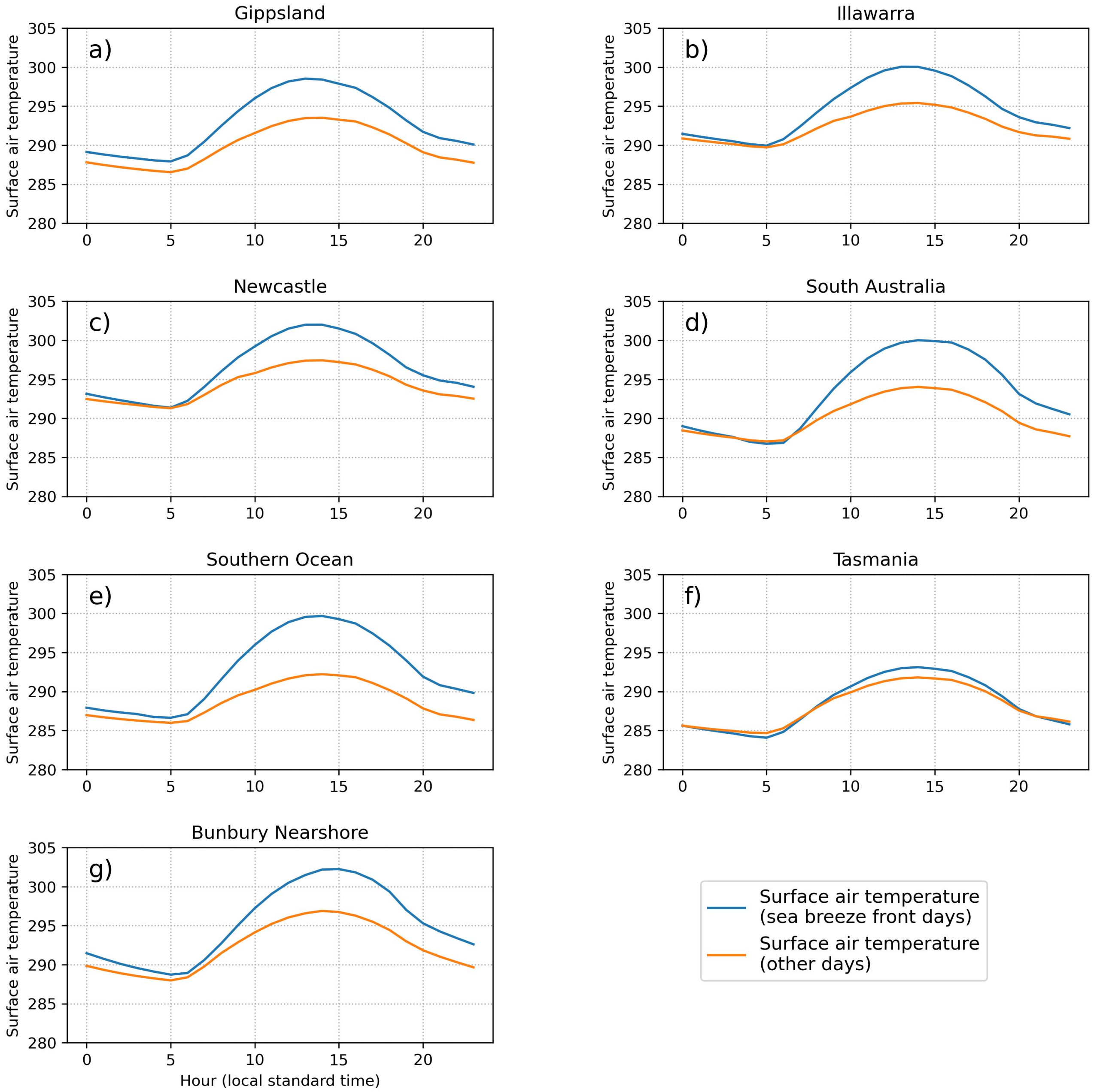

Figure S2: The average surface air temperature over coastal land regions adjacent to each offshore wind area, during the summer, on (blue) sea breeze front (SBF) days and (orange) other days.

S3: Odds Ratios for sea breeze front days across regions

The correlation of daily sea breeze occurrences between regions is quantified using the Odds Ratio in Figure S3. For two regions (say, region A and B), the Odds Ratio describes the ratio of the odds that a SBF day occurs in region A given a SBF day in region B, compared to a SBF day in region A without a SBF day in region B. An Odds Ratio significantly greater than 1 indicates that the odds of a SBF day occurring in region A are enhanced if there is a SBF day in region B, suggesting that SBF occurrences between the two regions are positively correlated. Similarly, an Odds Ratio significantly less than 1 suggests that SBF day occurrences between regions are anti-correlated, with values around 1 suggesting no correlation.

Figure S3 further quantifies the findings in the main text, with Odds Ratios > 1 between coastlines of similar orientations, and Odds Ratios < 1 for coastlines that are opposite-facing. For example, the odds of an SBF day in Illawarra is 2.7 times higher when there is a SBF day in Gippsland (as they are both east-facing coastlines), and vice versa. In contrast, the odds are reduced by 50% when there is a SBF day in the Southern Ocean region (as the Illawarra and Southern Ocean coastlines are opposite-facing). Similarly, for the South Australia region, the odds of an SBF day is 5.2 times greater if there is a SBF day in the neighbouring Southern Ocean region, while the odds are reduced by around 70% if there is a SBF day in the Illawarra or Newcastle regions.

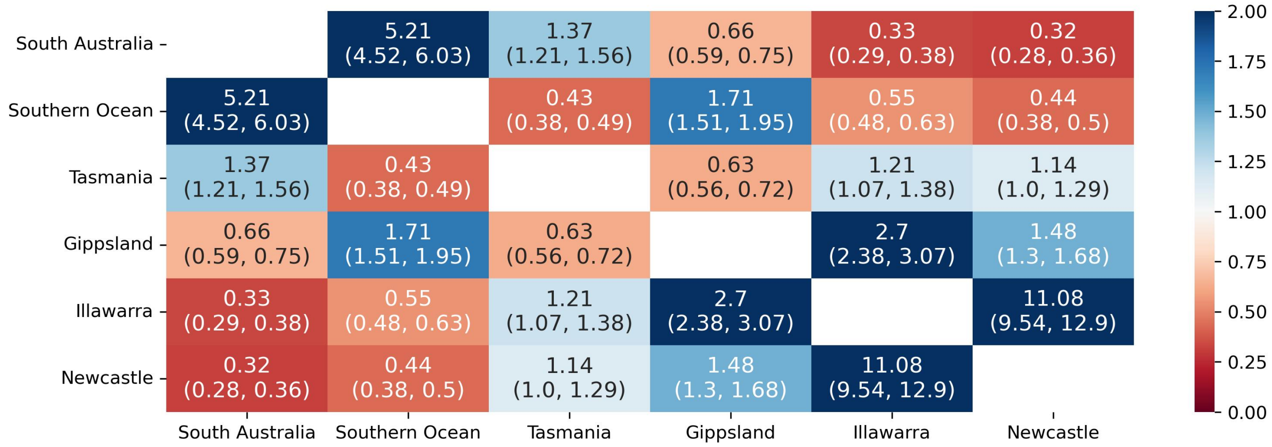

Figure S3: Odds Ratios describing the relationship of sea breeze front (SBF) day occurrences between regions. Values greater than 1 indicate that a region has greater odds of a SBF day if a SBF occurs in another region, with the oppostie true for values less than 1. A 95% confidence interval is also shown.

References

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