Article

Abrupt wind speed changes on northern Port Phillip

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People of Melbourne are familiar with the changeability in its weather. Melburnians may head to work in solid rain but return home in warm, bright sunshine. On hot summer days many residents look forward to the "cool change" in which the hot, northerly wind is swept away by a southerly wind and the temperature drops by 15°C or more. However, through sad experience Melburnians know the dangerous impact of these sudden wind changes on bushfires. Sudden wind changes are also a concern for mariners venturing on to Port Phillip. At Mornington there is a memorial to 15 young men lost in May 1892 after a squall hit their boat as they returned from a football match at Mordialloc.

One example of an abrupt change in wind speed and direction, familiar through tragedy, is that on Black Saturday, 7 February 2009. The plot of the wind during the day at Fawkner Beacon (Figure 1) shows several significant wind changes.

The "cool change" arrived around 5pm when the 30 knot northerly backed to the south and gradually eased. A sudden increase in wind speed occurred around 10pm EDT from near calm to 28 knots within half an hour. Early in the day there was another rapid increase when the northerly wind increased in strength from 8 to 23 knots within half an hour with no significant change in direction.

These abrupt wind changes in speed and/or direction are a major concern for fire-fighters, but such increases in wind speed could be at least unpleasant but potentially hazardous for small boats too. Such an event on 11 June 2018, as described in the case study (page 15), led to the question "How common are such cases on Port Phillip and what causes them?". This investigation aims, from the perspectives of would-be sailors and meteorologists, to provide an indicative answer.

Data

This study concentrates on Fawkner Beacon which is located in Port Phillip approximately six kilometres west of Sandringham as representative of wind conditions in the northern area of Port Phillip (see Figure 2). Automatic Weather Station (AWS) data were acquired from the Bureau of Meteorology. The wind observations contain 10-minute average wind speed and direction every ten minutes, covering the period from 1998 to January 2019. Gusts are also a significant safety consideration but this study only considers changes in the 10-minute average wind.

"Abrupt wind speed changes" were taken as half hour wind speed changes exceeding 30 km/hr (16 knots). These were identified by computing the wind speed change over half an hour for every 10-minute increment. In cases of several successive ten minute starting times the case of the greatest wind speed change was selected. A further test was added so that cases more than an hour apart would be counted as a separate event, meaning that there could be more than one event (either increase or decrease) on a given day. Local time is used.

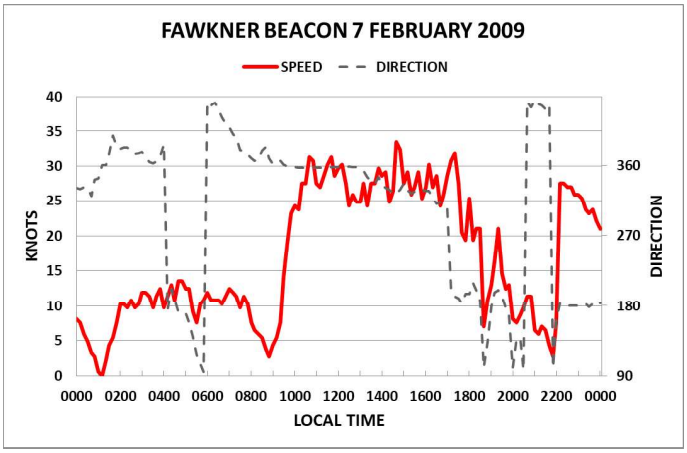


Figure 1: Wind speed and direction at Fawkner Beacon for 7 February 2009.

Figure 2: Location map of Bureau observation sites around Melbourne. Source: Bureau of Meteorology website.

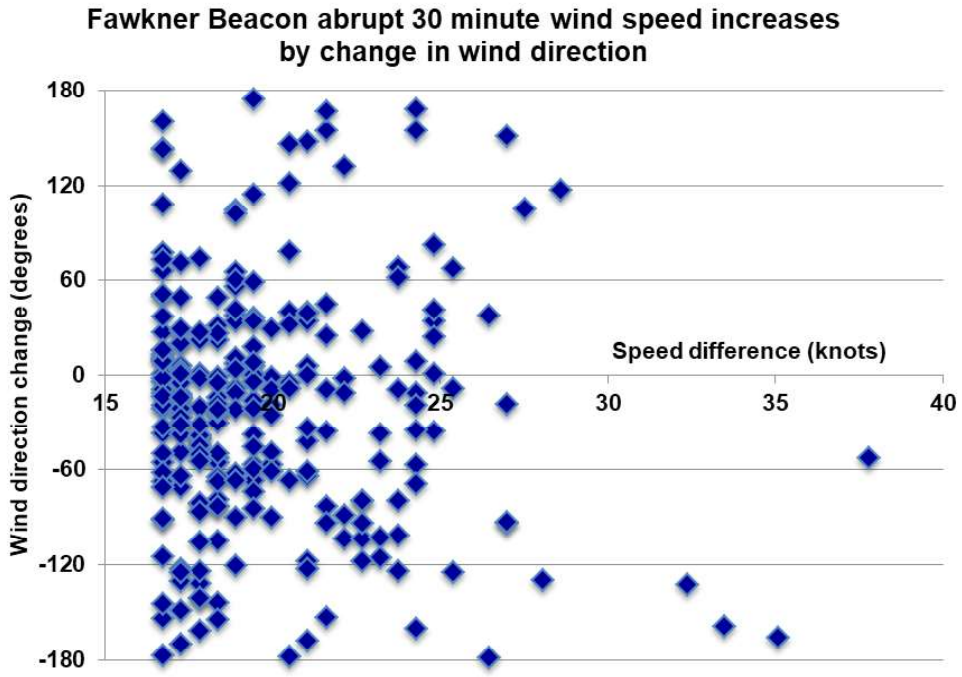


Figure 3: Scatter diagram showing direction and speed changes for the cases of abrupt wind speed increase.

The change in direction is simply taken as the difference between the initial and final compass bearing over the half hour. Positive (clockwise) changes are referred to as *veering* while negative (anticlockwise) changes are *backing*. However, the change in direction is limited to 180 degrees, leading to ambiguity if the directional change exceeded 180 degrees. Examination of the data shows that such cases are rare.

It should be emphasised that the discussion here concerns the north of Port Phillip which is a large body with many variations in wind across it. In particular, there may be large variations in wind strength from north to south in strong easterly or westerly flow.

Overall Results

There were 248 cases of abrupt increases in wind speed of 16 knots or more over the 21 years of data representing about 12 cases per year. There were 56 cases of abrupt wind speed decreases.

In nine cases there were abrupt increases and decreases within adjacent or overlapping 30 minute periods. A review of available weather radar data showed that these events were typically associated with a line of thunderstorms crossing Port Phillip.

Wind Speed Increases

Figure 3 shows a scatter plot of the speed and direction changes. One third of the events (86 cases out of the 248) have direction changes less than or equal to 30°, and in the discussion below are termed "straight line" wind speed increases. For the cases with a change in wind direction more than 30°, two-thirds (108 out of 162) were cases of a backing wind and one third associated with a veering wind.

Of note is that in four events the wind speed increased by more than 30 knots within 30 minutes. All were associated with significant backing in wind direction. Two examples are shown in Figure 4. Around 4am on18 November 2001 winds increased from 7 to 39 knots between successive 10-minute data points. Winds stayed around 30 knots for most of the remainder of the day. An even sharper but shorter-lived event was 14 March 2009. Around 6:30pm the wind speed increased from 8 to 47 knots in a 20 minute period. The synoptic situation in each case involved a low moving over Victoria.

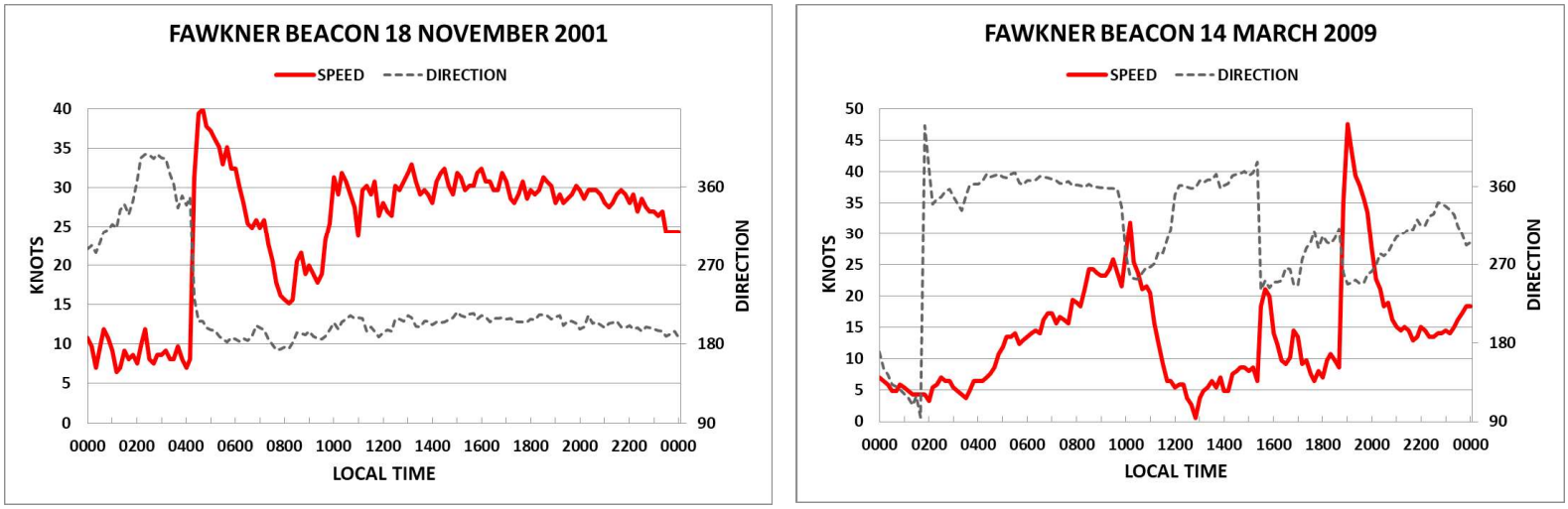


Figure 4. Wind speed and direction at Fawkner Beacon for (a) 18 November 2001 and (b) 14 March 2009.

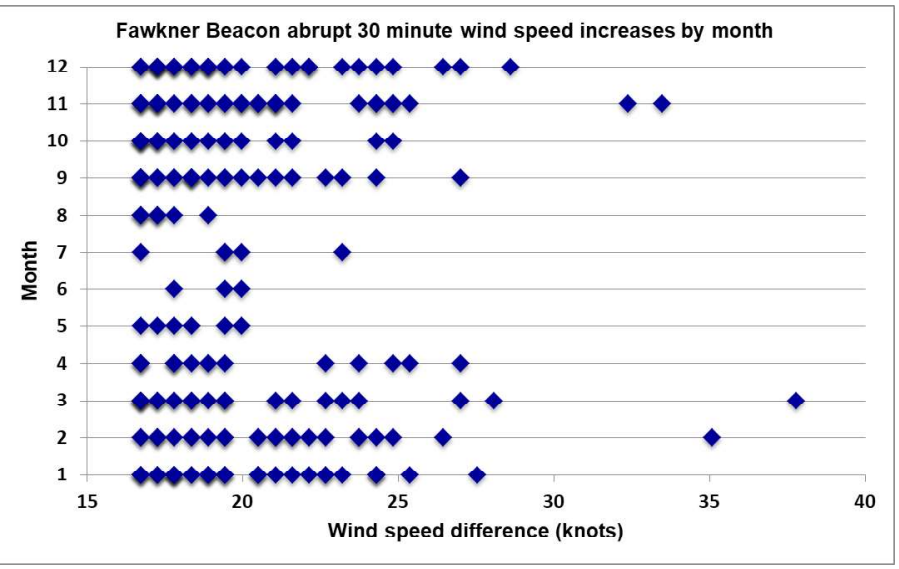


Figure 5: Scatter plot of wind speed increases by month.

The abrupt wind speed increases, particularly the stronger events, are concentrated between September and April (Figure 5). The strongest winter event was 23 July 2003, when wind speed increased by 23 knots around 7am. In this case the direction change was only 5 degrees.

There is not a strong relationship between time of day and number, or strength, of abrupt wind speed increases, although two thirds of cases occurred after 1200 Local Time. The three strongest cases occurred in the afternoon or early evening.

Wind speed changes with large direction changes are more typical, but are normally well forecast and the associated hazardous conditions expected. The behaviour of the "straight-line" events is less familiar and the following discussion focuses on the one third of events with direction changes of 30° or less.

"Straight line" wind speed increases

The 86 events (which include the June 2018 event) were divided into quadrants based on initial wind direction. Numbers in each category are shown in Table 1. About 40 per cent of the cases are for winds in the North quadrant.

East Quadrant

There were only two cases in the east quadrant at Fawkner Beacon, both being abrupt speed increases in pre-existing south-easterly winds.

Table 1: Number of "straight-line" abrupt wind speed increases according to the quadrant of the initial wind direction.

	Wind direction range	Number of cases
North	330-059	35
East	060-149	2
South	150-239	26
West	240-329	24

South and West Quadrants

Around half of the west and south quadrant speed increases showed a two stage wind change associated with the passage of a front. The initial wind change from northerly winds (often strong) to the south brings a drop in wind speed, a lull, before the onset of strong south-southwesterly winds, sometimes as a squall.

One stark example is 22 January 2006 (Figure 6a). Around 7pm the 20 knot northerly winds backed to southerly and decreased to below 15 knots. An hour later the wind speed increased suddenly reaching a 10-minute average of 40 knots before abating two hours later. The "Black Saturday" case shown in Figure 1 falls into this category.

The other pattern was of short fluctuations within an extended period of generally strong winds. An example is the time series for 15 October 2011 (Figure 6b). The synoptic pattern showed a deep low moving south of Victoria.

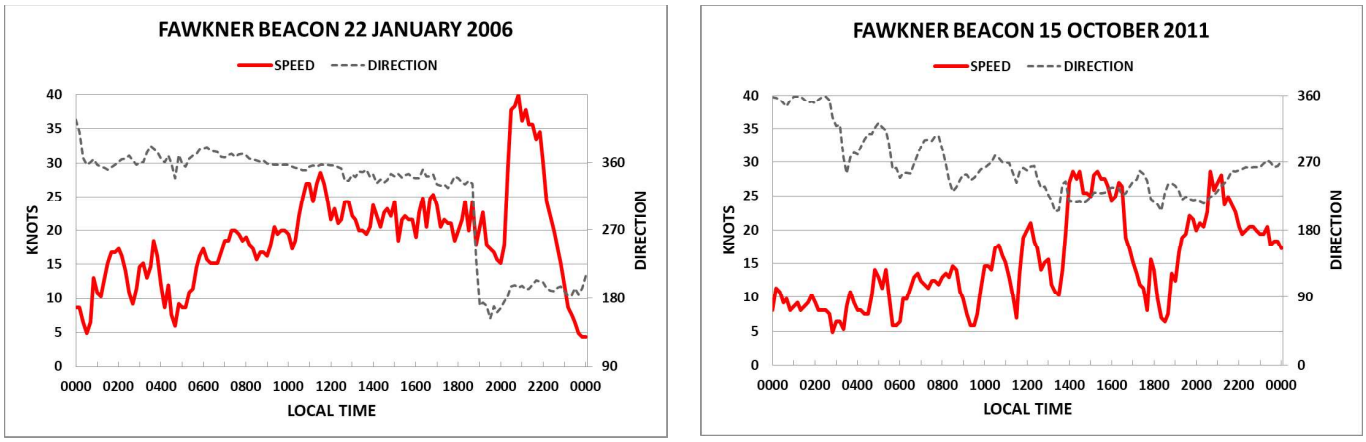
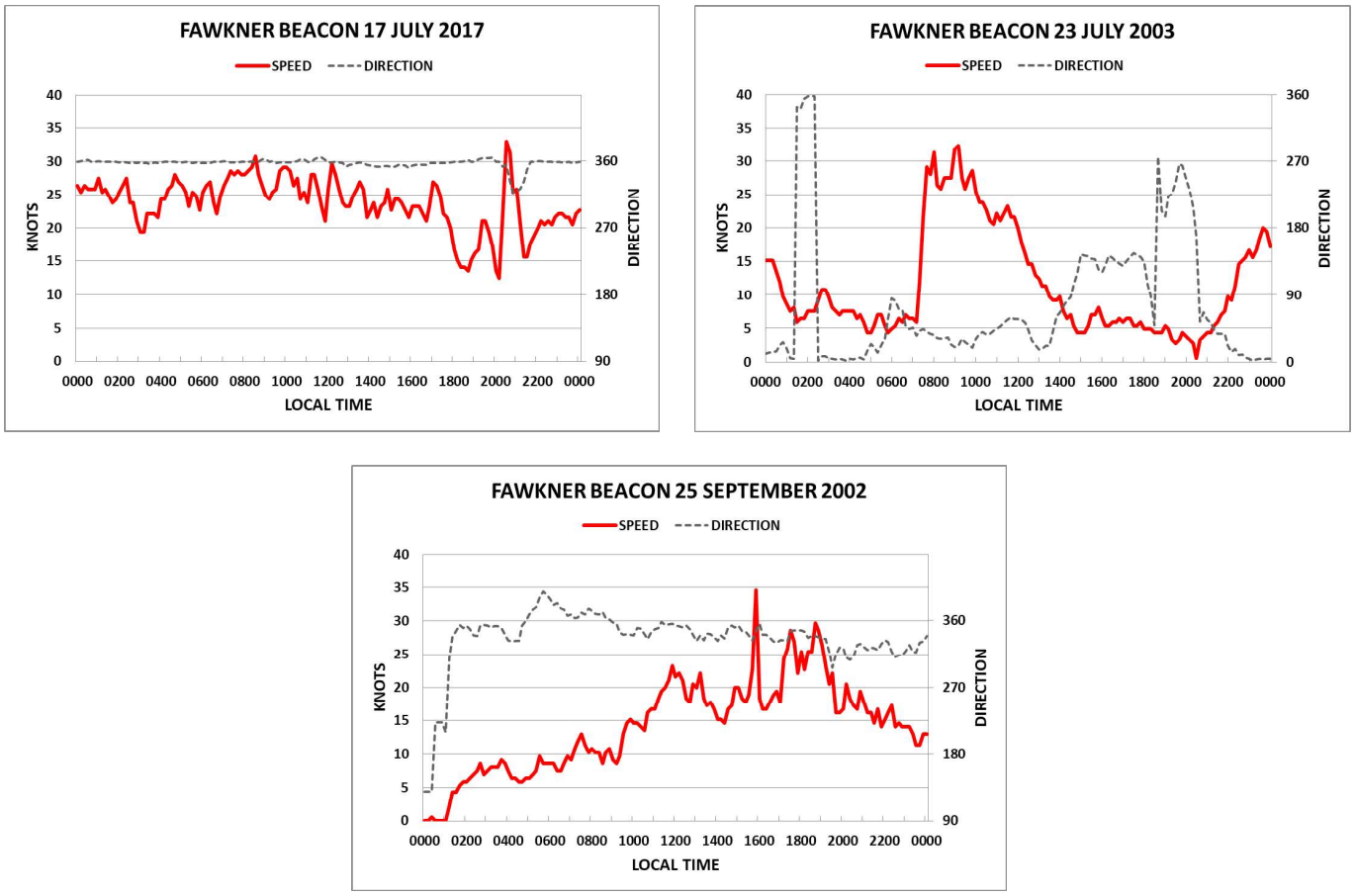


Figure 6: Wind speed and direction at Fawkner Beacon for (a) two stage wind change (example from 22 January 2006) and (b) short fluctuations (example from 15 October 2011).

Figure 7: Wind speed and direction at Fawkner Beacon for (a) Lull in wind speed (example from 17 July 2017), (b) abrupt onset of northerly winds (example from 23 July 2003) and (c) Squall or spike in wind speed (example from 25 September 2002).



Again there is a preference for the warmer months with fourty of the fifty cases for these quadrants occurring between October and April. The winter/spring cases tended to result from fluctuations in strong westerly flow, rather than the double wind change category.

North Quadrant

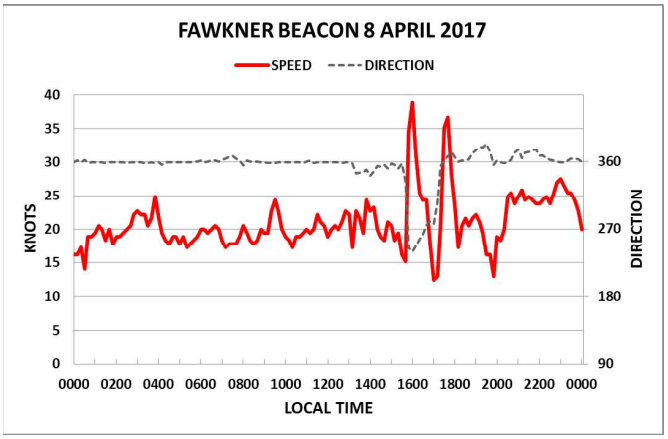
About 40 per cent of the "in-line" abrupt wind speed increases occurred for winds in the North quadrant. They fall into three subjective categories: (a) after a lull in an extended period of significant winds (12 of the 35 events), (b) an abrupt onset of strong northerly winds from a period of light winds (15 of 35 events), and (c) squalls or spikes in wind speed typically lasting less than 20 minutes (8 cases). An example of (b) occurred on 7 February 2009 (Figure 1), and it was this type of event that is described in the case study (page 15). Another example for each category is shown in Figure 7.

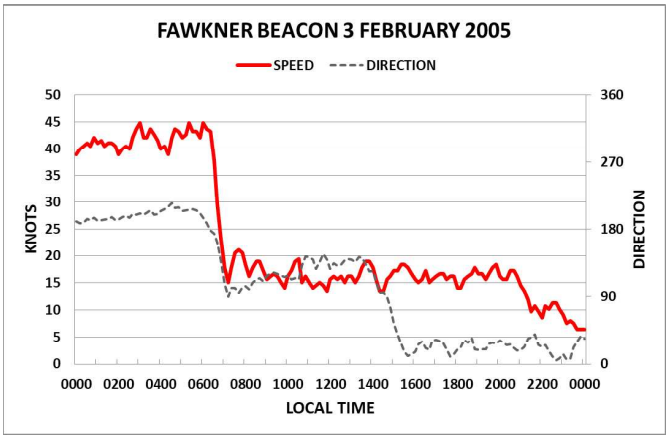
The "lull" cases occurred in synoptic situations with a series of fronts or a major low with embedded fronts crossing Victoria. The "abrupt onset" cases occurred in northerly flow ahead of a front approaching from the west, but still located over South Australia.

In the "abrupt onset" cases the 925 hPa wind (about 700 metre altitude) was typically northerly at 30–40 knots several hours before the onset of the strong winds at the surface. These events are likely due to the mixing down of the low-level jet once the surface inversion has been eroded, as is hypothesised for the case of 11 June 2018 (case study, page 15). All except one of the 15 "abrupt onset" cases occurred before 1300 Local Time.

The onset of strong winds at Fawkner Beacon is generally more abrupt than the simultaneous time series of winds at other stations in the north of Port Phillip. For example, of the 15 "abrupt onset" cases at Fawkner Beacon only two would have met the same onset criteria (an increase of 16 knots in half an hour) at Point Wilson. Several of the very marked cases occurred in the cooler months when the water over the bay is quite cold and does not respond to the diurnal warming that would take place over land. In some cases there are even hints of an incipient sea breeze.

Figure 8: Wind speed and direction at Fawkner Beacon for (a) fluctuations in wind speed (example from 8 April 2017) and (b) sudden drop in wind speed (example from 3 February 2005).





Wind speed decreases

For sailors, a sudden decrease in wind speed can also be disconcerting. In the study data there were 56 events when the speed decreased by 16 knots or more within half an hour. As was the case with the events showing an increases in wind speed, the events were concentrated between October and April.

Twenty five of the events were associated with spikes or squalls lasting 20 minutes or less and they included the nine cases mentioned earlier where abrupt increases and decreases occurred within adjacent or overlapping 30 minute periods. Apart from these cases, the abrupt decreases in wind speed fall into two main categories. Some are short term fluctuations within a more extended period of stronger winds (such as the case 15 October 2011 in Figure 6(b)). In some cases sudden increases and decreases both occurred within the same day associated with short-lived fluctuations in the wind speed.

The second category is a sudden drop-off in wind with the passage of a trough or front (see the case of 22 January 2006, Figure 6a). As noted earlier, these sudden decreases can be temporary with the stronger southerly winds appearing some time later. The two largest decreases in wind speed illustrate these two types as shown in Figure 8.

Summary and messages for boaties

Sudden wind speed changes can occur on Port Phillip especially during the warmer months when boaties are more likely to be on the water. There are many variations of the wind around the bay and each area will have its own peculiarities. The analysis above suggests several messages for the northern part of Port Phillip.

Most abrupt wind speed increases are associated with: a backing change from northerly (generally strong) to southerly, often squally, and associated with thunderstorms. These changes are generally well forecast and should be taken seriously. There may also be short lulls in wind speed within an extended period of strong winds.

There are several less familiar situations that also deserve caution. In the warmer months, there may be a two-stage change in wind—the strong northerlies ahead of a front or trough may give way to moderate, or even light, southerly winds. Then the main burst of often squally south to south-westerly winds may arrive two or more hours later. The "lulls" can be pronounced and extended as can be seen in the "Black Saturday" case. Boaties need to exercise caution. They may have expected a change and be fooled by the initial change and subsequent lull. Boaties should pay attention to the forecast and not necessarily think that the main change has arrived when the wind first changes to the south.

Another situation for caution is an abrupt increase in speed of northerly winds with little change in wind direction. These cases generally occur in the morning or early afternoon. An approaching front may be well to the west and there may be no clouds to indicate the presence of a front. Wind speeds can increase suddenly under a blue sky and boaties may be lulled into a false sense of security by clear blue skies and light winds. If strong northerly winds are forecast, boaties should take heed, as the onset of such northerly winds over the waters of northern Port Phillip can be more abrupt than for adjacent land stations.

Acknowledgements

The data for the study were obtained from the Bureau of Meteorology. We also made extensive use of the archive of Port Phillip time series graphs developed by Andrew Watkins, and accessible through the website he maintains http://www.baywx.com.au/. We are also grateful to Ted Williams (Bureau of Meteorology) for his insights into the June 2018 case.

June 2018 event—Case study

I (TH) was helping out on the start boat for the Australian Women's Keelboat Regatta held off St Kilda on 11 June 2018. The forecast had been for moderate, northerly winds strengthening during the day. The MSLP analysis showed a front well to the west, but it was a sparkling sunny day after a chilly morning with no cloud in the sky. We had one race in northerly winds, starting about 7 knots and dropping to 3 knots. Looking across to Williamstown the water appeared glassy smooth and we feared that the wind might drop out altogether. The second race started in about 6 knots but, looking out to Williamstown again, we saw a line of white caps approaching and soon after, the wind suddenly increased to a 10-minute average of 15 knots with gusts over 25 knots. Needless to say, this caused a bit of mayhem for a while with spinnakers flying from the tops of masts or dragging in the water, and over-powered boats leaning at dramatic angles. The increase in wind speed was even more abrupt and intense further down the bay at Fawkner Beacon, for which the time series shows a very impressive jump in 10-minute average wind speed from 4 knots to 24 knots in successive data points (i.e within 10-minutes and probably close to instantaneously if my experience further up the bay is representative).

By contrast the corresponding graphs for Moorabbin and Point Wilson (below), show a more gradual increase in wind speed, and are more in line with what would have been expected from the forecasts. I was interested in understanding the meteorology behind such a dramatic wind speed increase within an apparently benign synoptic pattern. Several colleagues suggested explanations but I am drawn to that provided by Ted Williams of the Bureau's Melbourne Office who pointed out that the wind at the 750 metre level was from the north at 37 knots. He suggested:

> **"the sudden increase in wind speed is due to mixing down of the stronger winds just above the inversion as things heat up. I think the suddenness would be less pronounced at Point Wilson and St Kilda due the effect of the land/friction stirring things up compared to Fawkner Beacon. A cool, stable pool of air over the cold water would gradually heat up (relatively uniformly) until the temperature trace sits along dry adiabatic lapse rate and reaches those winds at about 2000ft."**

Wind speed and direction for 11 June 2018 at Fawkner Beacon (top left), Point Wilson (top right) and Moorabbin Airport (bottom middle).