Australian Government
Department of Agriculture, Fisheries and Forestry

Future Drought Fund

SOUTHERN NSW Innovation Hub
SUSTAINABLE AGRICULTURE, LANDSCAPES AND COMMUNITIES

FOREWARNED IS FOREARMED

Forecasting tools for informed decision making

Wine Industry Workbook

Making better tactical decisions using the climate forecast tools

April 2023

This project is supported by funding from the Australian Government Department of Agriculture, Fisheries and Forestry as part of its Rural R&D for Profit program and developed in conjunction with the Southern NSW Drought Resilience Adoption and Innovation Hub as part of the Drought Resilience Adoption and Innovation Hubs Program, which received funding from the Australian Government's Future Drought Fund – an Australian Government initiative.

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The following organisations (including producer/farmer representatives) all contributed to the development of Forewarned is Forearmed extension resources, including reviewing the workbook and/or delivering the pilot workshops, ensuring the FWFA program is relevant and practical for industry:

- Meat & Livestock Australia
- Grains Research and Development Corporation
- Dairy Australia
- South Australian Research and Development Corporation
- Sugar Research Australia
- Wine Australia
- Primary Industries Climate Challenges Centre
- Cotton Research and Development Corporation
- Agrifutures
- Australian Pork
- Agrista
- Local Land Services NSW
- Pinion Advisory
- Enablers of Change

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Foreword

The Forewarned is Forearmed (FWFA) project is helping equip farmers to proactively manage the impacts of extreme weather events. Australia has one of the most variable climates of any country in the world. Extreme weather events (such as heatwaves, frost and heavy rainfall) and climate variability have a huge impact on our agricultural production and income.

The five-year, national FWFA project aims to help farmers by providing forecasts of extremes and equipping them with the information and tools to be forewarned and prepared. As a result, we're aiming to decrease the impacts that extreme climate events have on farm production and on business profit.

The Bureau of Meteorology (known as the BoM or just the Bureau for short) and its project partners have developed forecasts of the likelihood of weather extremes on multi-week and seasonal timescales—beyond the traditional seven-day weather forecast. The tools are focused on heat, cold and rainfall extremes. They help answer questions such as *'What is the likelihood of having an extreme rainfall this spring?'*; *'What is the chance of having a heatwave in the week after next?'*; and *'What is the likelihood of having more heavy rainfall events than usual in the upcoming fortnight?'*. This provides farmers with the first-ever forecasts of weather extremes in the weeks to seasons ahead.

A co-design process included agricultural climate and systems analysis researchers and extension specialists with expertise in the dairy, beef, sheep, grains, sugar and wine industries. They used Bureau outputs and worked directly with farmers and farm consultants to connect the forecasts with agricultural decision-making systems. They developed risk management strategies to help farmers proactively prepare for these events, and communicated the project outputs to farmers and advisors.

Seasonal forecasts provide us with extra information, and as Peter Hayman from SARDI says, "they help you know which way to lean, not jump. They are too good to ignore, but not good enough to be sure!"

Contents

"Use seasonal forecasts to help you know which way to lean, not jump. They are too good to ignore, but not good enough to be sure!"

Glossary

Average	The mean value obtained by adding a set of values and dividing the sum by the number of values.
Binomial	In Latin it means "having two terms". A binomial probability distribution describes the likelihood of only two possible outcomes occurring (above or below, success or failure, etc.) in each trial or model run.
Box and whisker plot	A graphical representation of a set of data through its quartiles and outliers, with a box showing the middle 50% of the data and whiskers representing the range of the data outside the box.
Bureau	The Bureau of Meteorology (BoM), which is the Australian government agency responsible for collecting and analysing data related to weather and climate.
Burst	A sudden and brief increase in wind speed or rain.
Climate	The description of the long-term pattern of weather in a particular area. It can be defined as the average weather for a particular region and time period, usually taken over 30+ years.
Climate driver	A factor or process that influences the behaviour of the climate system, such as solar radiation and ocean currents.
Climate outlook	A long-range forecast or projection of future climate conditions for a certain region.
Climatology	The scientific study of climate, including its patterns, variations, and changes over time.
Decile	A statistical term referring to one element of a dataset that is divided into ten equal parts.
Forecast	A prediction of future weather or climate conditions based on scientific data and models.
Forecast products as maps	There are three FWFA forecast products that have a map-based output: above/below median, chance of being in top 2 deciles or bottom 2 deciles and chance of 3-day totals. Apart from the 3-day totals, all of these products can be applied to temperature or rainfall and to different periods (coming weeks, months and 3-month seasons).
Forecast products as location specific graphs	There are three FWFA forecast products that have a location specific graph - time series (weeks or months), decile bars and probability of exceedance. All of these products can be applied to temperature or rainfall and to different periods (coming weeks, months and 3 month seasons).
Hindcast	The process of using weather or climate models to simulate past weather or climate conditions for the purpose of testing the accuracy of the models.
Likelihood	The probability of a certain event occurring, often expressed as a percentage or a fraction.
Median	The middle value in a set of ordered data, separating the lower 50% of the values from the upper 50%.
Model accuracy	How well a weather prediction model is able to make accurate forecasts of future weather conditions based on past and current data.
Model resolution	The level of detail in a weather or climate model, typically expressed as the spatial or temporal scale of the model.
Neutral forecast	A forecast indicating that the likelihood of all potential outcomes is similar.
Operational decision	Short term decisions with a planning horizon of 1-7 days that implement the tactics and strategies, and are influenced by weather forecasts.
Probability	The measure of the likelihood of an event occurring, often expressed as a number between 0 and 1.
Quartile	A statistical term referring to one element of a dataset that is divided into four equal parts.
Quintile	A statistical term referring to one element of a dataset that is divided into five equal parts.
Strategic decision	A long-term decision with a planning horizon of more than a year.
Tactical decision	A seasonal decision that is responsive to the current state of the farm system such as soil moisture, standing feed, commodity price, and can be guided by seasonal climate forecasts.
Weather	The state of the atmosphere at a particular place and time as regards heat, cloudiness, dryness, sunshine, wind, rain, etc. (I.e. the atmospheric conditions being experienced at a moment in time, at a particular place.)

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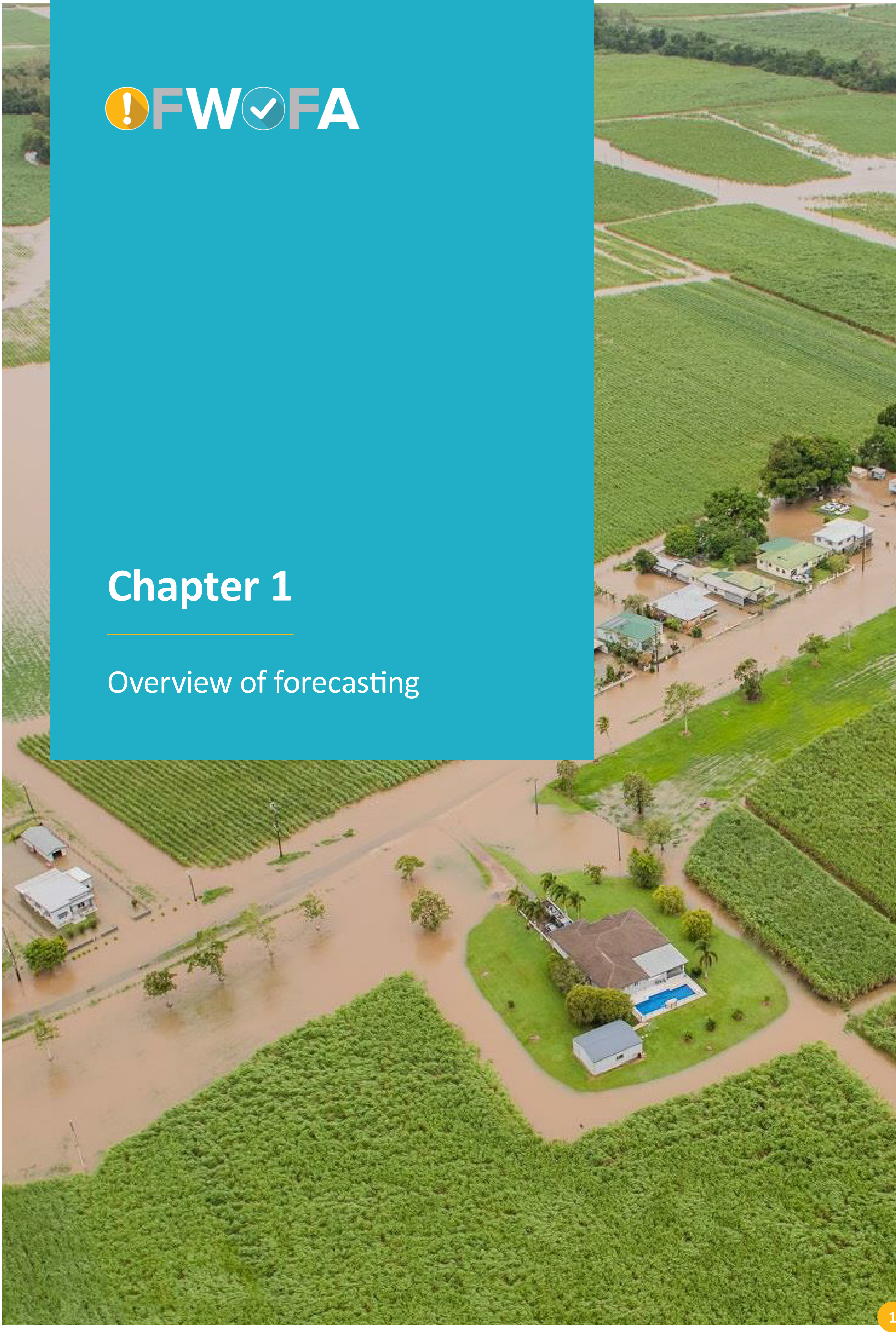

Chapter 1

Overview of forecasting

1 The overview of forecasting

The process of forecasting

The process of forecasting the short-term weather and the longer-term climate is both an art and a science. In this section, we'll introduce you to the concept of forecasting and help you understand some of the factors that affect it, such as climate drivers.

The climate decision gamble – is it like chess, poker, or the pokies?

Australia has a highly variable climate which makes farming decisions difficult. If we knew with certainty that our desired rainfalls and temperatures would occur when we needed them, we could maximise our opportunities and minimise our risks. Often, we think of climate forecasts as having a random chance of happening, like when we play the pokies[1]. We feed our money into the machine and have no idea whether we'll win or lose.

Farming is a risky enterprise, but unlike the pokies the decisions involve degrees of prediction and judgement. So, farming is more like a chess or poker game. In chess the only hidden information is the strategy and supporting tactical moves in the players' heads however, both players see all the chess pieces and their positions on the board. There is no rolling of the dice to make one of the pieces disappear from the board. Losing a chess game is based on poor tactical moves, not bad luck. Poker, on the other hand, is a game of incomplete information—this is decision making under uncertainty. Losing a hand of poker may involve bad luck, but the game involves a high level of skill, as evidenced by the world champion poker players. When we approach our farming decisions, we should be thinking like these poker players.

The first step in making a good farm business decision is to acknowledge that we are dealing with a level of uncertainty. Champion poker players are continually considering probabilities and recognise each decision has a range of possible outcomes; some of which are more likely than others and some carrying more consequence than others. The farming game involves a bit of chess and a bit of poker, but most climate-risk decisions are more like poker. We need to gather the best information available to us at the time and think through the possible outcomes.

Key messages

- Australia has a highly variable climate.
- Making climate-risk decisions in farming is like playing poker—it is decision-making under uncertainty.

Weather versus seasonal climate forecasts

While weather forecasts and climate forecasts are both types of predictions related to atmospheric conditions, they differ in several ways.

Weather forecasts are short-term predictions of atmospheric conditions, usually covering a period of a few hours to several days. The Bureau uses a weather prediction model that runs out to seven days and has a resolution of one to two kilometres. These forecasts provide information about temperature, rainfall, wind, humidity and other weather parameters. Weather forecasts are based on current weather conditions, as well as computer models that simulate how these conditions are likely to change over time. Weather forecasts are constantly updated as new information becomes available, allowing us to make decisions about our daily farming activities.

In contrast, seasonal climate forecasts are longer-term predictions of the average weather conditions for a particular region over a period of weeks to several months. The Bureau uses a physics-based dynamical climate model that runs out to six months and has a 25 km resolution. These forecasts provide information about the likely trends in temperature, rainfall, and other weather parameters, based on historical data and computer models that simulate

[1]Hayman, P., Mudge, B., Stanley, M., Anderson, G., & Grey, D. (2019, August). Agronomic advice in a variable climate; chess, poker or the pokies. In *Proceedings of the 2019 Agronomy Australia Conference* (pp. 25-29).

how the climate system responds to changes in atmospheric conditions. We can use climate forecasts to plan for longer-term activities (such as which crops to plant) and to prepare for potential disasters.

Another key difference between weather and seasonal climate forecasts is their level of uncertainty. Weather forecasts are typically more precise than climate forecasts because they are based on current conditions and predicting the weather in the coming days. By contrast, climate forecasts are based on long-term trends and can be affected by a wide range of factors, such as changes in ocean temperatures, and atmospheric pressure. As a result, climate forecasts are generally less certain than weather forecasts, and are often presented as a range of possible outcomes rather than a single prediction.

The Bureau has recently introduced multi-week forecasts, which are more like short term climate forecasts than long term weather forecasts. They can predict the weather more accurately due to advances in modelling incorporating overarching oceanic climate forces more so than small changes in the weather. The five tools we introduce in the next chapter use this advanced methodology.

In summary, weather forecasts are short-term predictions of atmospheric conditions providing information about daily weather patterns that can be used for planning operational activities. On the other hand, climate forecasts are long-term predictions of average weather patterns over a longer period, used for strategic planning.

Key messages

- Weather forecasts are short-term predictions, usually covering a period of a few hours to several days.
- Seasonal climate forecasts are longer-term predictions, covering a period of weeks to several months.

Forecast versus hindcast

A forecast is a prediction of weather conditions, for a specific time and place, in the near future. It is usually based on current weather observations and the use of computer models to simulate how the atmosphere is expected to evolve over the next few hours to several days. Weather forecasts are important for planning daily farming activities and making operational decisions about what to do. They are updated as new meteorological data becomes available and they become more accurate as the timeframe for the forecast becomes shorter.

Hindcast, on the other hand, considers what the weather was like in the past, usually for a period ranging from a few days to several decades. Hindcasts are used to evaluate the accuracy and reliability of weather and climate models by comparing their simulations to actual weather observations from the past. Hindcasting involves running a computer model backwards in time, using data (such as historical weather observations, atmospheric conditions, and ocean temperatures) to simulate what the weather would have been like for a particular time and place. As a result, hindcasts are useful for improving weather and climate models, verifying past weather events, and understanding how the climate has changed over time.

Key messages

- A forecast is a prediction of weather conditions, for a specific time and place, in the near future.
- Hindcast considers what the weather was like in the past, usually for a period ranging from a few days to several decades.

Climate drivers

Southern Australia's climate is influenced by several climate drivers, which can have a significant impact on farming activities. The Climate Kelpies website depicts these climate drivers as Climatedogs. There are four major Climatedogs (Enso, Indy, Ridgy and Sam), and two minor ones (Eastie and Mojo) which affect weather on a smaller scale. It's important to remember the Climatedogs work together to drive the climate, so we need to look at the combined effect of all the indicators to get a clear idea of what to expect in the future. Watch a short video about the Climatedogs at https://youtu.be/0LWKKtBrQPc.

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ENSO (Enso)

Enso, the El Niño Southern Oscillation (ENSO) is a climate pattern that occurs in the Pacific Ocean, which can significantly impact rainfall patterns in southern Australia. During a period of El Niño, equatorial trade winds weaken and warm surface water shifts to the eastern Pacific Ocean allowing cool water to upwell in the western Pacific Ocean, which can lead to reduced rainfall and drought conditions across southern Australia. In contrast, during a period of La Niña, the trade winds are stronger than average, moving warm surface waters to the western Pacific Ocean while cool water upwell in the eastern Pacific Ocean, which can lead to increased rainfall and flooding across southern Australia. Watch a short video about ENSO at https://youtu.be/Gy37fGiRO5Q.

IOD (Indy)

Indy, the Indian Ocean Dipole (IOD) is a climate pattern that occurs in the tropical Indian Ocean, which can also have a significant impact on rainfall patterns across southern Australia. During a positive IOD phase the tropical west Indian Ocean sea surface temperatures (SSTs) are warmer than usual, which can lead to reduced rainfall and drought conditions across southern Australia. In contrast, during a negative IOD phase, the tropical east Indian Ocean SSTs are warmer than average, which can lead to increased rainfall and flooding across southern Australia. Watch a short video about Indy at https://youtu.be/4E4MOeX9IdQ.

STR (Ridgy)

Ridgy, the Sub-tropical Ridge (STR) is a semi-permanent high-pressure system that influences seasonal weather variability across Australia. During summer it is positioned to the south of the continent and brings stable dry conditions, reducing rainfall and increasing temperatures. This can have a significant impact on farming across southern Australia, as it can lead to drought conditions, water shortages and reduced crop yields. We may need to adopt strategies such as irrigation, crop rotation and soil conservation to cope with these conditions. Watch a short video about Ridgy at https://youtu.be/mqHbpgzBQLA.

SAM (Sam)

The Southern Annular Mode (SAM) is a climate driver that occurs in the southern hemisphere affecting the strength and position of westerly winds which influence southern Australia's weather patterns. During a positive SAM event, the westerly winds are stronger and positioned further south, which can lead to reduced rainfall and drought conditions across southern Australia. In contrast, during a negative SAM event, the westerly winds are weaker and positioned further north, which can lead to increased rainfall and flooding across southern Australia. Watch a short video about Sam at https://youtu.be/ZQwgosJ_RL0.

ECLs (Eastie)

Eastie, the East Coast Low-Pressure systems (ECLs) are intense low-pressure systems that occur off the east coast of Australia, particularly during the autumn and winter months. They bring moisture-laden winds and heavy rainfall to the region, which can cause flooding and waterlogging. While ECLs can benefit agriculture, providing much-needed moisture for crops and pasture, they can also be destructive, causing damage to infrastructure, property and crops. Watch a short video about Eastie at https://youtu.be/m4wKGdZjBBU.

MJO (Mojo)

The Madden-Julian Oscillation (MJO) is a tropical weather pattern that can influence rainfall patterns across southern Australia. It is characterised by a band of clouds, rainfall and winds moving eastward across the tropical Indian Ocean into the western Pacific Ocean. When the MJO is in its enhanced phase it can increase the rainfall across southern Australia. However, when the MJO is in its suppressed phase it can reduce rainfall and bring drought conditions across southern Australia. Watch a short video about Mojo at https://youtu.be/AU8-I-IqJZU.

In summary, these six climate drivers significantly impact the rainfall patterns across southern Australia. Awareness of these drivers and their potential impact on crops, livestock and land will support our management decisions.

Key messages

- There are six climate drivers that work together to affect the climate.
- We need to look at the combined effect of all the drivers to get a clear idea of what to expect in the future.

Model accuracy

As well as understanding these drivers, we need to consider the model accuracy (also known as model confidence or model skill) of the computer models that are used by the Bureau to predict the weather and climate. These models use hindcasts to understand the spread of historical events with 99 forecast model iterations run over a three-day period to determine the chance of a modelled forecast occurring. The time of year and location for which these forecasts are made can make a big difference.

Key messages

- Model accuracy refers to how well a weather prediction model is able to make accurate forecasts of future weather conditions based on past and current data.

Correctly understanding a daily weather forecast

To understand a daily weather forecast from the Bureau, you need to pay attention to three main aspects: the *forecast icon*, the *chance of any rain*, and the *possible rainfall*.

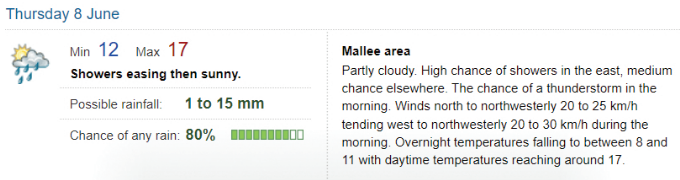

Figure 1. An example daily weather forecast.
Source: www.bom.gov.au

The *forecast icon* is a symbol that represents the general weather condition for the day or the hour. For example, a sun icon means sunny weather, a cloud icon means cloudy weather, and a raindrop icon means rainy weather.

The next item to look at is the *chance of any rain*. This is represented as a percentage that tells you how likely it is that *at least 0.2 mm of rain* will fall in your area. For example, if the forecast says there is a 80% chance of rain, that means there is a 80% chance of getting some rain, and a 20% chance of getting no rain at all.

Finally, the *possible rainfall* provides a range between two numbers. However, it's important to note that there is more behind these numbers than meets the eye. The first number is the least amount of rain that is *75% likely*, while the second number is the least amount of rain that is *25% likely*. So, in this example, there is a 75% chance of receiving at least 1 mm, while there's a 25% chance of receiving at least 15 mm.

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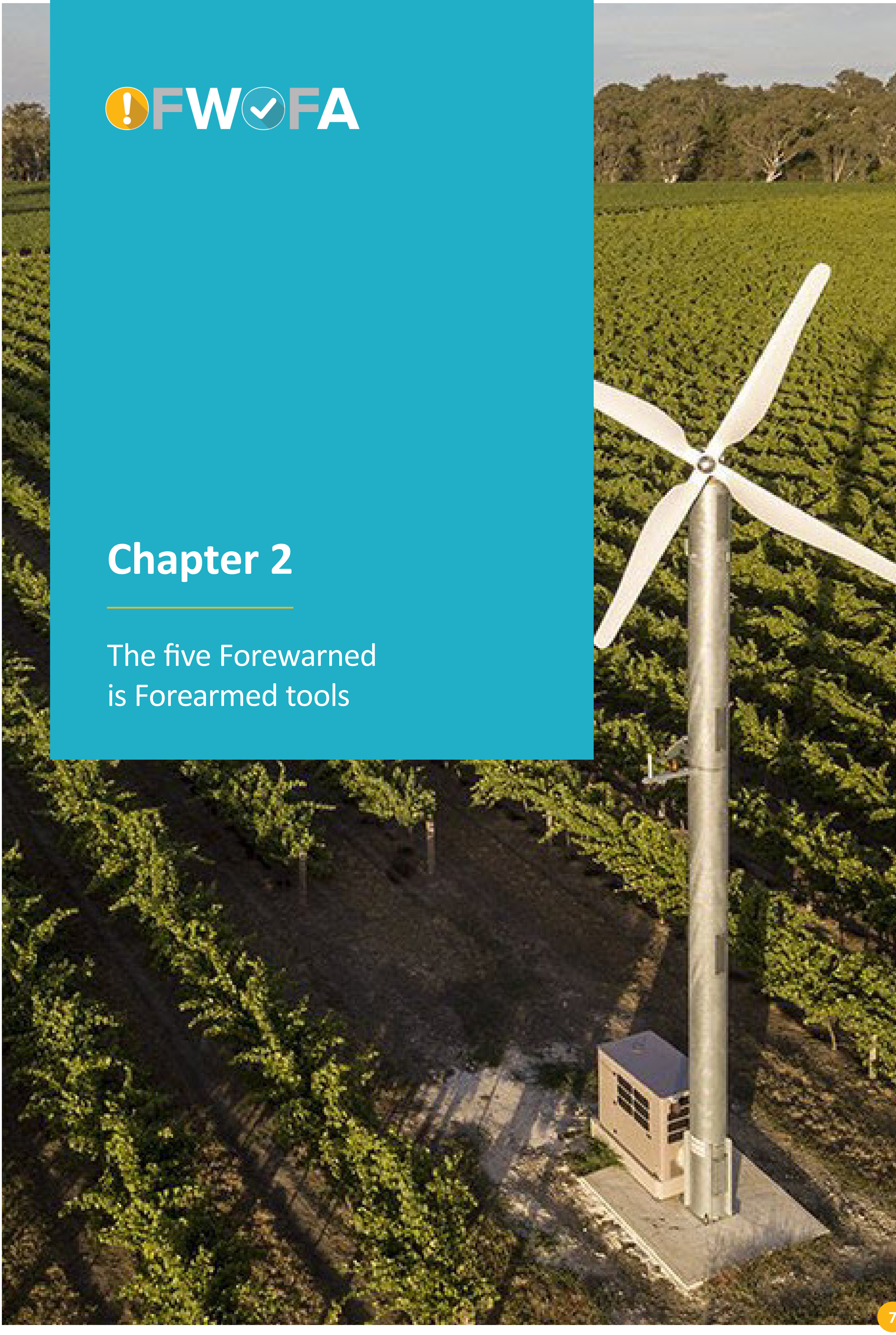
Read more about this on the Bureau's website: https:\media.bom.gov.au\social\blog\209\right-as-rain-how-to-interpret-the-daily-rainfall-forecast\

Notes



Chapter 2

The five Forewarned is Forearmed tools

2 The five Forewarned is Forearmed tools

As part of the FWFA project, the Bureau of Meteorology launched five seasonal climate forecasting tools. These tools provide more insight in predictions, especially when considering the possibility of extreme weather events.

The tools are:

1. The **chance of extremes maps** for rainfall and temperature.
2. The **chance of 3-day totals maps**.
3. The **decile bar charts** for rainfall and temperature.
4. The **timeline graphs** for rainfall and temperature.
5. The **probability of exceedance graphs** for rainfall.

Before diving further into the tools, let's establish some definitions to guide correct interpretation.

The four key risks

The four weather extremes of most interest to farmers are heat, cold, wet and dry. Extreme heat refers to defined periods of high temperature and can be accompanied by high humidity. It can affect livestock production, joining, crop growth stage, on farm operations along with increased risk of bushfires in the landscape. Prolonged periods of low temperatures, on the other hand, can affect vulnerable livestock or crop yield and quality. Extended or intense periods of extreme rainfall and wet conditions can disrupt infrastructure at farm-level or supply chain-level. In the case of flooding, livestock and crops can be lost. Finally, prolonged absences of rainfall can lead to periods of drought, often accompanied by scarcity of vital resources, such as feed and water.

Extreme weather events can occur in combination or in isolation. Devastation involved with the effects of extreme weather events often outweigh potential benefits, such as enrichment of soil and regeneration of vegetation after fire or flood. Depending on the level of impact, recovery can have significant temporal, economic and social costs. So understanding the likelihood of an extreme weather event can support our preparation, planning and on-farm responses through better decision making.

Forecasting terminology

Interpretation of forecasting information can become confused if the terminology is not well understood. Meaningful interpretation of the information presented enables better decision making.

Medians

The median of a dataset represents the middle value when the data is arranged from lowest to highest value. It is often used as a measure to capture the more central values, especially when a dataset contains outliers (unusual or extreme values). As such, it can provide an understanding of the typical or more representative value of a dataset.

The median is different from the average, or mean, because it is less affected by outlier data. An average considers all values, including outliers, by summing all values and dividing that by the number of data points. The average is a mathematically calculated value and may not actually appear in the dataset. The average is a useful value for summarising data into a single, central value, though the value can be skewed by outliers and misrepresent the central value or 'typical' value of a dataset.

After the median of a dataset is determined, other values can be compared to it, and either be *higher* or *lower* than the central value: this is referred to as the dataset being *binomial*. **In the FWFA's tools, the median is used to describe the typical or more representative value of historical weather events at a certain time of year.** An example is shown in Figure 1. The forecasts use the median to explain if we can expect a typical weather event more like the average historical value for that time of year, or if we can expect an unusual weather event, which is much lower or higher than the median historical value for that time of year.

Deciles and quartiles

While comparing values to the median, we deal with a binomial distribution of the dataset where the values can either be higher or lower than the median. Further detail from a dataset can elaborate on where the 'value of interest' is positioned on the data scale from high to low. For example, if it's not equal to the median, is it much higher, lower, or not that much different?

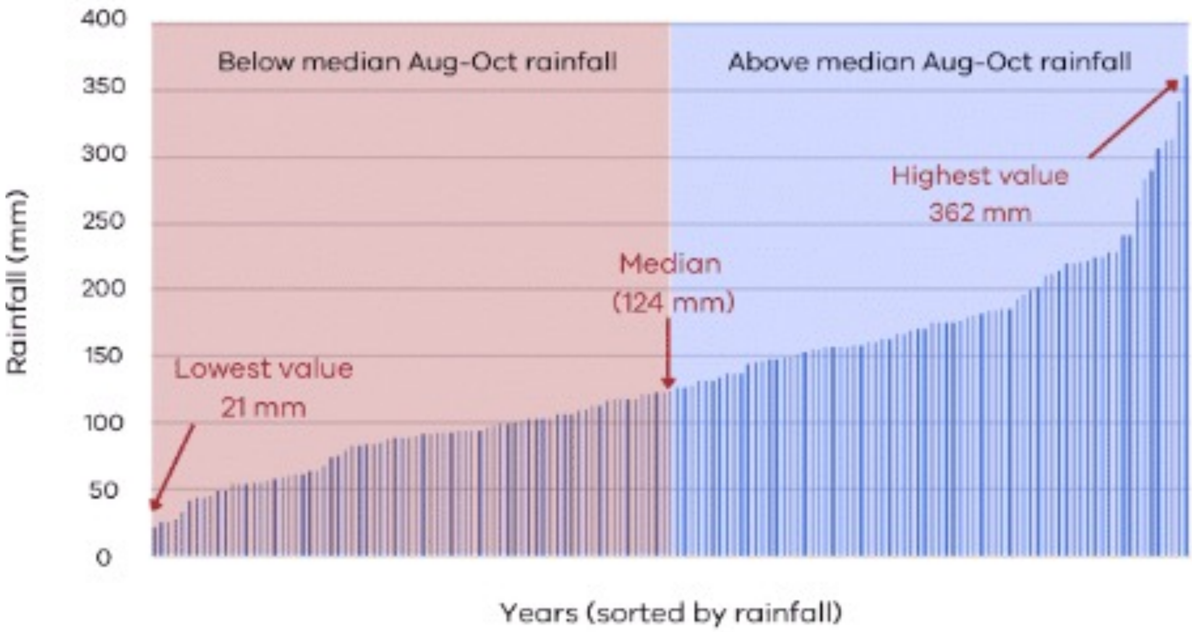


Figure 1. The binomial distribution of August – October rainfall for 146 years (1875 – 2021) in Dubbo, NSW. Rainfall is either above or below the median rainfall (124 mm). Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

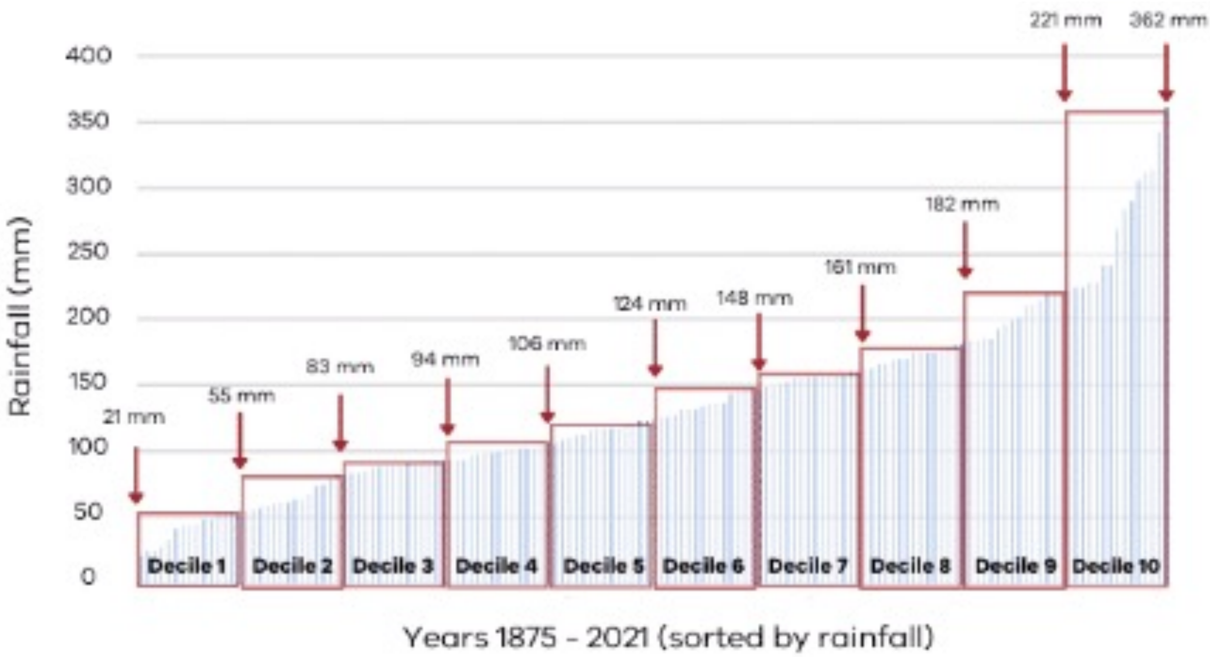
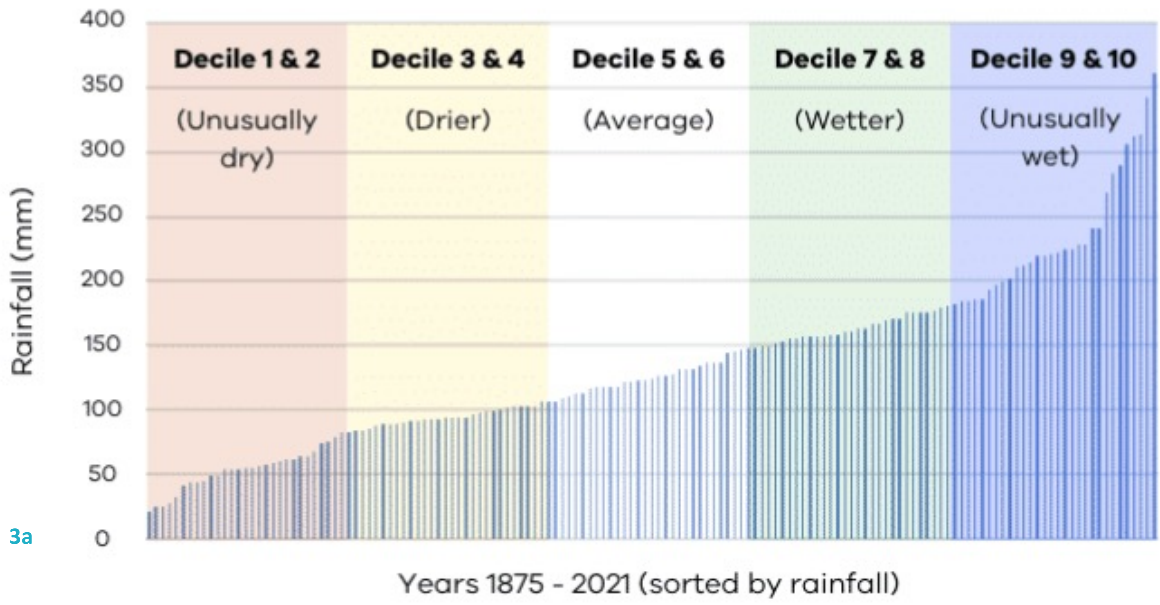
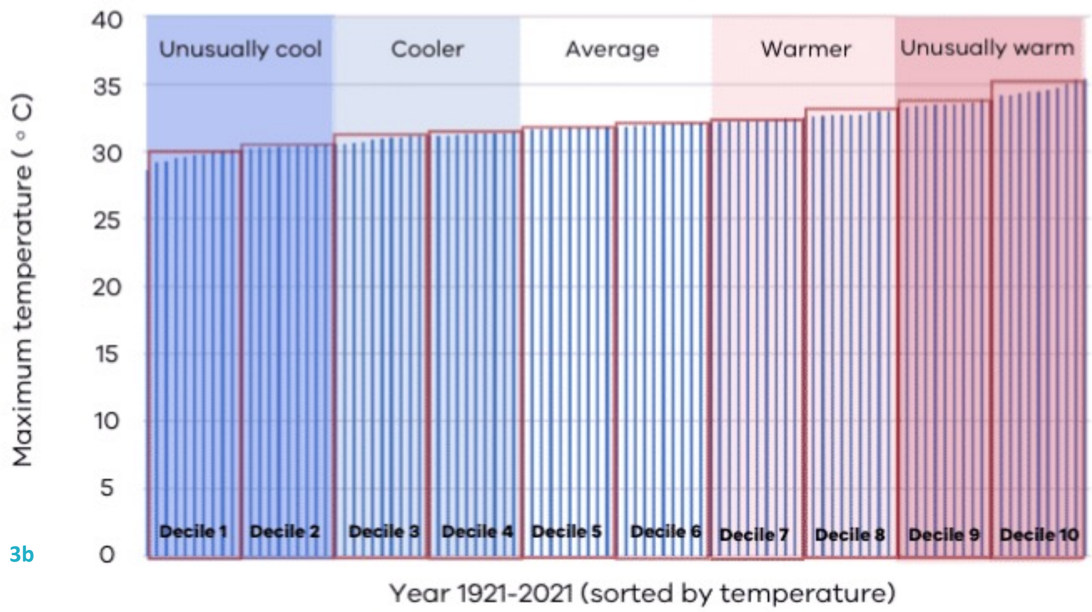


Figure 2. Decile bar graph showing August – October rainfall for 146 years (1875 – 2021) in Dubbo, NSW. Rainfall is divided in 10 equal groups of data (deciles) each with a lower and upper value defining the decile. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

Instead of dividing the dataset into two groups and creating a binomial distribution (higher and lower), the dataset can be divided into 10 equal groups, referred to as ***deciles***. Each decile contains a group of data that explains 10% of the dataset, with a lower and an upper value defining the decile, as shown in Figure 2.

As such, we can understand the context of and refer to the value as being (for example) in decile 9 (significantly higher than the median but not quite the most extreme value measured) or in decile 5 (not that far off the median, but a little lower).





Figures 3a and 3b. Decile bar graphs showing August – October rainfall for 146 years (3a at top) and December – February maximum temperatures for 101 years (3b) in Dubbo, NSW. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

In the FWFA tools, this concept is used to describe rainfall (Figure 3a) or temperature (Figure 3b) as summarised in Table 1. These tools visually combine two deciles (referred to as a ***quintile***) which describes 20% of a dataset, or one of five equal groups of data. Another common term used to group data is quartile, where a dataset is divided into four equal groups and each ***quartile*** explains 25% of the dataset.

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A short video about understanding percentiles in climate data can be viewed at https://youtu.be/e3ak-ognuTU.

Table 1. Decile descriptors for rainfall and temperature used in the Bureau of Meteorology climate outlook and forecasting tools.

	Rainfall	Temperature
Decile 1 & 2	Unusually dry	Unusually cool
Decile 3 & 4	Drier	Cooler
Decile 5 & 6	Average	Average
Decile 7 & 8	Wetter	Warmer
Decile 9 & 10	Unusually wet	Unusually warm

Probabilities

A probability is a measure of the likelihood (or chance) of an event occurring. It is calculated by determining the number of times an event has happened, divided by the total number of events and expressing the outcome as a value between 0 and 1, or 0% and 100%. Probability is often used to explain the likelihood of future events based on historic information.

When referring to deciles, there is a 20% chance of a historic rainfall or temperature value falling in any of the decile groupings. For the purpose of climate forecasts, we are focused on the chance of a decile 1 & 2, or a decile 9 & 10 event. The FWFA tools present this chance for us.

Box and whisker plots

A box and whisker plot graphically summarises the distribution of a dataset, as shown in Figure 4. It displays the data distribution including the median, quartiles and outliers. It consists of a box and two 'whiskers' extending from above and below the box. The box represents the middle 50% of the data, with the bottom of the box delineating the first quartile (Q1) and the top of the box delineating the third quartile (Q3). The median, or second quartile (Q2), is typically represented by a line within the box.

The whiskers represent the minimum and maximum values of the data which are not considered outliers (outliers are sometimes represented as individual points or circles beyond the whiskers). The length of the box and whiskers are dependent on the distribution of the dataset. If the data is evenly distributed, the box will be longer and the whiskers shorter. If the data is skewed, the box and whiskers will be shorter on one side and longer on the other.

The neutral forecast

As previously explained, a forecast places probabilities of certain forecast model runs occurring in the deciles that describe the hindcast weather data for a particular point in time. If a particular extreme weather event occurs, then the data input from climate drivers and weather patterns might influence the forecast model outcomes, implying a high chance of an extreme event. If the majority of forecast model runs suggest a high chance of a particular extreme event occurring, the chance of the event not occurring remains, because not all model runs would have generated the same outcome.

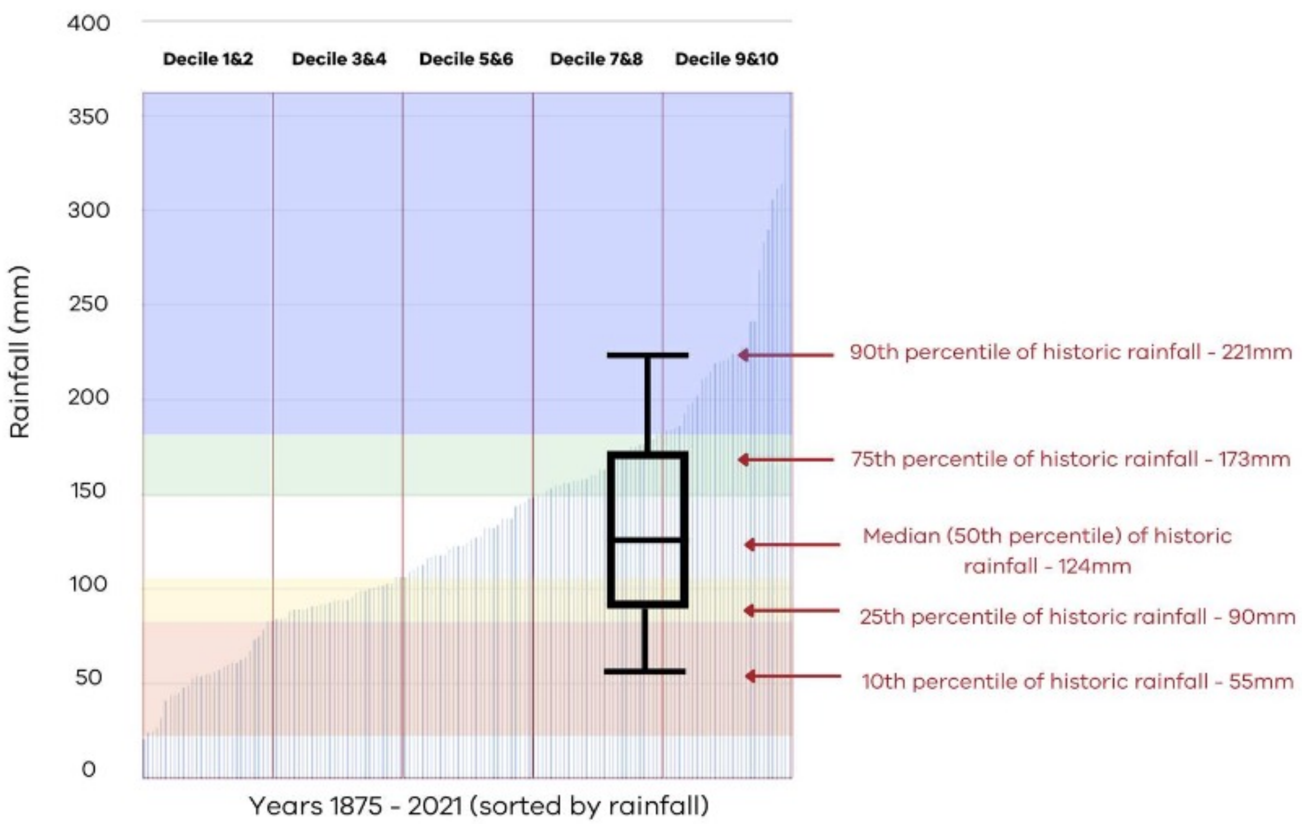


Figure 4. A box and whisker plot explained. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

Table 2. Summary of FWFA tools.

FWFA tool	Format	Parameters	Time frame/s	Limitations	Best use
Chance of extremes	Australia-wide map	Rainfall and temperature	1 week, 2 week, 1 month, 3 months	• Not location specific, so need to zoom in on the map. • No information about heatwave or extended cold period.	• Simple, quick overview, for all timeframes, to highlight if can expect something unusual or average. May provide a prompt to dig deeper with the other tools.
Chance of 3-day totals	Australia-wide map	Rainfall only	1-2 weeks	• Not location specific (which might be expected), so need to zoom in on the map. • Most useful for northern Australia.	• Northern Australia - monsoon and heavy rain forecast. Start of wet season prediction. • Southern Australia – autumn break indication.
Decile bar chart	Australia-wide map	Rainfall and temperature	1 week, 2 week, 1 month, 3 months		• Next level up from chance of above median map – provides some more detailed information. Often helps with understanding of *above median* maps and *chance of extremes* map. • Easier to understand.
Timeline graph	Australia-wide map	Rainfall and temperature	4-weeks, 5-months	• Categorised rating for accuracy.	• Box and whisker plots shape and size is visual and provides information about the confidence in the model runs. • Provides recent history as well.
Probability of exceedance	Australia-wide map	Rainfall only	1 week, 2 week, 1 month, 3 months	• More complex to understand.	• In-depth understanding (essentially all of the information in other tools in one); most suitable for deliverers.

So, in essence, the more forecast model runs that align, the higher the chance of the forecasted outcome. In some instances, the distribution of forecast model outcomes can be so spread there is no skew to the outcomes and any outcome is just as likely to occur as another. This is referred to as a ***neutral forecast***. Examples are a 20% chance of all quintiles occurring, or a 50% chance of exceeding the median. In such situations, any outcome can be expected because all outcomes are equally possible.

The tools

Most of us might already be familiar with the *Chance of above median* tool from the Bureau, or at least have seen it featured in farm journals, webinars or Landline (Figure 5). This tool tells us if we can expect above or below median rainfall, for a selected period of time.

However, the Bureau's five FWFA tools provide us with an opportunity for more context than simply 'above' or 'below' the median, which we now understand to be a simple binomial result. The Bureau's climate outlook and forecasting tools provide additional context to forecasts by including the decile distribution of forecast model runs and the likelihood of them occurring, based on 99 model runs over weeks, fortnights and months. So essentially the FWFA tools can be described as short-term climate forecasts. They are not as accurate as a seven-day weather forecast, but they give us a better understanding of the climate outlook over a shorter time frame (one week to three months). The tools provide insight by presenting the range of forecasted outcomes in multiple ways and can help you plan operations past the seven-day weather forecast. Using the FWFA tools in combination with seven-day weather forecasts provides more confidence in interpreting and using the information to make decisions.

There are two types of tools: maps and location-specific graphs. Clicking on a location on a map or entering the location in the search function will bring up the location-specific graphs.

In this chapter, we present the five tools and show how you can use them to gain insight into the chance of an extreme weather event occurring.

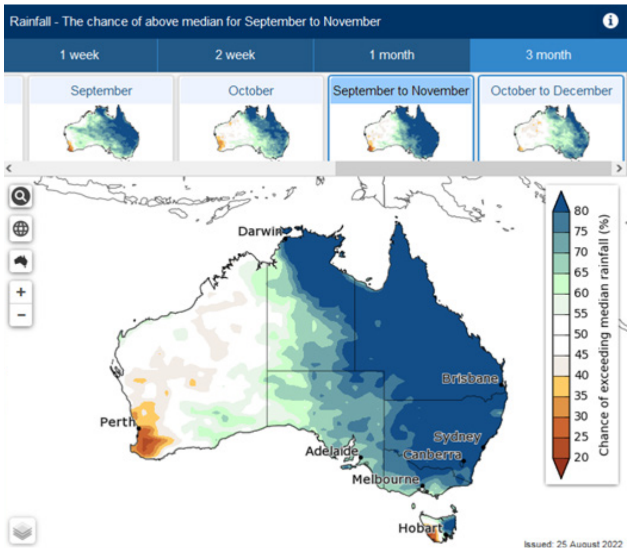


Figure 5. An example of the *Chance of above median* tool from the Bureau for a three-month outlook (September - November), issued at 25 August 2022. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

Chance of extremes

The *chance of extremes* maps show the predictions for unusually high and low rainfall or temperatures over one week, two weeks, one month or three months. These maps are an extension of the *chance of above median* maps.

The colouring in the maps indicates the chance or likelihood of experiencing extremes in rainfall or temperature as shown in Figure 6. The increasing intensity of colours used in the maps correlates to increasing chance of rainfall or temperature in extreme deciles. In a neutral forecast, the likelihood of any outcome is 20%. As such, the likelihood of an extreme dry or cold (decile 1 & 2) or extreme wet or hot (decile 9 & 10) is also 20%, and no distinct indication can be drawn from the forecast model results. Areas without data are represented in grey.

In the example in Figure 6, the map shows an above 80% chance of rainfall being in decile 9 & 10 of historical data for central Queensland. This means the likelihood of extremely wet conditions is four times higher than the chance of median rainfall typical for that time of year.

The *chance of extremes* map can show the likelihood of extreme cold events, however, it can't indicate a frost. Minimum temperatures may give an indication of frost potential at certain times of the year, and this can be explored further using other Bureau tools and seven-day forecasts.

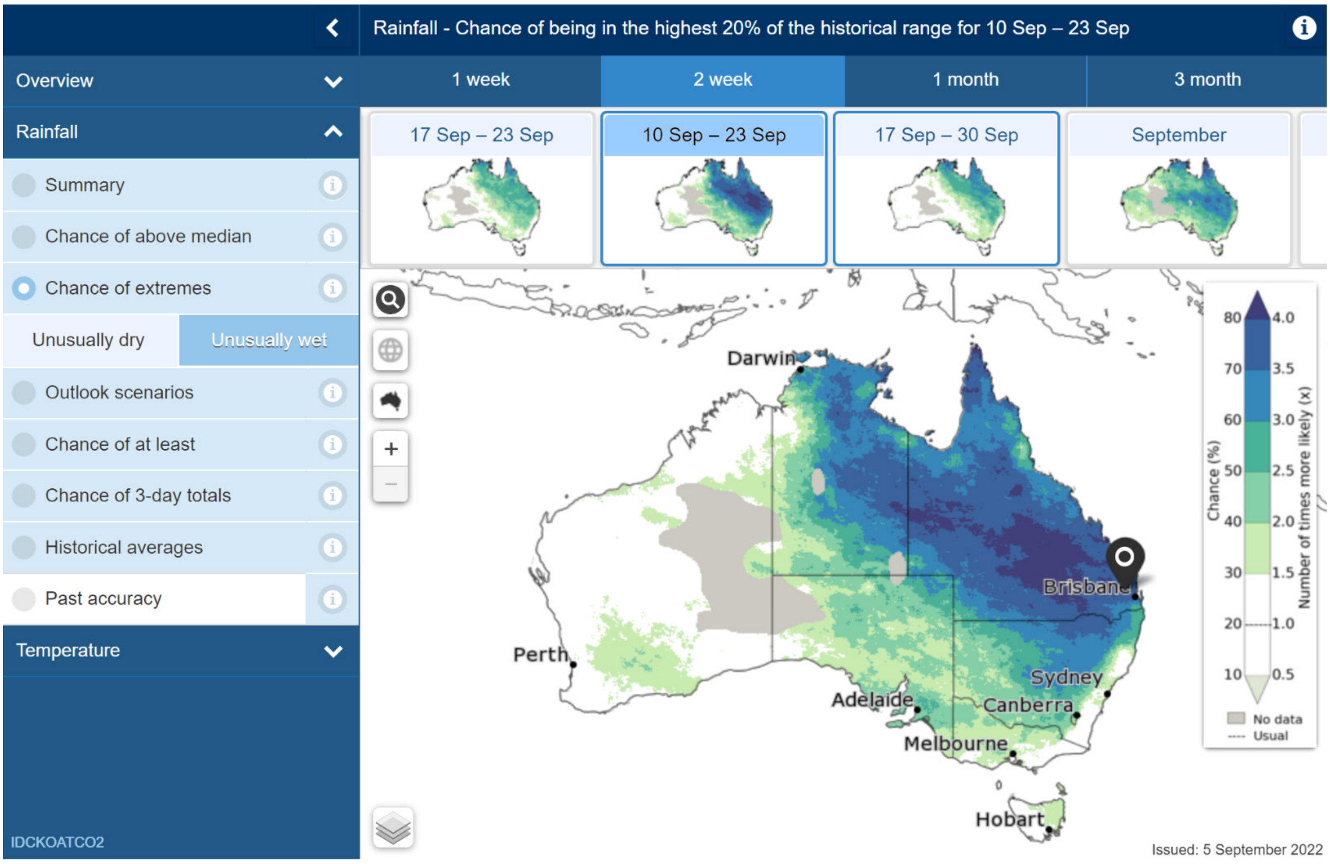


Figure 6. An example of the Climate Outlook Map forecasting unusually wet conditions issues during September 2022 for the two weeks between 10 – 23 September across eastern Australia. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

Notes

Chance of 3-day totals

The *chance of 3-day totals* forecast maps show the chance of receiving 'at least' a given amount of rainfall total over three consecutive days. Forecasts are available for 15 mm, 25 mm, 50 mm and 75 mm of rain during a one-week or two-week period. Historic data (1960 – 2019) for *chance of 3-day totals* is available and accessible. Figure 7 shows a *chance of 3-day totals* map for the period 21 March to 3 April 2023.

SCAN ME

Dr Tim Cowan, USQ, demonstrates using the rainfall burst forecast map in a short video (2min 11sec) at https://youtu.be/I5iqDl3qlr8.

SCAN ME

Dr Chelsea Jarvis, USQ, discusses the application of the rainfall burst forecast tool in the cotton, livestock and sugar industries in a short video (2min 32sec) at https://youtu.be/u8_je1NC3r4.

Note that the location-specific graphs in the *chance of 3-day totals* map do not present probabilities or deciles on a three-day timeframe. Instead, the location-specific graphs present data on the outlook for either one week or two weeks when selected in the *chance of 3-day totals* map, as with the *chance of extremes map.*

Decile bar charts

The location-specific decile bars for rainfall and maximum and minimum temperature show the forecasted probability of a given range of rainfall or temperature outcomes. The chart can be accessed by selecting a location on the map or entering a location in the search function.

The forecasted probability of a given range of rainfall or temperature outcomes is compared with the typical probability of 20%, indicated as the dotted grey line in Figure 8. In this example, the forecast shows that 38 from 99 forecast model runs fell into deciles 1 & 2 (unusually dry weather) which is nearly twice more likely than the likelihood of median rainfall for that time of year. However, note that the likelihood of the other ranges remains. For instance, there are still 11 out of 99 model runs that fell into deciles 9 & 10 (unusually wet weather) which means other outcomes (besides deciles 1 & 2) are still possible.

The tool's infographic includes the historical median rainfall, which in this example is a historic median rainfall of 61 mm for Clear Lake (VIC) during the

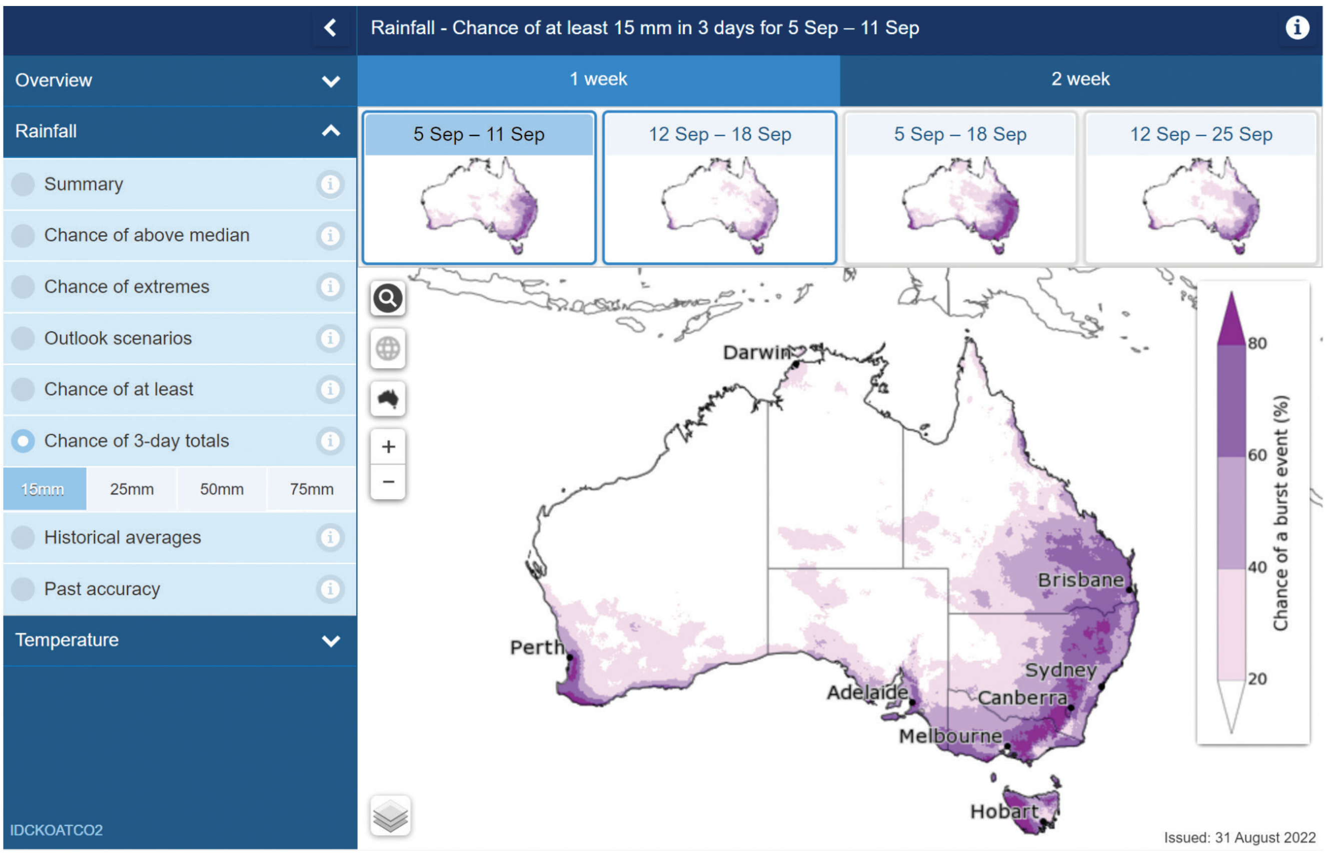


Figure 7. *Chance of 3-day totals* map for Australia for the period of 21 March – 3 April 2023. Source: www.bom.gov.au 16/3/23.

2

period February – April. In some locations the median rainfall can be 0 mm at certain times of the year. In those instances, the range of likelihood of rainfall falling in a certain historic range for the given period is not that meaningful.

The star ratings beside the likelihoods indicate the past accuracy of the outlook. If the model has been reasonably successful at forecasting for this location and time during the past, it receives three out of three stars — a highly accurate result. Two out of three stars indicates medium past accuracy, and one out of three stars indicates low past accuracy.

Outlook for February to April at Clear Lake

Rainfall		
Historical median	61 mm	
Chance of unusually dry (< 41 mm)	38 %	★★☆
Chance of above median (> 61 mm)	33 %	★★☆
Chance of unusually wet (> 97 mm)	11 %	★☆☆

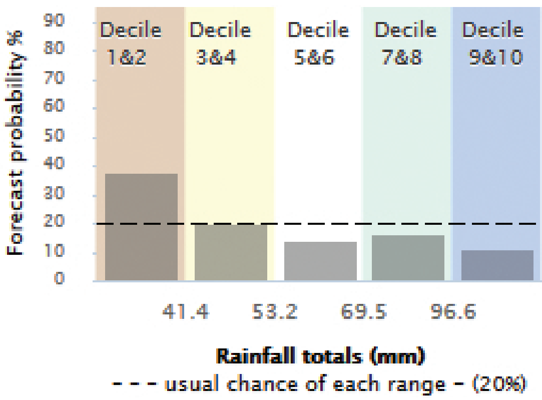


Figure 8. Decile bars for the rainfall outlook at Clear Lake, Victoria, for February – April 2022. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

Timeline graphs

Timeline graphs display a timeline of recent climatic observations from the previous weeks and months, against historic averages, to illustrate what might happen in the future. The box and whisker plots show the variability of the 99 model runs for the four weeks or five months ahead. To make it easier, the shading of the graph aligns with the markers of the box and whisker plot to show the recent rainfall deciles (recent average rainfall indicated by the solid black line) and the predicted deciles (predicted medians indicated by the dotted black line) as illustrated in Figure 9. The timeline graph can be accessed by selecting a location on the map or entering a location in the search function.

As with the decile bar charts, the timeline graph includes star ratings to indicate past accuracy for the outlook. The length of the whiskers and size of the box indicate the range of predictions. So, if most of the 99 model runs are within a tight range (compact box and shorter whiskers, e.g. July in Figure 9), it provides greater confidence in the prediction. However, as we've seen with the decile bar charts, any outcome is still possible.

Probability of exceedance

The *probability of exceedance* is a graph with lines representing the forecasted and historical data of a certain location for a particular rainfall total as shown in Figure 10. The graph can be accessed by selecting a location on the map or entering a location in the search function.

The red line in Figure 10 shows the likelihood of the chosen location receiving the median rainfall over the specified timeframe. In the example, Murray Bridge typically has a 60% chance of receiving 18.6 mm rainfall, 40% chance of receiving 27.6 mm and 20% chance of receiving 40.8 mm during October. A drier time of year would typically show a steeper red line, whereas a wetter time of year would decrease the slope of the red line.

The blue line in Figure 10 represents the forecast. It shows how often the 99 model runs exceed a range of rainfall values. A blue line below the red line would indicate a drier outlook. A blue line above the red line, as shown in Figure 10, indicates a wetter outlook.

Note the shading of the graph aligns with the defined deciles for rainfall summarised in Table 1 and Figure 3a. Hovering over the graph brings up the percentage chance for the corresponding rainfall.

Key messages

- The four weather extremes of most interest to farmers are heat, cold, wet and dry.
- Meaningful interpretation of forecasting information enables better decision making, which is why it is important to understand the involved terminology.
- The Bureau's five climate outlook and forecasting tools provide additional context to forecast results by including the decile distribution of forecast model runs and the likelihood of them occurring, which helps you plan operations past the seven-day weather forecast.
- There are two types of tools: maps (the *chance of extremes* and the *chance of 3-day totals*) and location-specific graphs *(decile bar charts, timeline graph* and *probability of exceedance).*

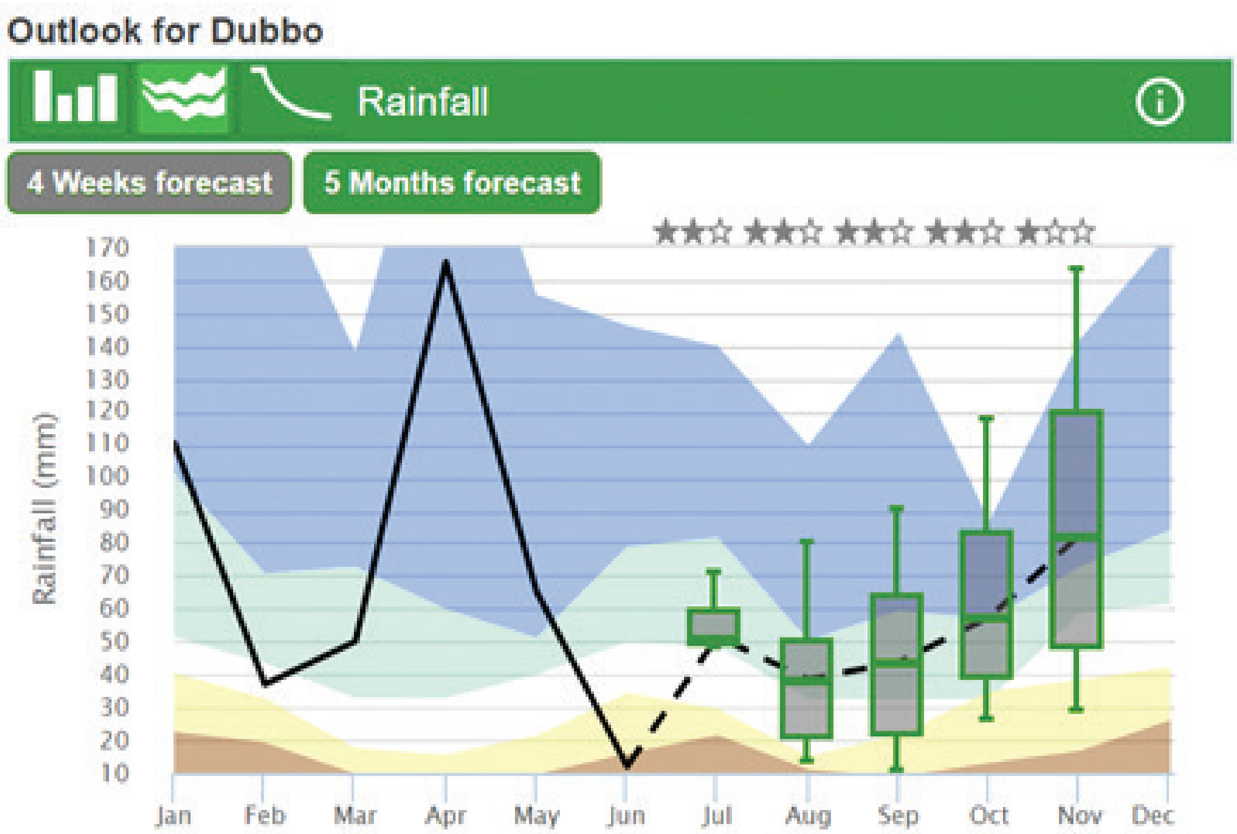


Figure 9. Five-month timeline graph for predicted rainfall in Dubbo, NSW. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

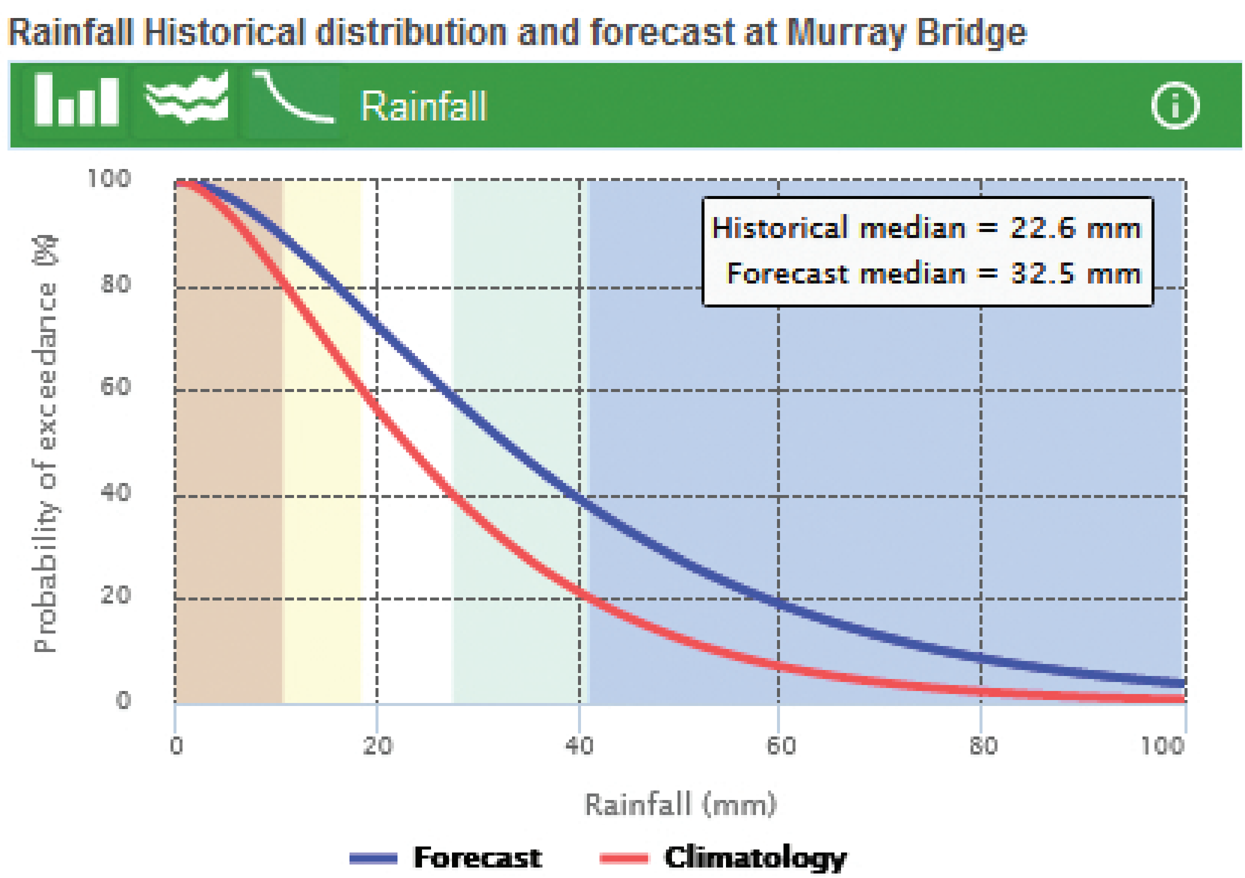
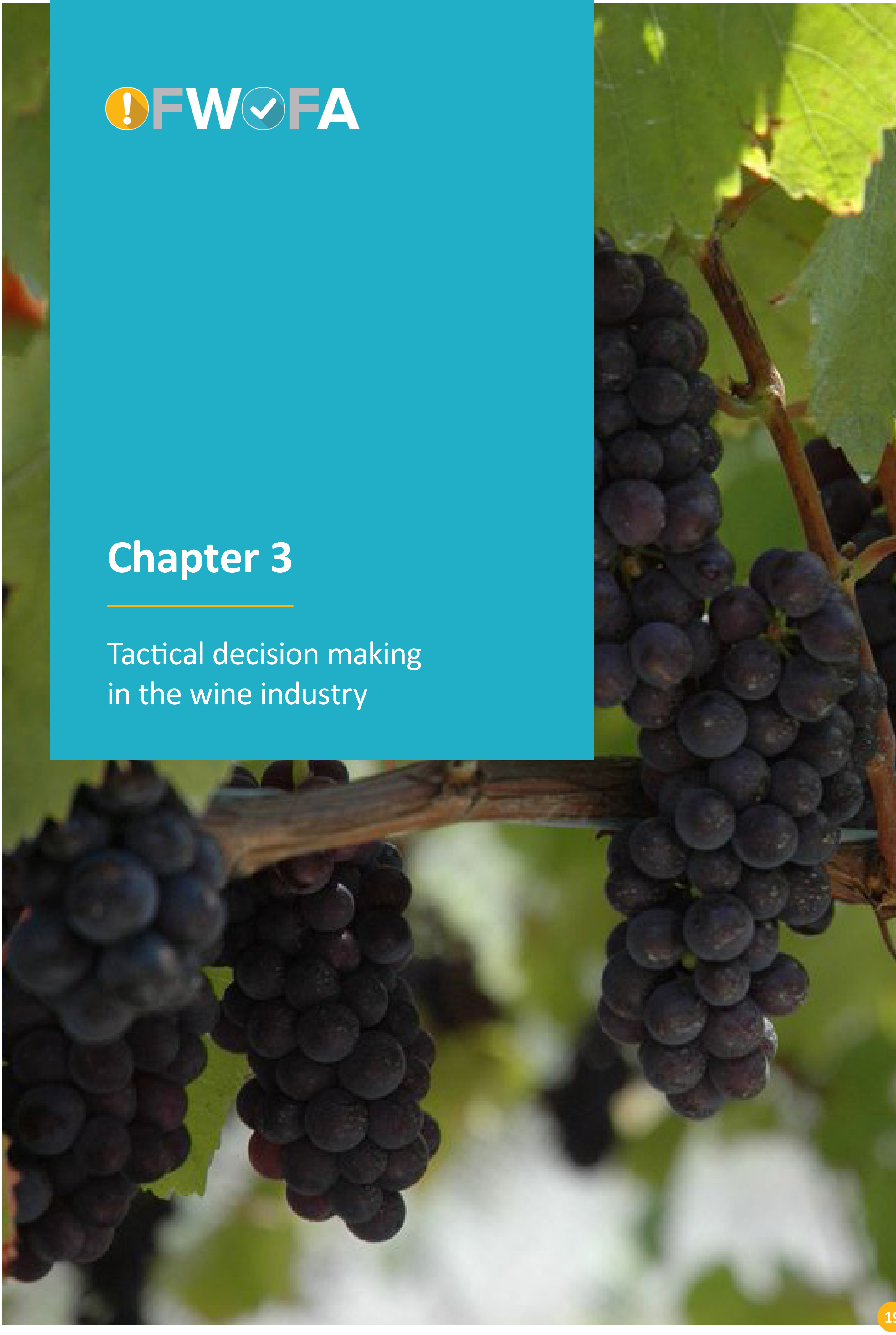


Figure 10. Rainfall outlook for the month of October 2022 at Murray Bridge, SA. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

Notes



Chapter 3

Tactical decision making in the wine industry

3 Tactical decision making in the wine industry

Decision making

Decisions are made daily in a farming business. Some decisions relate to the day-to-day operation of the wine business, such as prioritising spraying jobs, or when to apply fertiliser. This is operational decision making. Decisions made for the longer term of the business are strategic decisions and examples include deciding whether to invest in capital items, setting targets (such as return on investment and gross margin targets), and optimising labour use efficiency. Tactical decisions and plans are designed to achieve the longer term strategy, usually with a medium-term view (1 – 12 months). Examples of tactical decisions for a wine business might include planning crop protection for the weeks ahead, whether to crop thin, minimising frost risk through vineyard practices or scheduling of harvest around grape maturity.

A tactical climate sensitive decision is one where the time frame is within the season and the ideal decision depends on the weather. Examples include timing a disease protection spray during flowering, irrigation and the timing of harvest to avoid a rain event.

Information from FWFA is most relevant to tactical or operational decisions, however, long-term or strategic decision making can be the most cost-effective way to manage extreme events. Examples include planting wind breaks, installing overhead irrigation for frost protection, changing interrow species for improving water infiltration and retention, switching to more heat tolerant wine grape varieties and/or changing row orientation. Determining the costs and benefits of these decisions requires historical climate data and climate change projections on the frequency and severity of rare events. Historical climate data can be accessed via the Bureau's website: http://www.bom.gov.au/. Under *Our services, Climate and past weather*, the rainfall and temperature records are available under *Rainfall history* and *Temperature history*.

Farmers deal with weather variability daily, influencing their operational decision making. This type of decision making is something we are more familiar (and comfortable) with, than those decisions around less frequent, but more impactful, extreme events. As a part of the FWFA project, the Bureau developed five tools to support short-term and medium-term decision making regarding extreme climate risks. As these tools focus on a seasonal timeframe, they are most suited to supporting on-farm operational and tactical decision making.

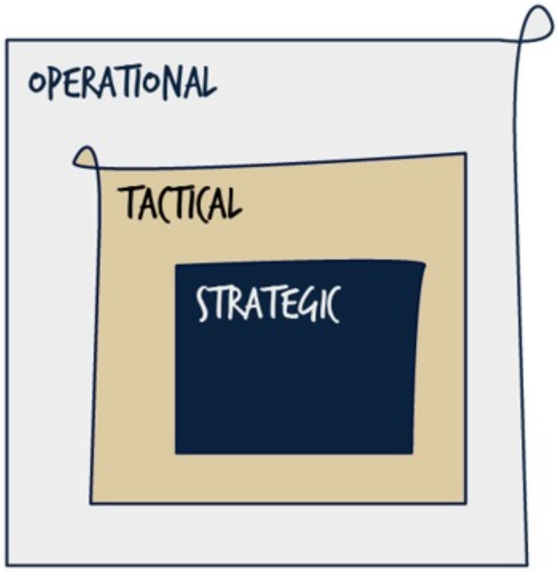


Figure 1. The three types of decisions (from Dairy Australia – Our Farm Our Plan)

Before you can use these tools effectively in your wine business you need to fully understand the operations and assets of your business that can be affected by an extreme event. While we often focus on the risks of these events, it's important to realise they may also create opportunities. Following are some examples of tactical decisions that can potentially mitigate these risks or capitalise on the opportunities. These are not designed to operate in isolation from a whole enterprise risk assessment and management plan, but rather to complement them.

Key messages

- A tactical climate-sensitive decision is one where the time frame is within the season *and* the ideal decision depends on the climate.
- FWFA tools are best used to support tactical and operational decision-making for managing extreme weather events.

Key risks

A wine business' calendar of operations usually considers the seasonality of activities relevant to the location of the farm. Extreme weather events are highly likely to disrupt these operations.

The four extreme events of most concern to wine producers are extended wet periods, extended dry periods (drought), extreme high temperatures (heatwaves) and extreme low temperatures (frost). These can affect grape yield and quality, soil condition, infrastructure and operations, cashflow and social wellbeing. Each of these impact areas can be impacted differently by extreme events (e.g. extreme wet events are of particular concern during flowering or harvest), and may require different tactical responses. Some tactical responses are more relevant in cases when the duration of the extreme event is prolonged.

Extreme events can disrupt business cashflow, irrespective of the industry in which the business operates. Additionally, extreme weather events can have a flow-on effect on commodity prices, with a range of possibilities that may create risks for some businesses and opportunities for other businesses (e.g. if production in one region is impacted by drought, this may drive up prices, meaning regions unaffected by the drought will benefit).

Tools such as farm management deposits or budget contingencies for unforeseen costs can aid a business' financial security. Planning for these allowances can be part of a business' strategic and tactical decision making. Ensuring ways of staying up to date with the availability of industry and government funding for extreme events is another way to manage some of the financial risks. These opportunities may involve funding for improving infrastructure, mitigating impacts of future extreme weather events, or recovery after an extreme event. These funding sources often lag an event or are not immediately accessible and can take time to move through regulatory processes. Such funding should not be relied on, and sound financial management with contingencies should be built into management of the business.

Social wellbeing is another area that can be impacted by extreme events. Mental fatigue from dealing with challenging circumstances, particularly when these events are extended, is not uncommon. Enduring losses or traumatic experiences related to an extreme event can impact mental health and affect relationships. Seeking support early, by being aware of your emotional wellbeing and the wellbeing of people around you, is invaluable.

Extreme events can also cause workplace health and safety issues by affecting conditions in the workplace, including new hazards following extreme conditions. For example, an extreme heat event can impact the people who work in such conditions. Tactical responses such as early starts or finishes to the workday can circumvent the need to work during the hottest time of day, reducing the risk of heat stress. On a vineyard, extreme weather relating to bushfire risk can also influence work practices with some tasks, such as the slashing of midrow grass in the summer, not able to safely continue under extremely hot conditions. Other safety issues can involve the accessibility of sheds, equipment and vineyards in case of floods following an extreme wet event. Having emergency policies and procedures in place, communicated, and understood by all staff can help mitigate risks and keep people safe from adverse impacts during extreme event.

Understanding the extreme weather events your location and industry are susceptible to, is critical in planning and preparing responses for those extreme events. Establishing thresholds or triggers for your business can provide early warning to implement an extreme weather response ahead of its occurrence, and can potentially mitigate or reduce the impact.

Key messages

- The extreme events of most concern to the wine industry are extended wet periods, extended dry periods (drought), extreme high temperatures (heatwaves), extreme cold temperatures (frost).
- Sound financial management with contingencies should be built into the business.
- Be aware of impacts on mental well-being - seeking support early for yourself or encourage those around you to do likewise.
- Use emergency procedures, communicated to, and understood by, staff, to help keep people safe during an extreme event.
- Be aware of the extreme weather events your location and industry are vulnerable to, and establish triggers or thresholds for response.

Extended wet

Periods of extended wet weather can derail intake scheduling between the vineyard and the winery and affect grape yield and quality. A common extreme event resulting from an extended wet period is a disease outbreak.

Multi-week rainfall forecasts will influence decision making including planning crop protection for the weeks ahead. Extended wet weather, when combined with warm weather, presents very challenging conditions for managing diseases in the vineyard as grape yield, berry and wine quality can all be severely affected.

Botrytis rot is a weather-driven disease that can cause significant loss of grape yield and quality, even after application of a full program of fungicides. Botrytis spores are almost always present in vineyards. Infection can be initiated from spores carried over from the previous season, in sources such as cane debris, bunch remnants, tendrils, leaf petioles and leaf blades. These spores spread in air currents, by rain splash and by insect carriers. Rain that causes berries to split often leads to direct infection of ripening berries. The key weather variables are temperature and the duration of surface wetness, provided by rain, fog, dew or mist. Free water is needed for the spore to germinate and high relative humidity may be sufficient to cause condensation of water inside tissues such as flowers. Temperature determines how fast infection occurs, with the optimum temperature in the range 18–21°C. Longer wetness periods are needed to achieve the same level of infection at sub-optimum temperatures.

Downy mildew is also driven by the weather. The disease can devastate individual vineyards and, in some seasons, affect production from entire regions. Downy mildew needs the combination of warmth and rainfall. Periods of high risk from downy can be determined by monitoring the vineyard microclimate for factors such as temperature, rainfall, relative humidity (RH) and leaf wetness.

Flooding can occur at the vineyard-level with multiple blocks getting waterlogged for an extended period. This is a different scale from when flooding occurs in the wider region with major roads being affected and major infrastructure disrupted. As such, the range of issues associated with extended wet periods can vary based on scale and impact. Subsequently, the variety of responses to these issues can vary by scale and impact, too.

At the vineyard-level, one of the primary issues of waterlogged blocks is the effect on vines. Flow-on effects from the affected vines is reduced yield and quality. Flooding may be caused by heavy localised rains, flood waters slowly flowing across the landscape or a combination of both. Whatever the cause, the duration and timing of flooding are important to consider. Flooding of well-drained soil types, where water disappears in one or two days, usually has little impact on vine growth. Where flood water is slow to recede, either due to soil type or the volume of water, some issues may arise. When soil becomes waterlogged, it becomes anaerobic as air is forced out from pores in the soil. Roots need air to function, and waterlogged roots will die over a period of time. Often there is a need to continue with crop protection sprays, and each tractor pass over the waterlogged area will compact the soil adjacent to the vines. Previous short-term flood events have shown that vines are resilient, and can return to production in the following season without significant side-effects. However prolonged flooding can result in vine decline and death.

The Bureau's timeline graph in combination with the *chance of 3-day totals* can be used to indicate the probability of exceeding median rainfall and highlight the chance of three-day total rainfall exceeding, for example, a 50 mm rainfall. Being a step ahead of a potential extreme weather event provides the opportunity to apply sprays to protect against disease, modify grape turgor through spray applications or irrigation, or to harvest early to avoid the rain. Figure 2 and Figure 3 provide an example of what an extreme wet event looks like using the *probability of exceedance* tool (Figure 2) and the *chance of 3-day totals* tool (Figure 3).

Wine producers have identified a range of challenges posed by extended wet weather, which are summarised in Table 1. Tactical responses are listed as suggestions and an overview of the range of impact of these responses is identified. Some responses might be targeted at a specific issue, but in turn provide a solution for multiple impact areas.

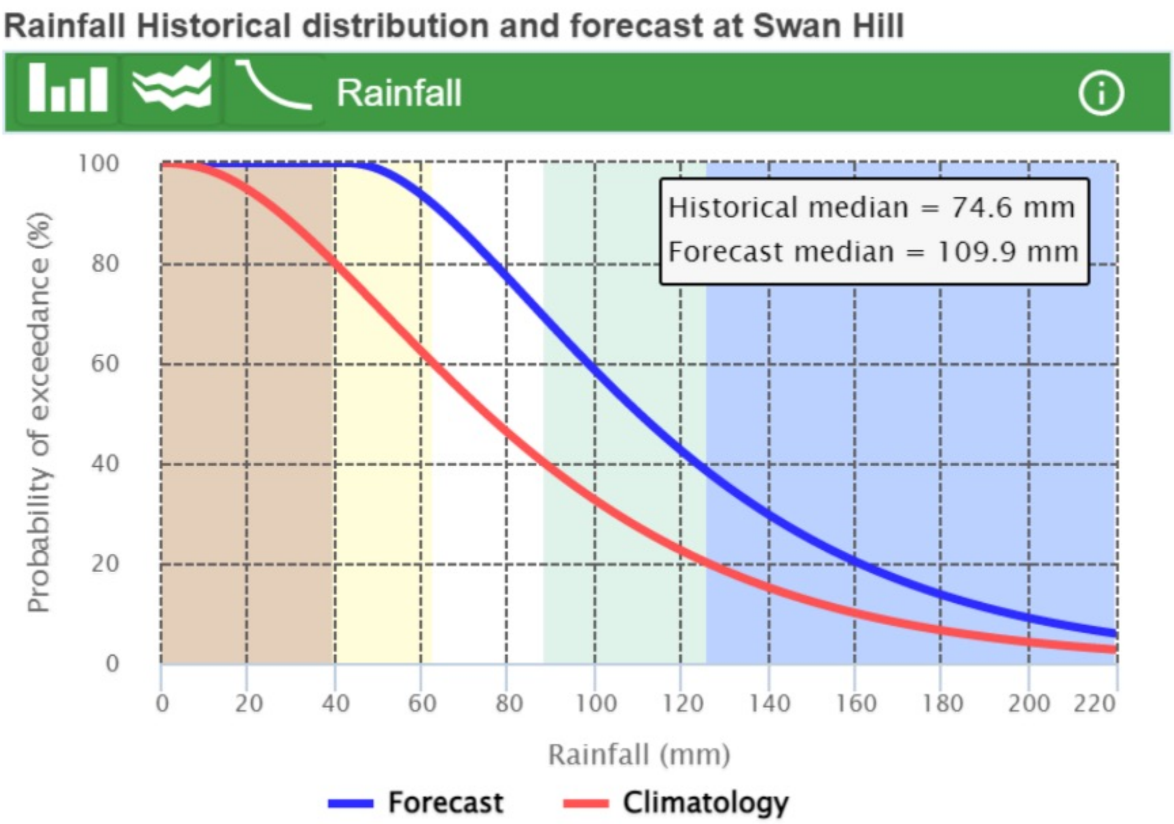


Figure 2. Example of the *probability of exceedance* tool, showing an extreme wet outlook. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

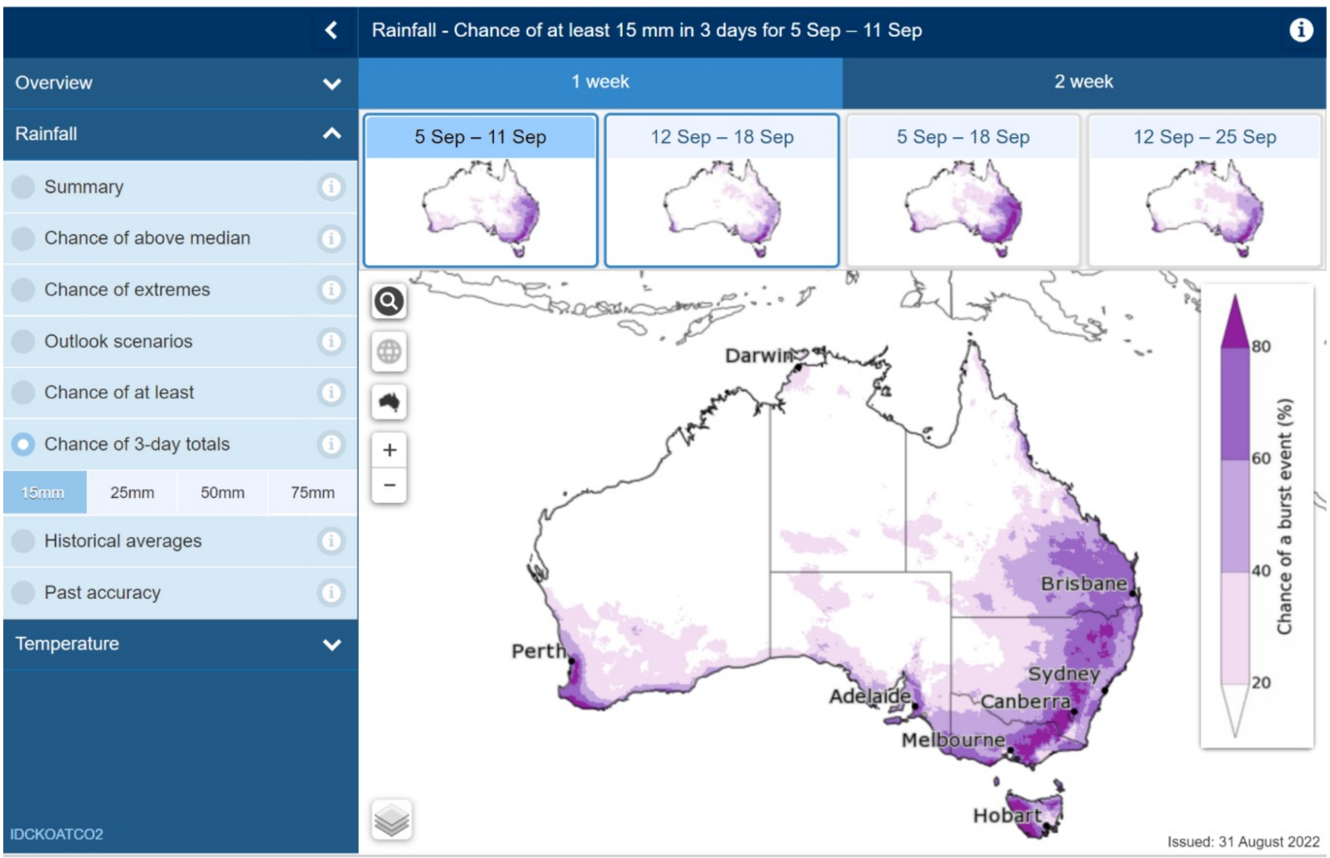


Figure 3. Example of the *chance of 3-day totals* tool, showing the chance of a burst event of at least 15mm in three days between 5 Sep and 11 Sep 2022 for Australia. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

Table 1. Summary of challenges and responses associated with the impact of periods of extended wet weather relevant to Australia's wine industry.

Potential challenges	Tactical response
Increased disease pressure	Apply fungicide sprays
	Canopy management to improve airflow
Split berries	Apply preventative sprays and irrigate, harvest early
Wheel ruts from vehicles	Reduce vehicle access
Increased logistical pressure	Planning intake scheduling
Bogged machinery	Consider aerial spraying for crop protection

Key messages

- Extended wet weather can present issues for vineyards through operational challenges as well as vine responses such as increased disease.
- Different tactical responses can be implemented at different times of the season if the soil profile is close to full and the likelihood of extreme wet weather is high.
- When wet weather coincides with harvest, it might be possible to harvest early to prevent berry splitting.

Extended dry weather

Periods of extended dry weather, more commonly referred to as droughts, often involves the limited availability of water resources. Generally, water availability is reduced, the cost of water increases and the vine growing season can be shortened due to drought.

The Bureau's decile bar chart tool can be used to indicate the probability of an unusual dry event and presents an opportunity for wine producers to create a water management plan and associated water budget to set them up for the season ahead. A successful water management plan provides information about current and projected water use and water security (availability, quality and costs). It also provides information about where water use efficiency improvements can be made to help growers prioritise and allocate funding to the activities. Being a step ahead of a potential event gives the opportunity to be prepared and make the most of a challenging situation. An example of what an unusually dry event can look like using the Bureau's decile bar chart tool is shown in Figure 4.

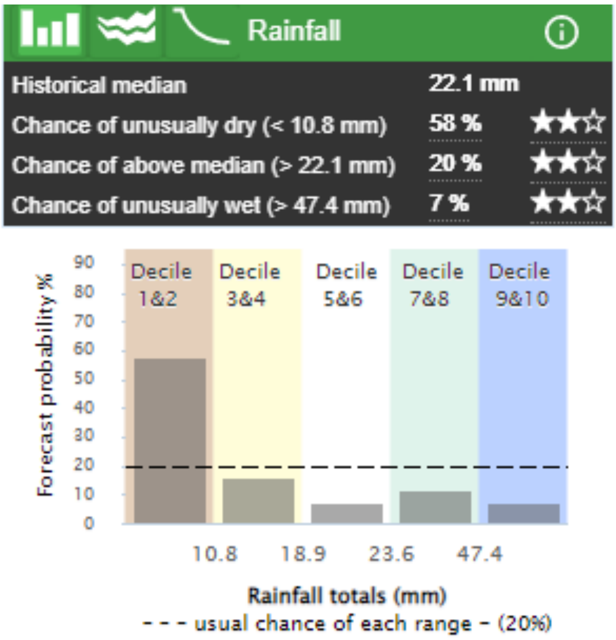


Figure 4. Example of the decile bar chart tool, showing the probability of an extreme dry (decile 1&2) event. Reproduced from www.bom.gov.au.

The severity of impacts that drought conditions have on grapevines depends on a number of factors that are specific to individual vineyards. Some of the factors that influence a grower's ability to manage severe water stress include:

- timing of water delivery
- amount of water available
- duration, intensity, and timing of hot spells
- soil texture
- soil depth
- method of irrigation

In newly planted vineyards, water management is critical for successful vine establishment.

For established vines, extreme water stress is most damaging when it occurs between flowering to pea-sized berries (late spring to early summer), when there is rapid shoot growth, ovule fertilisation, and rapid cell division in young berries. Water stress during this time will result in low yield due to poor berry set and small berries.

Properties that are reliant on localised catchment areas to supply on-farm dams are highly susceptible to dry conditions, where lack of rainfall not only requires more supplementary irrigation, it also impacts the replenishment of water storage (dam or aquifer), limiting the amount of water available to irrigate with. Larger irrigation schemes are typically impacted by broad-scale drought, impacting irrigation availability "down-stream".

Effective storage dam design, installation, monitoring and maintenance has a significant influence on water availability. Monitoring for leaks and seepage should be conducted regularly to identify and manage problems early. Regular maintenance should be conducted to prevent problems and improve the operation and longevity of the storage.

Wine producers have identified a range of challenges posed by drought, which are summarised in Table 2. Tactical responses are listed as suggestions and an overview of the range of impact of these responses is identified. Some responses might be targeted at a specific issue, but in turn provide a solution for multiple impact areas.

Key messages

- Drought can be an issue for wine producers whether it's for an extended period, or for shorter periods at important times of the year, such as the spring growth period.
- Tactical responses to managing crop failure can include changing crop load and target wine style.
- Managing a drought and its impacts can occur over multiple seasons as challenges such as weak canes and poor bunch numbers can persist after the drought has broken.

Table 2. Summary of challenges and responses associated with the impact of extended dry periods relevant to Australia's wine industry.

Potential challenges	Tactical response
Water supply	Alternate water source
	Monitor and manage water provision proactively
Restricted vegetative growth	Lightly fertilise, prune heavily and shoot thin to optimise shoot growth
	Irrigation scheduling
Restricted fruit development	As above plus shoot thinning and bunch thinning to optimise fruit growth

Heatwaves

Periods of extreme high temperatures, otherwise known as heatwaves, can cause shock to the farm management system and the underpinning biological systems. A combination of a prolonged dry event and a heat wave can lead to bush fires.

The effects of a heatwave on winegrapes will vary depending on the location of the vines. This is partly because vines acclimatise to certain conditions but also because viticulturists design irrigation systems and manage vineyards with a sense of what is normal or expected in their region.

The FWFA tools cannot indicate the occurrence of a heatwave as well as a weather forecast. However, the *chance of extremes* map for unusually warm temperatures for both maximum and minimum temperatures can provide an insight into periods when unusually warm conditions may be expected. An example of an unusually warm outlook is shown in Figure 2.

An insight into when unusually high temperatures could be expected over the warmer months presents an opportunity for wine producers to plan ahead for best practice water management to assist with managing the heat using water. Producers can also prepare to mitigate against fire and smoke damage. Being a step ahead of a potential event gives the opportunity to be prepared for a potentially challenging situation.

The effects of extreme heat on grapevines vary depending on the timing of the heat event relative to the developmental stage of the grapevine. Flowers are highly susceptible to heat stress. Exposure to extreme weather events may result in poor fruitset and in turn yield loss. Later in the season, grapes become more susceptible to heat damage as they soften, and stressed leaves reduce in photosynthetic activity, slowing the ripening period. Dark coloured grapes may get much hotter than the surrounding air temperature. Berries may shrivel or be sunburnt, leading to loss of yield and quality. Losses may also occur at the winery due to the increased requirement for cooling.

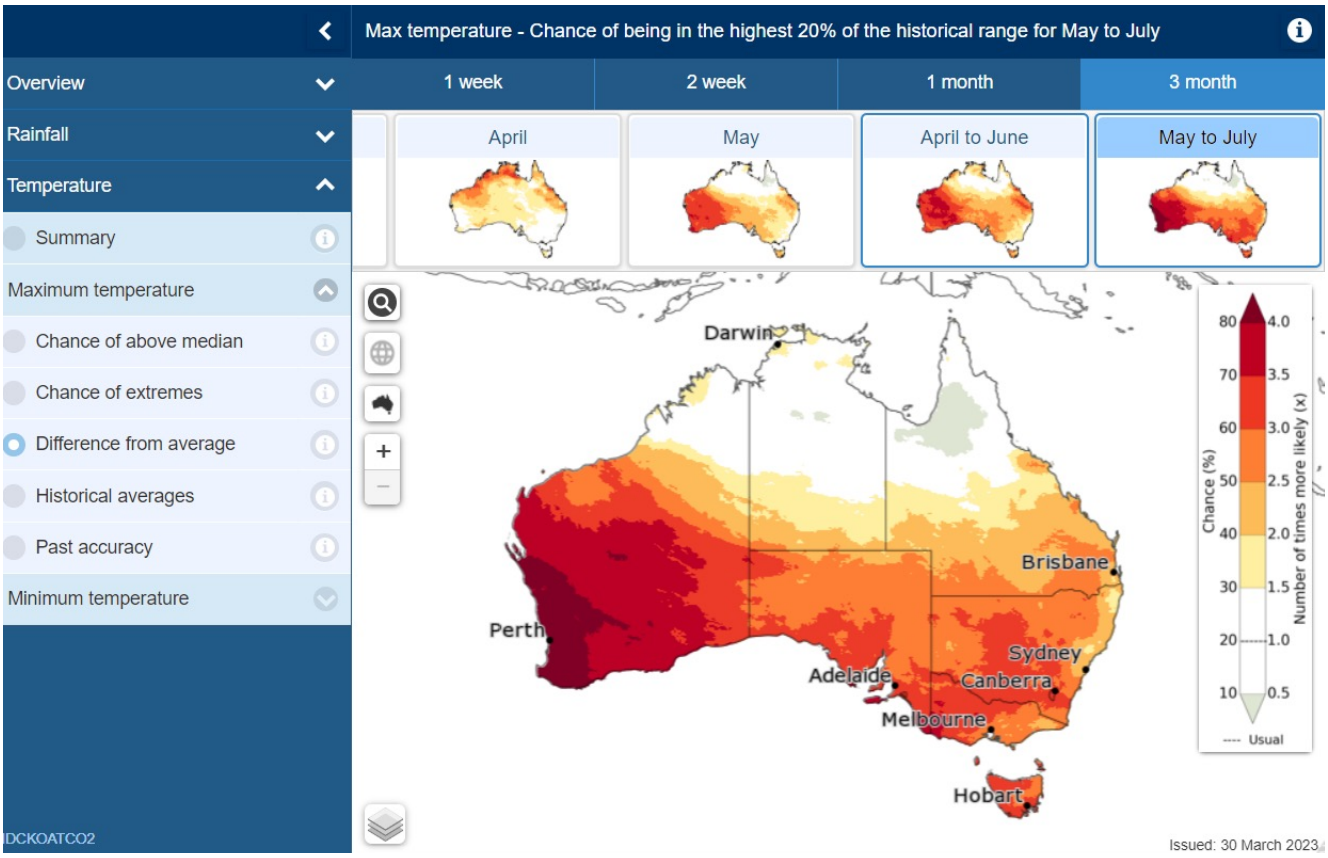


Figure 5. Example of the *chance of extremes* map for maximum temperatures in the period between May and July 2023 for Australia. Source: www.bom.gov.au 4/4/2023.

Bushfires are a possibility in any wine region around Australia. Fires present danger to vineyards, wineries, plant and equipment. Smoke from fires also brings with it a risk that fruit may be affected by the free volatile phenols that are produced when wood and vegetation is burnt.

Following a fire event, the impact within the vineyard can present itself in different ways. Some damage is obvious, such as dehydrated leaves and burnt bark, while some are more difficult to identify, such as that from radiant heat. Grapevines are capable of growing new shoots if trunk damage is not too severe. Depending on the extent of the fire damage, vines may be able to be rejuvenated or they may need to be replaced.

Smoke exposure can affect grapes any time during their development. Smoke taint risk depends on factors such as intensity and duration of the fire, proximity of the vineyard to the fire, prevailing weather conditions and grape variety.

Wine producers have identified a range of challenges posed by heatwaves, which are summarised in Table 3. Tactical responses are listed as suggestions and an overview of the range of impact of these responses is identified.

Key messages

- Heatwaves can impact both grape yield and quality, as well as winery operations.
- Fire danger from paddock operations is a key concern during heatwaves, which can affect operations.
- Smoke exposure can impact grape quality.

Extreme cold events, including frost

Technically a frost occurs when the temperature at ground level falls below 0°C. Most temperate plant species, including vines, tolerate this temperature, even though surface ice may have formed. At about –2°C, water from within the cells in leaves, buds or flowers begins to move out into the ice layer that has been forming on the surface, resulting in desiccation and death of all or part of the exposed tissue. The lower the temperature and longer the duration, the more severe this desiccation and consequent damage becomes. To plant cells, frost damage is much like a sudden and severe drought.

Frosts damage buds, shoots and inflorescences, which are often actively growing when spring frosts occur. Damage to these parts of the grapevine result in loss of yield. In the case of a very severe late spring frost, there might even be carryover effects into the subsequent season if vine shoots are severely damaged.

Extreme cold conditions, including frosts, can also have operational impacts. For example, some herbicides will have reduced efficacy on weeds that have experienced stress from frost prior to spraying. Knowing when a period of extreme cold is likely can help you prioritise jobs in the spray program.

Although the FWFA tools do not predict frost events, the *chance of extremes* maps for unusually cool temperatures can provide insight as to whether there is an increased risk of frost events occurring, with a longer outlook than a 7-day weather forecast. An example of the *chance of extremes* map for unusually cool temperatures is shown in Figure 4.

Table 3. Summary of challenges and responses associated with the impact of heatwaves relevant to Australia's wine industry.

Potential challenges	Tactical response
Heat stress	Maximise transpirational cooling with sprinklers
	Reduce bunch exposure using canopy shading or artificial shading
	Apply irrigation and refill root zone prior to heat wave
	Consider applying a sunscreen spray
	Reconsider any planned leaf removal or canopy manipulation (e.g. foliage wires) strategy that may lead to increased bunch/berry exposure
Water supply	Alternate water source
	Monitor and manage water provision proactively
Fire damage	Bushfire prevention and action plan

A range of issues identified with frost are summarised in Table 4. Tactical responses are listed as suggestions.

Key messages

- Frosts can have severe impacts on grape yield and quality, and profitability, for a wine business.
- Being prepared to protect vines during frost events and maintain best practice vineyard floor management is important.

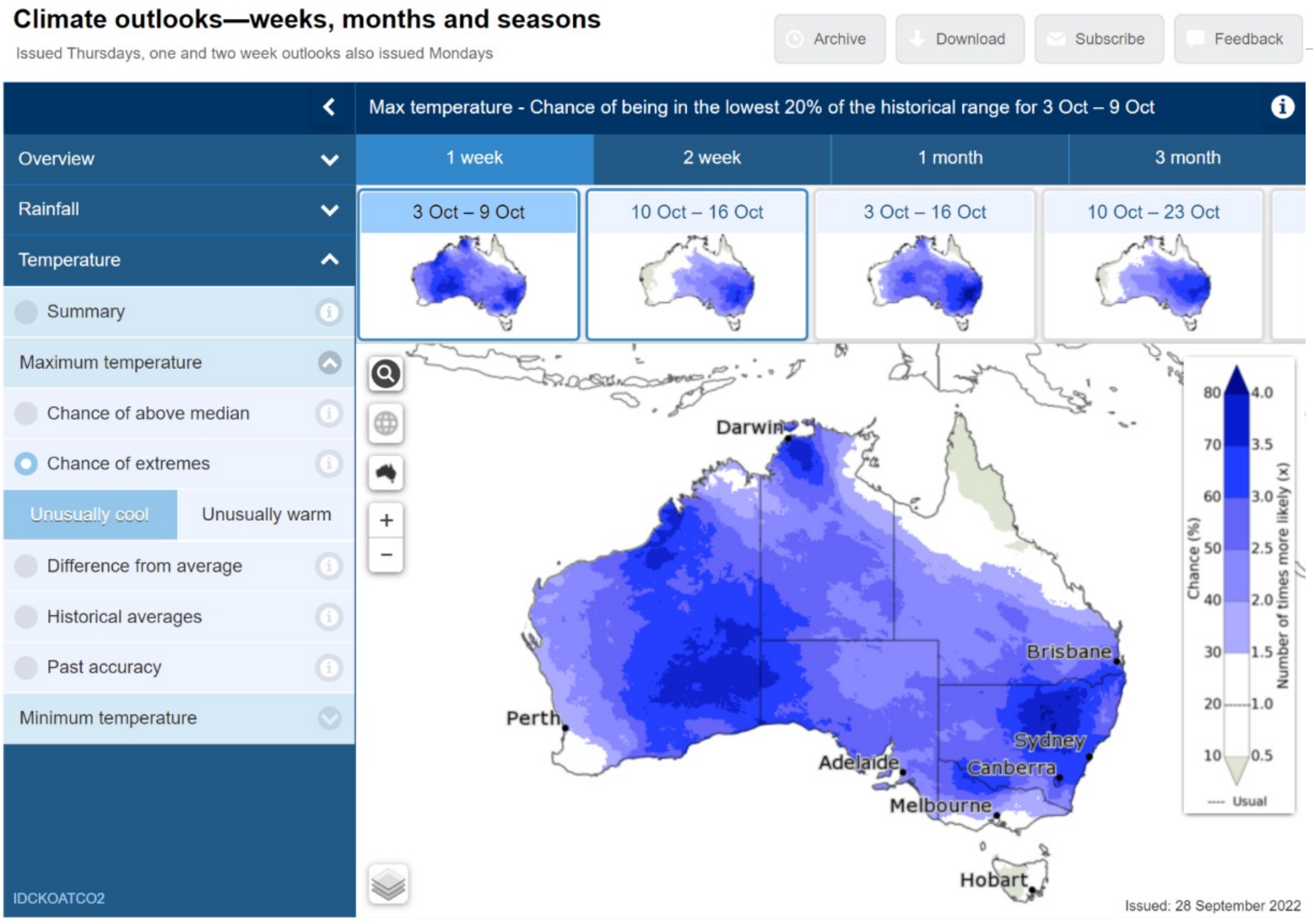


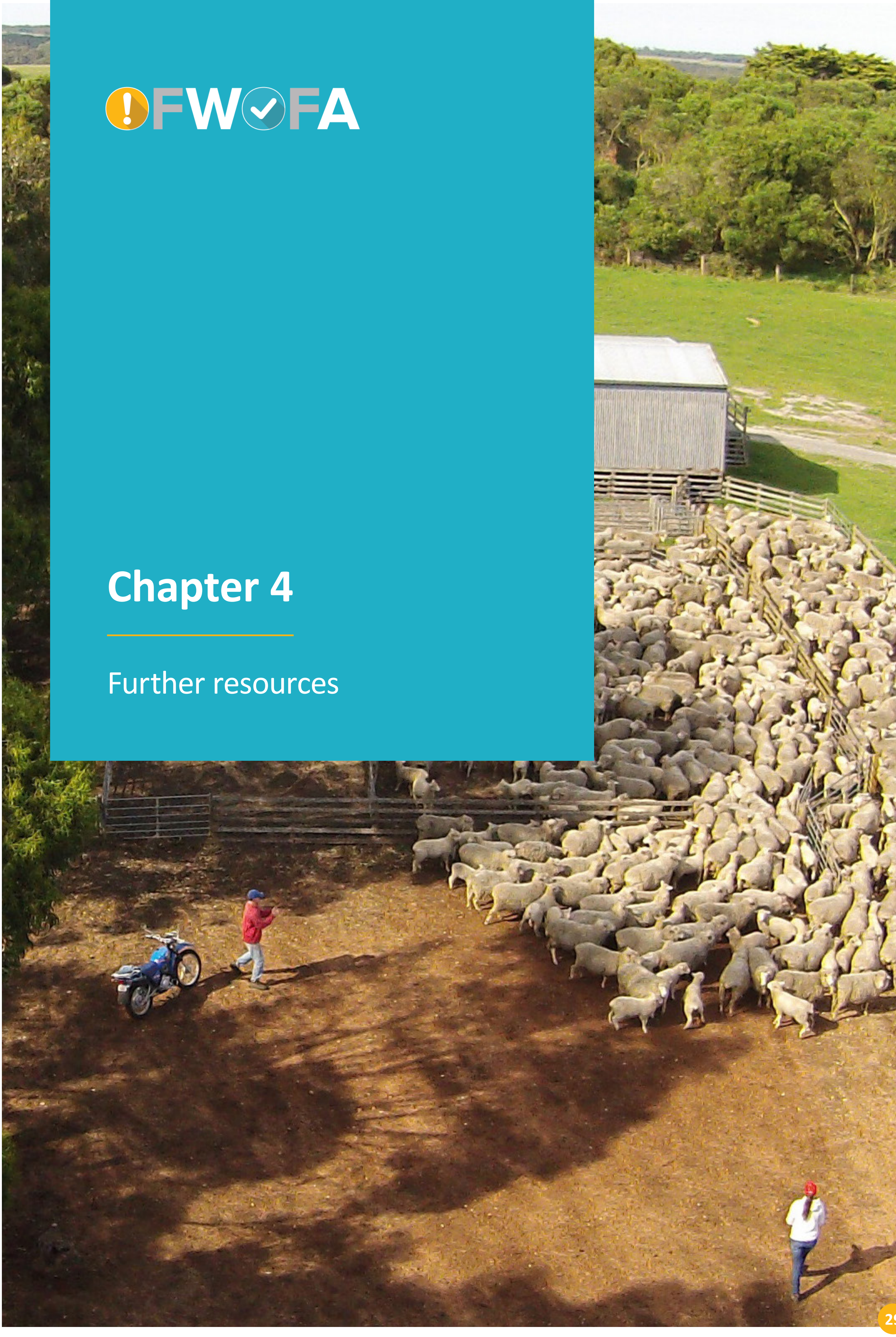
Figure 6. Example of the *chance of extremes* map for unusually cool maximum temperatures between 3 oct and 9 Oct 2022 for Australia. Reproduced from Agriculture Victoria's eLearning course 'Using seasonal climate prediction tools'.

Table 4. Summary of challenges and responses associated with the impact of frosts relevant to Australia's wine industry.

Potential challenges	Tactical response
Damage to vine tissue	Maintain clear moist soil or short grass in the interrow
	Employ fan or helicopter protection
	Employ irrigation protection
	Consider introducing heat through strategically placed heating
	Consider protectant sprays

Chapter 4

Further resources



4 Further resources

An overview of the Forewarned is forearmed project is available on the Climate kelpie website.

For any technical support in using the tools, contact agriculture@bom.gov.au

Online courses

Agriculture Victoria has produced some excellent online courses, including Climate Outlook tools from the Bureau of Meteorology, which can be accessed for free at https://agriculture.vic.gov.au/support-and-resources/elearning/climate-and-weather-courses

The Northern Australia Climate Program has developed the *Climate Training Course – Forecasting for Decision Making*, which can be accessed for free at https://nacp.org.au/outreach/training/videos

Climate drivers

The following transcripts of the Climatedogs videos (http://www.climatekelpie.com.au/index.php/climatedogs/) provide extra information about the climate drivers.

The roundup – introducing the Climatedogs

Meet the Climatedogs. They represent the climate processes that drive the rainfall variability across Australia. These working dogs love rounding up our rainfall.

From a farmer's perspective, when they're behaving, they bring moisture from the oceans and allow it to fall as rain – hopefully delivering the right amount at the right time. But they don't always work how we'd like them to, and can sometimes scatter the mob, effectively chasing rainfall away from Australia. These dogs often work as a team, helping one another to bring about our wetter and drier seasons.

Over recent decades, some of these dogs have started to change their behaviour, contributing to the variability and changing weather patterns that many farmers have noticed. While we can't control what these climate dogs are up to, there are tools that can assist farmers to keep an eye on the pack, helping to improve our understanding of seasonal forecasts and manage climate risks.

Introducing ENSO – The El Niño Southern Oscillation

The El Niño Southern Oscillation, or Enso, has a big influence on Australia's climate and seasonal variability.

In a normal, or neutral, year, the Pacific Ocean trade winds blow from east to west, pushing moist air towards Australia. This moist tropical air is a big source of rain across many parts of Australia. But Enso's behaviour can vary from year to year.

During La Niña, Enso chases greater amounts of moist tropical air across Australia. Many La Niña years have seen higher winter and spring rainfall across large parts of Australia. And in northern Australia, the first rains of the wet season tend to be earlier during La Niña years, along with an increased chance of floods and tropical cyclones.

During El Niño, Enso changes its mind and drives warm moist air away from Australia and towards South America instead. El Niño years have often resulted in a drier winter and spring for eastern Australia, as well as an increased chance of frost and heatwave events. Up north, El Niño can bring a later start to the wet season rains, with typically fewer tropical cyclones and floods.

Enso often teams up with the other Climatedogs to affect our seasonal rainfall. Climatologists closely follow Enso's behaviour, looking at ocean temperatures, the SOI, and cloud and wind patterns to work out where it might chase that moisture next. So Enso is definitely an important dog to keep your eye on.

Introducing INDY – The Indian Ocean Dipole

This is the Indian Ocean Dipole, also known as Indy, who influences south-east and central Australia's rainfall, mainly in spring. Indy likes to herd moisture from the warm north-east Indian Ocean across to south-eastern Australia. When this moist air meets up with southern weather systems, it can deliver significant rainfall. Some years, the north-eastern Indian Ocean is cooler than normal, meaning less evaporation and Indy can't deliver as much moisture, usually meaning a drier spring in the centre and south-east.

Historically Indy often likes to team up with Climatedog Enso, with both being a significant source of rainmaking moisture. In recent years, scientists have noticed that much of the Indian Ocean has been getting warmer, and that's why they are investigating Indy's behaviour, so we can better understand this Climatedog and improve our rainfall forecasts in the future.

Introducing Ridgy
– The Sub-tropical Ridge

This is Ridgy or, as scientists like to call him, the Sub-tropical Ridge. Ridgy is one of the major drivers that shapes southern Australia's weather. So let's look at how he does it.

As warm air rises in the tropics, moves south, then cools and falls, large areas of high pressure are created. This band of high pressure – in this case, Ridgy – is great at blocking rain-bearing fronts. From November through until April, Ridgy chases away cold fronts around southern Australia for days or even weeks at a time. When winter sets in, Ridgy heads north and cold fronts find it much easier to reach southern Australia and deliver their rain, until Ridgy returns again next November.

Ridgy travels north and south every year, but in recent decades he's been getting more effective at chasing away cold fronts from parts of southern Australia, meaning more dry weather and later autumn breaks. The Bureau of Meteorology has observed that Ridgy's increasing strength is related to the rising global average temperature. but the scientists are continuing to investigate how this climate dog might change his behaviour in the future.

Introducing Sam
– The Southern Annular Mode

Meet Sam. Sam herds cold fronts up from the Southern Ocean, a significant source of rain for much of southern Australia. If we take a look at the Southern Ocean, we can see westerly winds roaring around Antarctica, throwing out cold fronts of stormy wet weather. The strength and position of these winds is known as the Southern Annular Mode, or Sam.

Sam is an unreliable climate dog, often changing behaviour over a matter of weeks. This can affect southern Australia's rainfall in winter, and even parts of eastern and northern Australia's rainfall in summer. When Sam is tied up, strong winds are pulled south towards Antarctica and there is a reduction in the number and strength of cold fronts that reach southern Australia, reducing winter rainfall.

When Sam is let off the leash, this can drive westerly winds further north, increasing the chance of cold fronts and rainfall across the southern states. But in summer, Sam acts a bit differently. If Sam is sitting further south, it can actually coax more moisture and summer rain over parts of eastern & northern Australia.

Sam's behaviour is complicated, and is linked to what the other Climatedogs are up to. However, over recent decades Sam has been tied up more often, resulting in fewer cold fronts and less cool-season rainfall for parts of southern Australia. Scientists are watching this climate dog closely, hoping to tease out how it may impact our weather and seasonal climate variability down the track.

Introducing Eastie
– East Coast Low-Pressure Systems

This is Eastie, better known as the East Coast Low. Eastie represents the deep low-pressure systems that are an important climate feature along the south-east coast of Australia. These deep low-pressure systems can be caused by upper-atmosphere disturbances, decaying cyclones, existing low-pressure conditions or in the wake of passing fronts.

Scientists have found that Eastie tends to have a mind of his own and can be quite hard to predict. This energetic little dog can be triggered into action overnight causing strong winds, big surf, heavy rains and lots of rough weather. Eastie can appear all year round but typically prefers the seasons of autumn and winter. Even one-off events can dominate a region's annual rainfall tally, explaining a lot of the seasonal variability east of the Great Dividing Range.

Eastie usually cares little about what the larger climate dogs are up to; however, scientists have noticed that Eastie can be a bit timid when Ridgy, with his high pressure, is around. Scientists continue to look into Eastie's behaviour.

Introducing MOJO
– The Madden-Julian Oscillation

This is the Madden-Julian Oscillation or, as we like to call him, MOJO. He can have a big influence on Australia's weather and climate, especially during the warmest months of the year.

Mojo runs eastward moving a pulse of cloud and rainfall close to the equator and travels around the earth every thirty to sixty days. Mojo sends a wave of weather across the Indian Ocean which can create cyclones and bring widespread rain events through parts of Australia. Scientists track these rain making waves providing updates on the intensity and timing of the next wave.

Mojo mainly affects northern Australia, but can influence rain events further south, especially if one of Mojo's moisture waves feeds into a timely weather event down south. Mojo's behaviour is often unpredictable, with periods of moderate to strong activity followed by periods of little or no activity, but this dog is well worth keeping an eye on.

La Niña and El Niño

La Niña and El Niño are two phases of the El Niño-Southern Oscillation (ENSO) cycle, which is a natural climate pattern that occurs in the Pacific Ocean. Both La Niña and El Niño can have significant impacts on weather patterns in Australia.

La Niña is characterized by cooler than normal sea surface temperatures in the central and eastern Pacific Ocean, which can lead to increased rainfall and flooding in Australia. During La Niña, the Pacific Ocean trade winds strengthen, pushing warm water to the western Pacific and bringing cool water to the eastern Pacific. This can lead to a strengthening of the Australian monsoon, which results in increased rainfall and cooler temperatures in northern and eastern Australia, particularly during the summer months. La Niña can also lead to an increased risk of tropical cyclones and flooding events in Australia.

On the other hand, El Niño is characterised by warmer than normal sea surface temperatures in the central and eastern Pacific Ocean, which can lead to reduced rainfall and drought conditions in Australia. During El Niño, the trade winds weaken, allowing warm water to move towards the eastern Pacific. This can lead to a weakening of the Australian monsoon, resulting in reduced rainfall and warmer temperatures in northern and eastern Australia, particularly during the summer months. El Niño can also lead to an increased risk of bushfires and heatwaves in Australia.

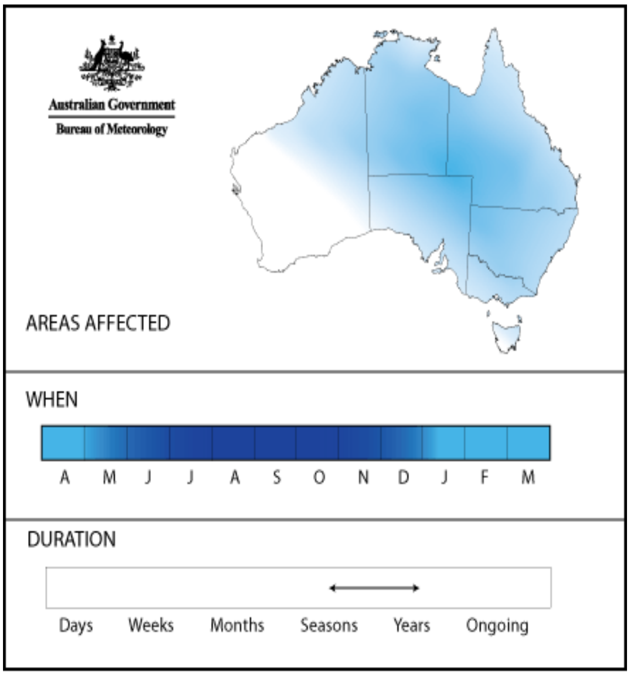


Figure 1. The area affected by La Niña, when it occurs and how long it may last.

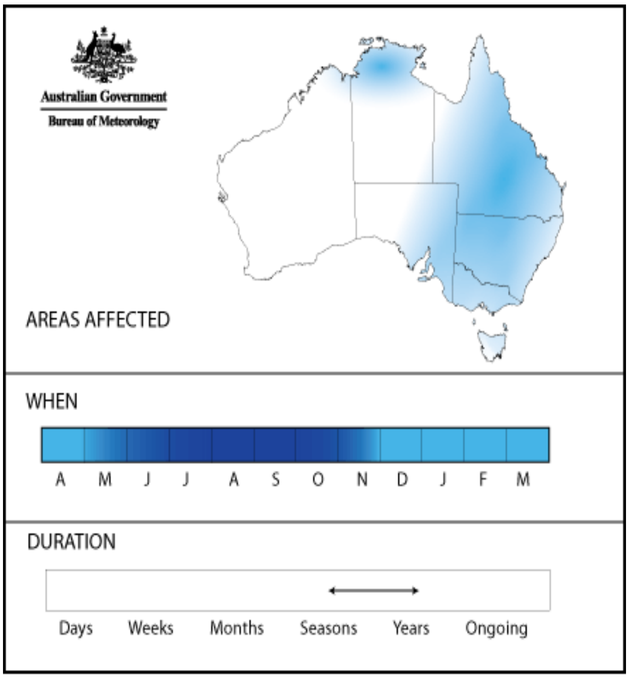


Figure 2. The area affected by El Niño, when it occurs and how long it may last.

The impacts of La Niña and El Niño on weather patterns in Australia can vary from year to year, and their effects are often not uniform across the country. Other climate drivers, such as the Indian Ocean Dipole (IOD) and the Southern Annular Mode (SAM), can also interact with ENSO to influence weather patterns in Australia.

Notes

References

Agriculture Victoria has produced some excellent online courses, including *Climate Outlook tools from the Bureau of Meteorology*, which can be accessed for free at https://agriculture.vic.gov.au/support-and-resources/elearning/climate-and-weather-courses.

Hayman, P., Mudge, B., Stanley, M., Anderson, G., & Grey, D. (2019, August). Agronomic advice in a variable climate; chess, poker or the pokies. In *Proceedings of the 2019 Agronomy Australia Conference* (pp. 25-29).

The Northern Australia Climate Program has developed the *Climate Training Course – Forecasting for Decision Making*, which can be accessed for free at https://nacp.org.au/outreach/training/videos.

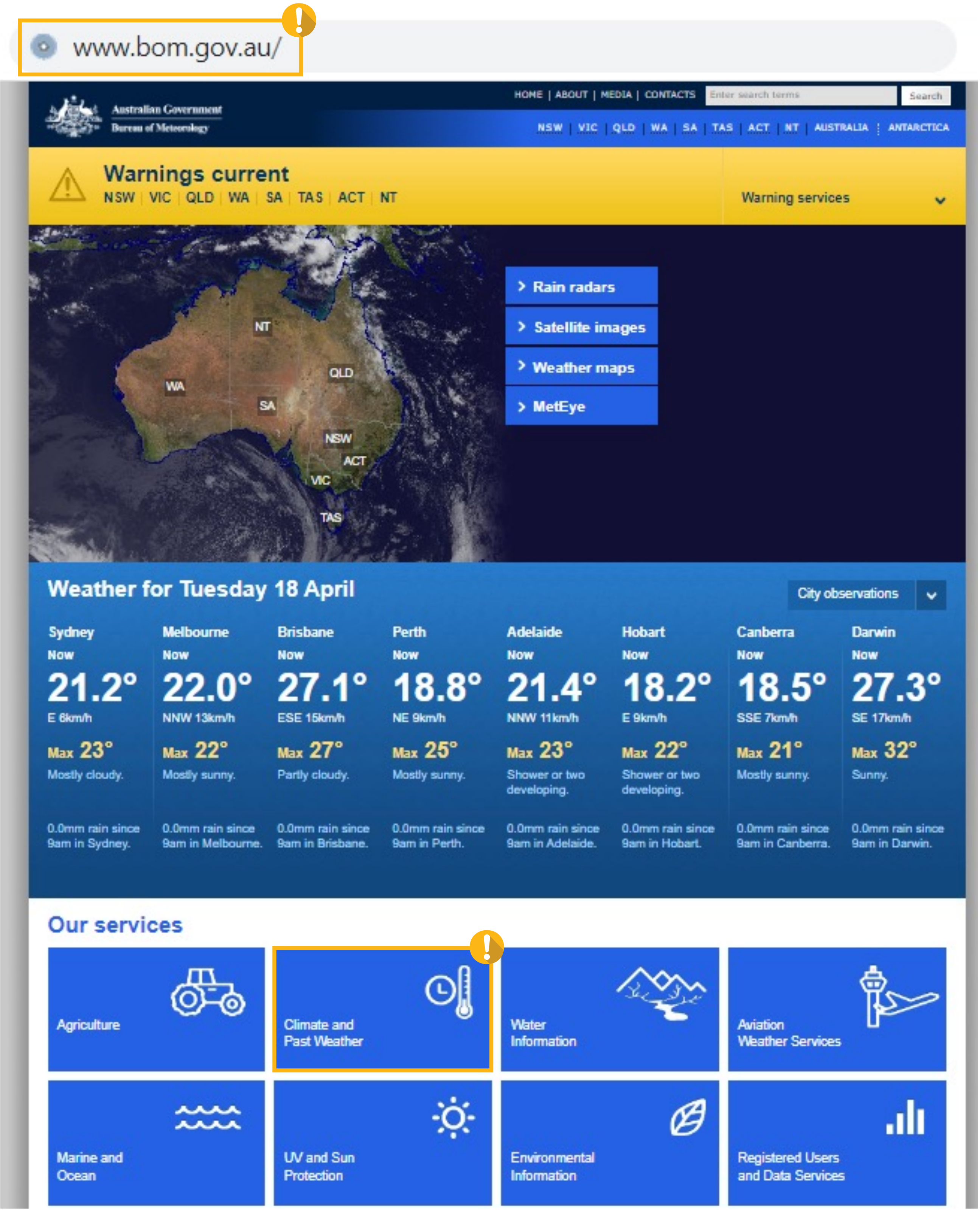
Notes

Appendices

How to access and navigate the FWFA tools

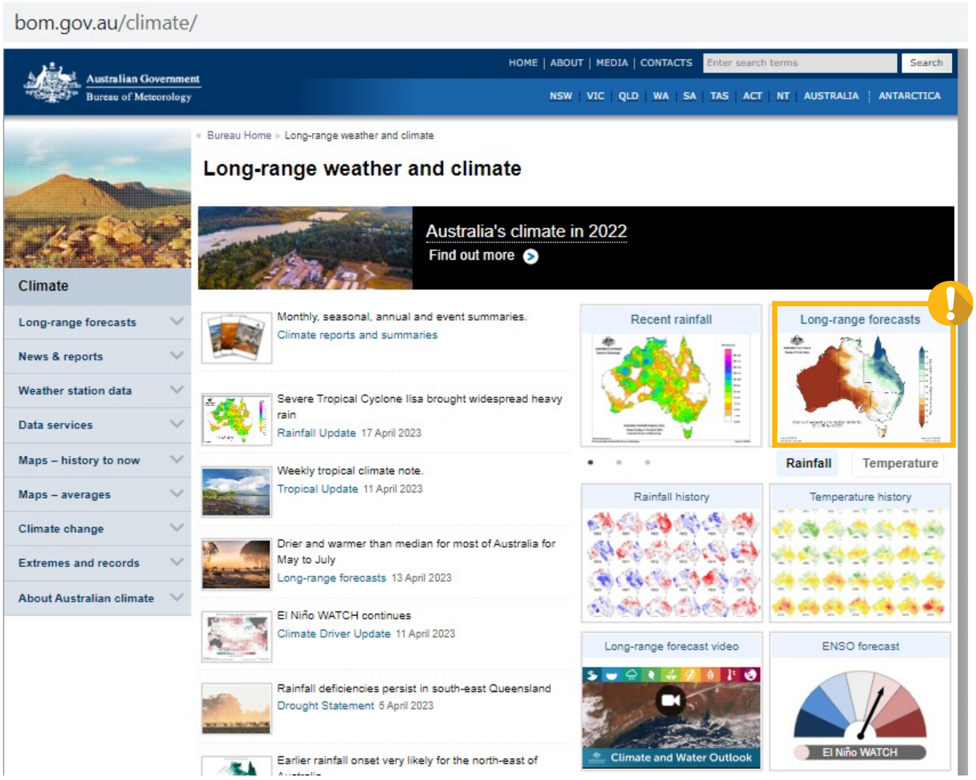
A1 Appendix 1 – how to access the FWFA tools

The Bureau of Meteorology has various tools and resources available on their website, accessible through www.bom.gov.au. The five climate forecast tools can be accessed through the homepage of the Bureau by clicking *Climate and Past Weather* under *Our Services*.



Please note: key website navigation items are indicated with a yellow box and FWFA exclamation (!) icon.

From here, the *Long-range forecasts* can be found on the right side of the page.



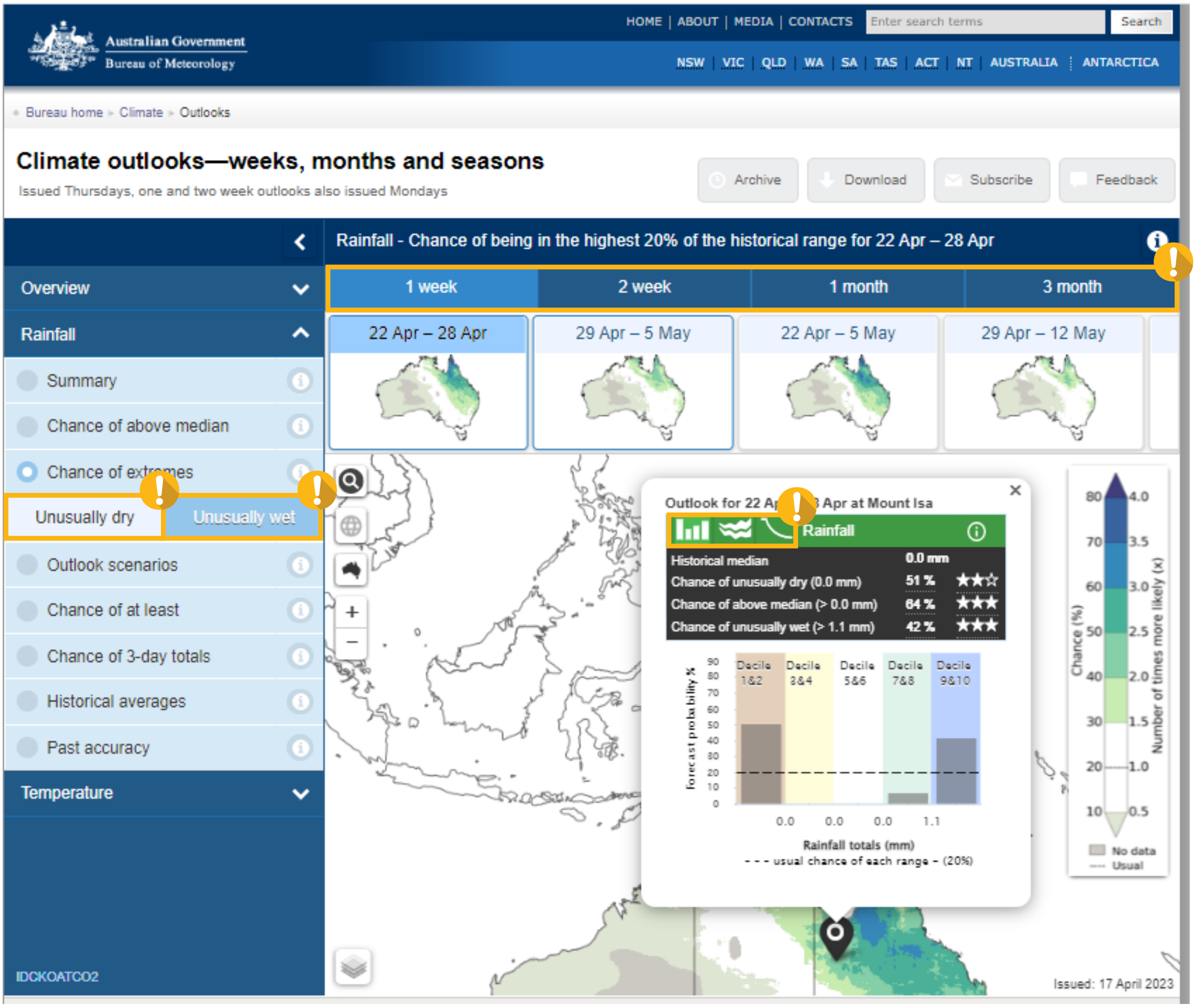
The next page presents an overview of the climate outlook tools, with options for *Overview, Rainfall and Temperature*.

Both under *Rainfall and Temperature*, we have access to several maps. Most of us will be familiar with the *Chance of above median*. Below this, we can select our *chance of extremes* map by clicking on *Chance of extremes*. For our *chance of 3-day totals* map, we can click on the *Chance of 3-day totals*.

A1

In the *Rainfall – Chance of extremes* setting, we can hit either *Unusually dry* or *Unusually wet* on the left side. It shows the map presenting the likelihood of that extreme. If we hit the magnifying glass on the map, we can search for any location in Australia by typing in the pop-up search box. Once the location is selected, a pin-drop will appear on the map and another pop-up will appear. This pop-up contains the other three tools, indicated with the icons on the top of the pop-up box. In order from left to right, they are the *decile bar chart*, the *timeline graph* and the *probability of exceedance*.

bom.gov.au/climate/outlooks/#/rainfall/extremes/p80/weekly/0



A2 Appendix 2 – navigating the FWFA tools

The FWFA tools can be found by following the navigation instructions outlined in Appendix 1. This section refers to features of the FWFA tools to help explain how to use them.

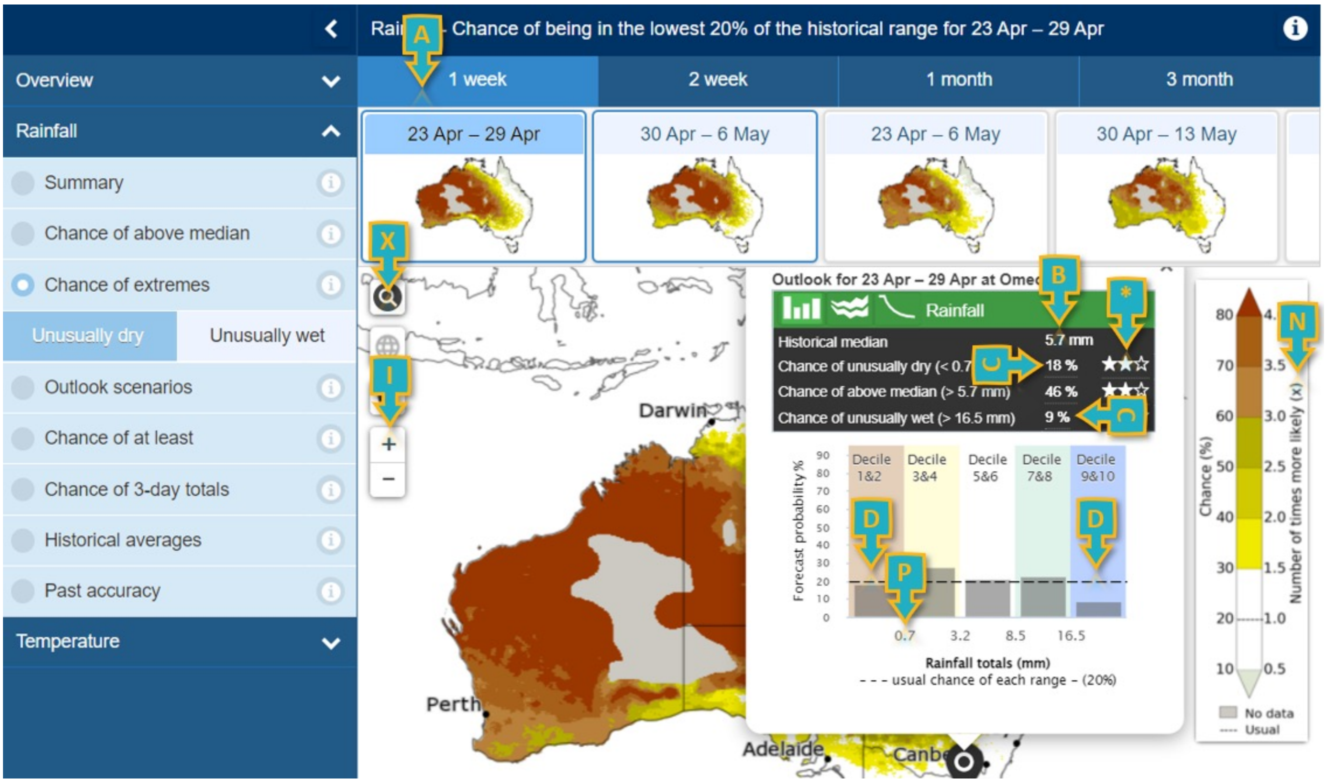


Figure 1. The *chance of extremes* map for unusually dry conditions displayed with the decile bar chart for Omeo (VIC), including markers to explain various features of the tools. http://www.bom.gov.au/ 18 April 2023.

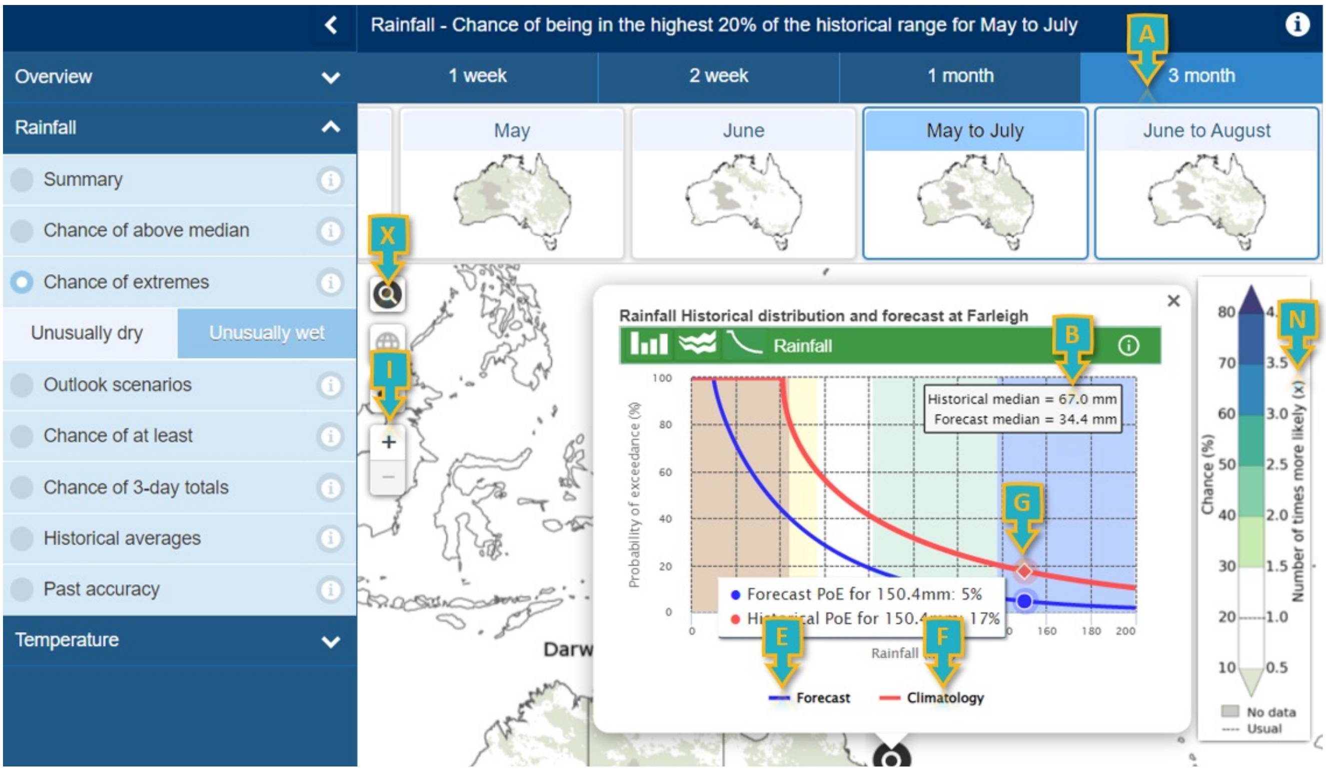


Figure 2. The *chance of extremes* map for unusually wet conditions displayed with the *probability of exceedance* graph for Farleigh (QLD), including markers to explain various features of the tools. http://www.bom.gov.au/ 18 April 2023.

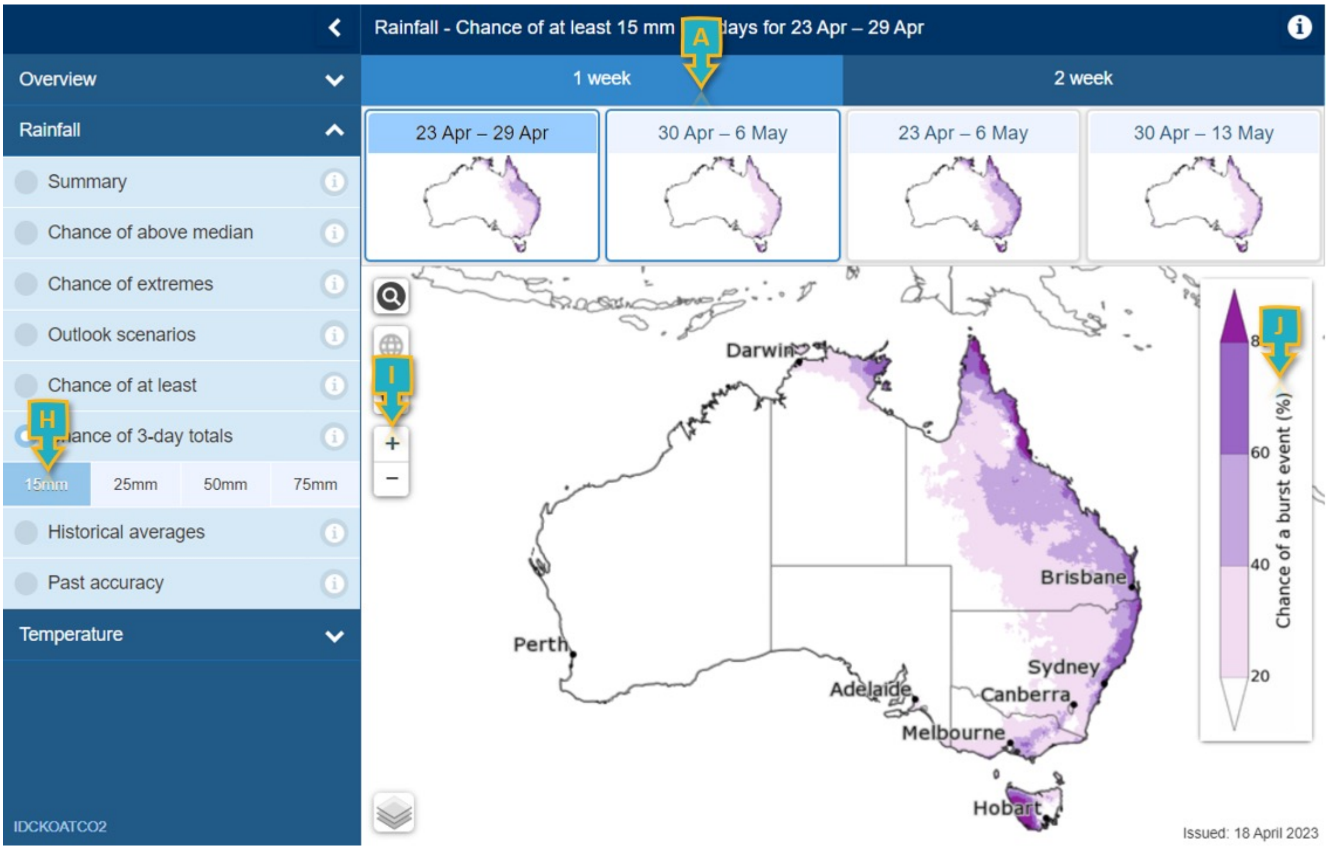


Figure 3. The *chance of 3-day totals* map for unusually dry conditions, including markers to explain various features of the tool. http://www.bom.gov.au/ 18 April 2023.

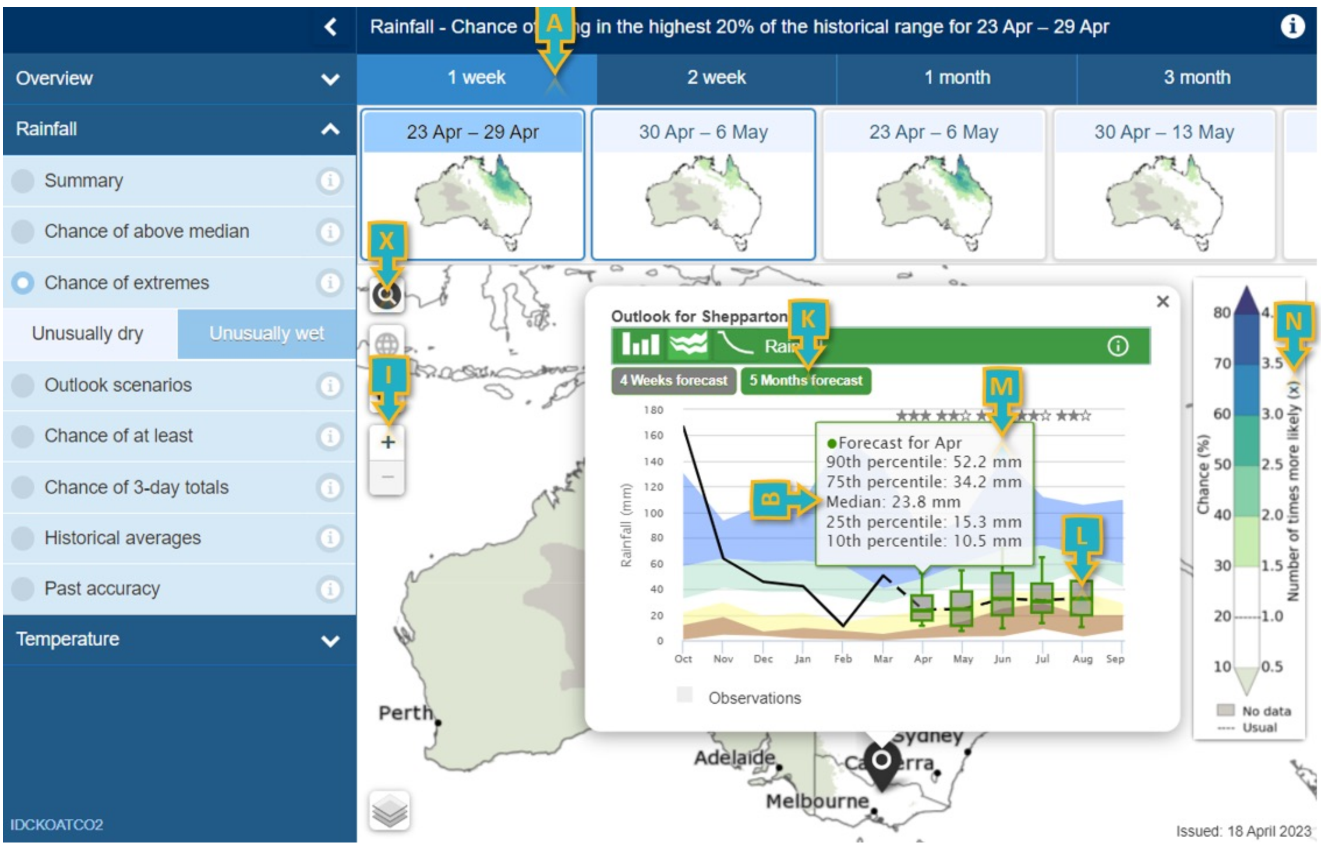


Figure 4. The *chance of extremes* map for unusually wet conditions displayed with the timeline graph for Shepparton (VIC), including markers to explain various features of the tools. http://www.bom.gov.au/ 18 April 2023.

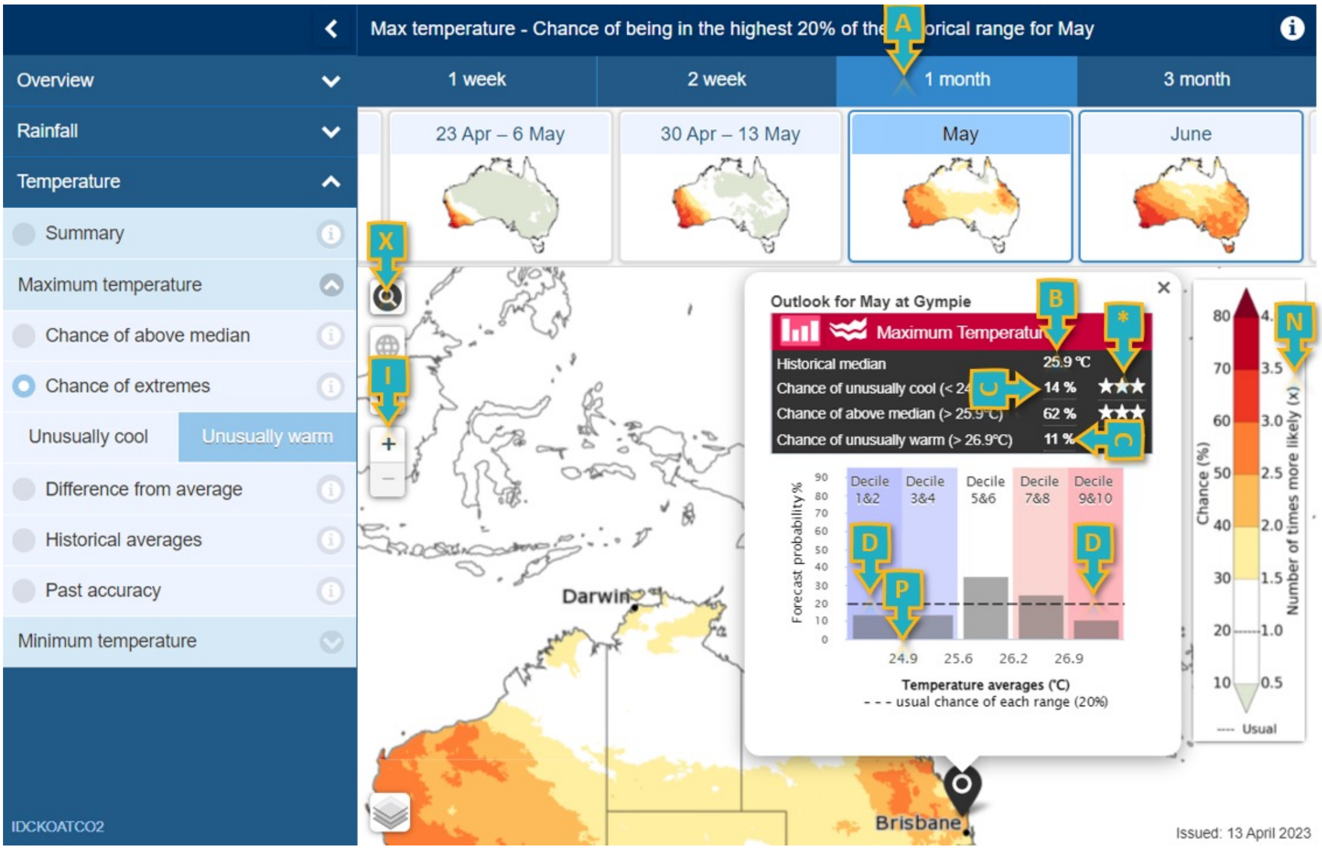


Figure 5. The *chance of extremes* map for unusually warm conditions displayed with the decile bar chart for Gympie (QLD), including markers to explain various features of the tools. http://www.bom.gov.au/ 18 April 2023.

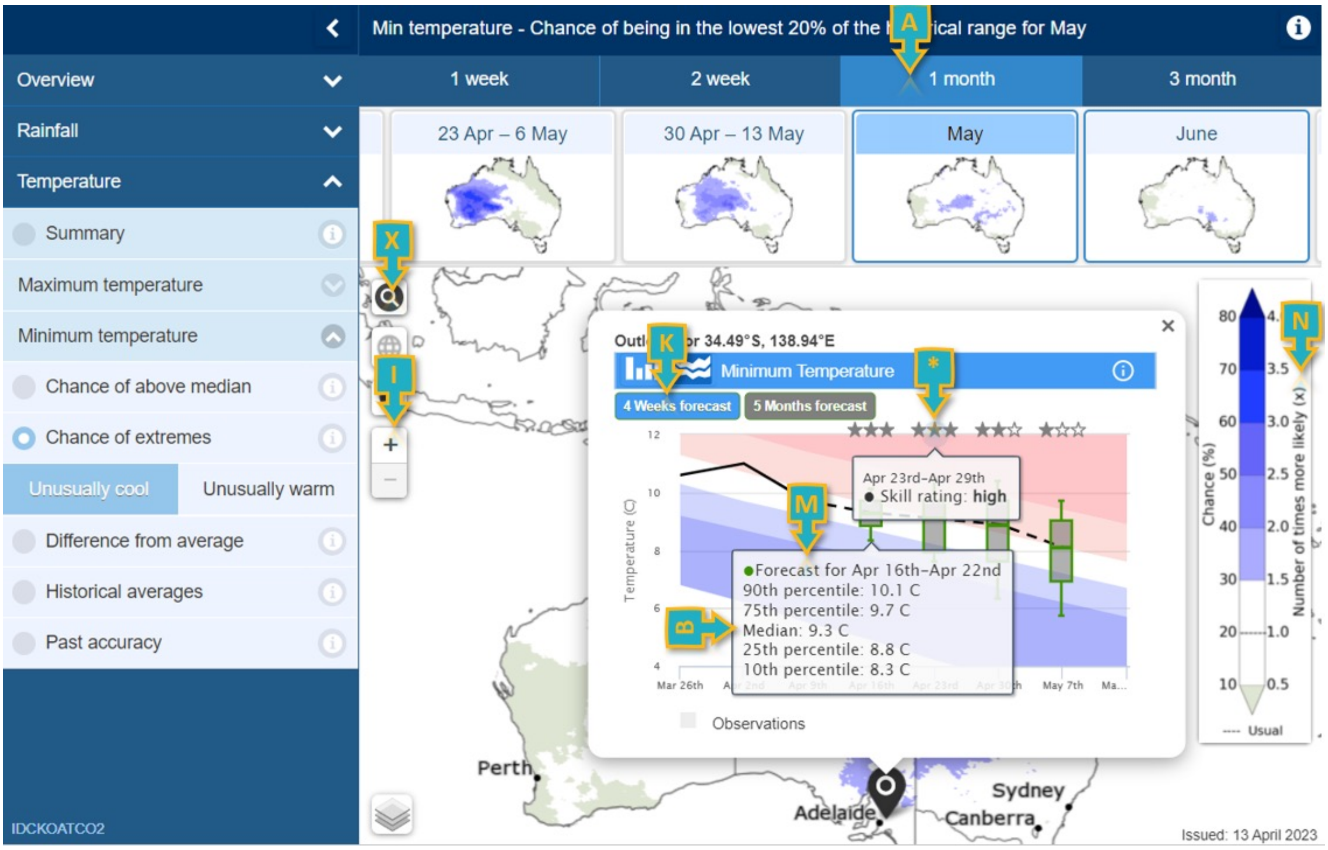


Figure 6. The *chance of extremes* map for unusually cool conditions displayed with timeline graph for a location in South Australia, including markers to explain various features of the tools. http://www.bom.gov.au/ 18 April 2023.

Marker	Description
A	Selection of time scale from the ribbon: 1 week, 2 weeks, 1 month or 3 months
B	Median temperature or rainfall (historical or forecast)
C	Chance of an extreme (i.e. unusually cool/warm or dry/wet)
D	Decile bar
E	Forecast line in the *probability of exceedance* graph
F	Climatology line in the *probability of exceedance* graph
G	Selected rainfall on the X-axis with associated probability of exceedance
H	Selection of a rainfall total in a *chance of 3-day totals* event
I	Zoom function on the map
J	Probability scale for a burst event with corresponding colour coding
K	Selection of 4-week or 5-month forecast in the timeline graph tool
L	Box and whisker plot
M	Pop-up box with details for a box and whisker plot
N	Probability scale with corresponding colour coding
P	Upper limit of a decile in the decile bar chart tool
*	Accuracy estimate/scale
X	Location search function

Notes

Notes

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