Effect of potential atmospheric warming on temperature-based indices describing Australian winegrape growing conditions

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Abstract

Background and Aims: This paper describes the changes in temperature-based indices used to classify viticultural climates in Australia for three warming scenarios produced by the Commonwealth Scientific and Industrial Research Organisation: Mk3.0 global climate model for the years 2030, 2050 and 2070.
Methods and Results: Temperature indices that describe grapevine growing season temperature (GST), ripening period temperature, accumulated biologically effective degree days and growing season length were calculated to produce maps of Australia for each warming scenario. Summary statistics of each index's median and range are presented for each Australian wine region under each warming scenario. The greatest change in GST (above the 1971–2000 mean) was modelled to occur for the Perth Hills region, increasing by 1.0°C by 2030, 1.9°C by 2050 and 2.7°C by 2070. The least change in GST was modelled to occur for the Kangaroo Island region, increasing by 0.5°C by 2030, 0.9°C by 2050 and 1.3°C by 2070.
Conclusion: Of the 61 recognised wine regions, a median GST of over 21°C (an indicator of the limit of quality wine grape production conditions) was found for three regions for the period 1971–2000, for eight regions for the 2030 scenario, 12 regions for the 2050 scenario and 21 regions for the 2070 scenario.
Significance of the Study: Without appropriate adaptations, some established viticultural regions of Australia may become less suitable for quality winegrape production, whereas regions that were once considered unsuitable for quality winegrape production may become more suitable.

Abbreviations

BEDD biologically effective degree days; **CSIRO** Commonwealth Scientific and Industrial Research Organisation; **DEM** digital elevation model; **GCM** global climate model; **GDD** growing degree days; **GHG** greenhouse gases; **GST** growing season temperature; **IPCC** Intergovernmental Panel on Climate Change; **MTA** mean temperature anomaly; **RPT** ripening period temperature; **SRES** Special Report on Emissions Scenarios

Keywords: *climate change, temperature index, viticulture, wine*

Introduction

The 2007 IPCC reports contain best estimates for global temperature increases under six different GHG emission scenarios (as well as likely ranges for these estimates) for the period 2090–2099 relative to 1980–1999. The total range for the estimated temperature increase for all scenarios over this period is 0.7 to 10.4°C (IPCC 2007), reflecting the diversity of scenarios and the variability and uncertainty in the forecasting models. Spatial heterogeneity in future warming is expected, and for the area of Australia south of 30°S, the predicted median warming by the year 2100 of the models included by the IPCC is 2.6 (with an inter-quartile range of 2.4 to 2.9°C) and 3.0°C (with an inter-quartile range of 2.8 to 3.5°C) for Australia north of 30°S (Christensen et al. 2007). These projections are similar to earlier studies, and therefore, projections made by CSIRO in 2001 (CSIRO 2001) remain valid (Christensen et al. 2007). The climate warming projections made by CSIRO (2001) are that by 2030, annual average temperatures will have increased by 0.4 to 2.0°C above 1990 temperatures over most of Australia, and by 2070, annual average temperatures will have increased by 1.0 to 6.0°C above 1990 temperatures. Spatial variability in the rate of warming is expected with temperature

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increases in the lower end of the range for some coastal areas of Australia, particularly in the south (Suppiah et al. 2007).

Temperature is widely accepted as being the primary climatic factor affecting the quality of viticultural production (Winkler et al. 1974, Jackson and Lombard 1993, Gladstones 2004). As a consequence, increases in temperature due to an enhanced greenhouse effect will likely have a significant effect on viticultural production (Bindi et al. 1996, Schultz 2000, Jones et al. 2005). Possible beneficial aspects of climate change include less bud and crop damage from frost events and less extreme winter minimum temperatures that would otherwise damage grapevines (Jones 2005b). A reduction in cold events may lead to a poleward shift in the zones of viable viticulture (Jones 2006), and a move to more beneficial climates for some cool climate regions such as the Okanagan Valley (Caprio and Quamme 2002), the Mosel Valley, Alsace, Champagne and the Rhine Valley (Jones et al. 2005). In Europe, higher average temperatures may allow for grapevine production to become more suitable in the north and east through higher temperature accumulation and longer growing seasons and change the spatial distribution of varieties in already established viticultural regions (Schultz 2000). From 1952 to 1997, Jones and Davis (2000) report that warming in Bordeaux has led to shorter phenological intervals and greater potential wine quality. However, temperature increases in several warm climate viticultural regions (southern California, southern Portugal, Barossa and Hunter Valleys in Australia) may have a detrimental effect on winegrape production, perhaps becoming too warm to produce high-quality wine of any type (Jones et al. 2005). It may be inferred that Australia will also experience significant changes to both varietal suitability in its cooler climate viticultural regions and to the spatial distribution of viable winegrape growing areas (Jones 2005a).

The length of the growing season is considered an important determinant of grape quality and consequent wine value (Jackson and Lombard 1993; Coombe and Iland 2004) because air temperature during ripening affects the composition of harvested grapes (Gladstones 1992, Mullins et al. 1992, Webb et al. 2006, 2007). Therefore, the time at which ripening takes place, whether it be in the heat of midsummer or in cooler autumn months, can determine potential wine quality for a particular vintage. For example, in Alsace (France), a move of the ripening period to warmer conditions resulted in changes to grape composition at harvest (Duchene and Schneider 2005). The temperature of the final ripening month is regarded as a particularly important factor influencing wine styles. Studies under controlled conditions have demonstrated that temperature influences many components of grape development, including the breakdown of acids (Buttrose et al. 1971) and berry colour development (Buttrose et al. 1971, Kliewer 1977). In particular, prolonged periods with temperatures above 30°C can induce heat stress, which may lead to premature veraison, berry abscission, enzyme inactivation and reduced flavour development (Mullins et al. 1992).

Modelling the effect of different warming scenarios on the phenology of grapevines has been completed for Australia (Webb et al. 2007). The major conclusions of this study were that shorter seasons would be experienced, chilling requirements might not be met in all regions and harvest would occur in warmer conditions earlier in the year. The study presented in this paper differs from that of Webb et al. (2007) in terms of (i) the way in which grapevine response to warming scenarios is derived; and (ii) its geographic extent. In comparison with Webb et al. (2007), who use a specially modified version of proprietary software, i.e. Vinelogic (Godwin et al. 2002), to conduct grapevine phenology modelling, this study uses easily repeatable and widely accepted temperature-based approaches to characterise climatic suitability for winegrape growing. In addition, this study ascertains suitability of viticultural production under different warming scenarios for all established viticultural regions of Australia.

Methods

To investigate the effect of potential warming on the geography of Australian winegrape growing conditions, average GST, BEDD, grapevine growing season length and RPT (for a grapevine variety that requires 1300 BEDD) were calculated using maps of average daily temperatures for the period 1971–2000 and for each modelled future time period. It must be noted that this study considers projected rises in temperature in deriving models of future grapevine growing conditions only; other climatic changes associated with an enhanced greenhouse effect are not considered but are likely to have significant effects on viticultural production in the future. For instance, simultaneous rises in atmospheric CO_2 concentration will likely have a confounding effect on the response of grapevines to temperature increases (Schultz 2000). Elevated CO_2 environments have been shown to stimulate grapevine production with expected rises in CO_2 leading to increases in yield. A 40–45% increase in fruit dry weight for atmospheric CO_2 concentrations of 550 ppm (cf. the seasonally adjusted CO_2 concentration of 383 ppm in August 2007 (Keeling et al. 2001)) has been reported with no apparent loss in grape and wine quality (Bindi et al. 2001). Higher CO_2 concentrations may, however, cause vegetative growth that increases canopy shading and potentially decrease fruitfulness (McInnes et al. 2003). In addition, changes to the moisture balance (i.e. the net change in precipitation and evaporation) are not considered in the modelling presented in this paper. A range of climate model simulations all suggested that for Australia, the moisture balance deficit will become larger under enhanced greenhouse conditions (IPCC 2007). Average decreases in the annual water balance in Australia range from about 40 to 120 mm per °C of warming (CSIRO 2001). Possible consequent changes to water allocations to vineyard irrigation may, therefore, have a significant impact on the viability of some viticultural regions notwithstanding the effects of changes in average temperature (Jones 2003).

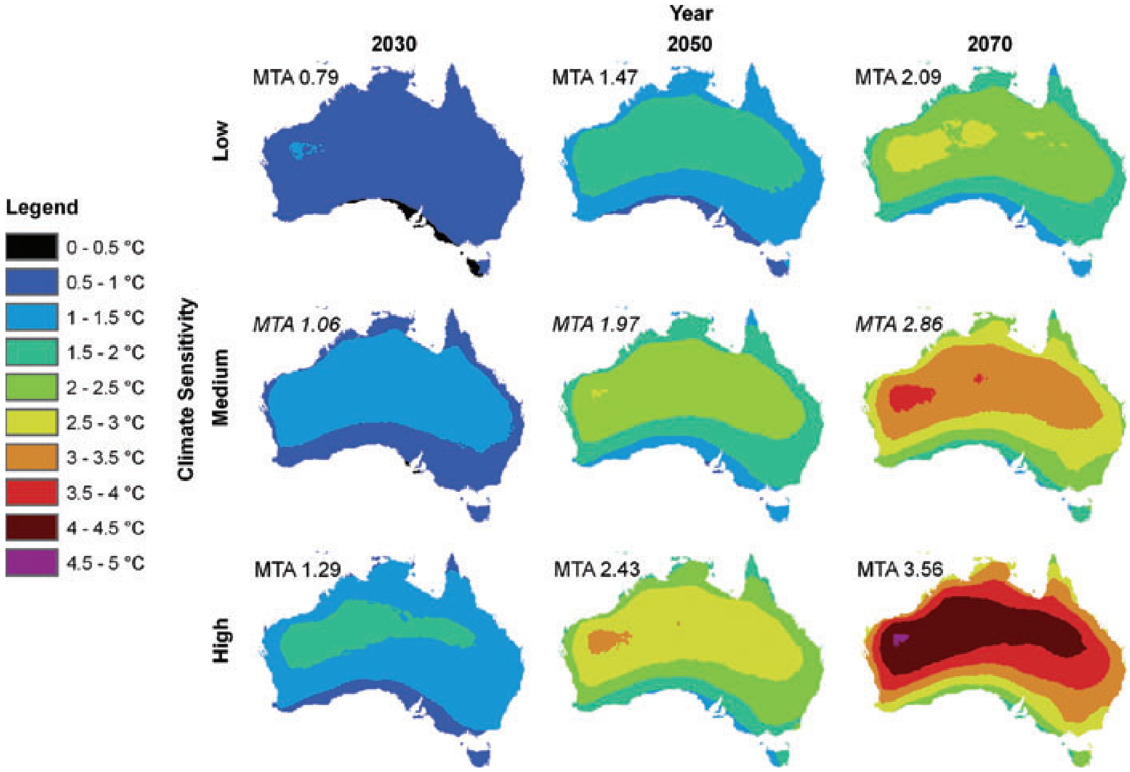

Figure 1. Projected mean temperature increases from 1971–2000 temperature average using three climate system sensitivity levels for the period 1 October to 30 April in 2030, 2050 and 2070, presented as maps of temperature increases. Mean temperature anomalies (MTA) for each scenario are included at the upper left of each panel. An italicised MTA indicates the climatic sensitivity and year combination was selected for modelling in this paper. Sensitivity levels: warming of 1.7°C for low, 2.6°C for medium and 4.2°C for high in response to a doubling of atmospheric CO_2 from 280 to 560 ppm. Global Climate Model: CSIRO Mk3.0. SRES Emission Scenario: A1B.

Projections of future warming used in this study are derived from the CSIRO Mk3.0 GCM (Gordon et al. 2002) accessed via the OzClim web interface (CSIRO 1996). GCMS deliver modelled forecasts of climatic outcomes based on GHG emission scenarios from the IPCC's SRES of which there are 40, each being 'equally valid with no assigned probabilities of occurrence' (IPCC 2000). Each SRES scenario encompasses different projections of temporally varying atmospheric GHG concentrations resulting from various probable future demographic, economic and technological developments. The SRES scenario selected for this study is the mid-range A1B case. The A1 'family' of scenarios describes a future with very rapid economic growth, a global population that peaks mid-century and then declines and the rapid introduction of new and more efficient technologies. The appended 'B' describes the technological emphasis as balanced across fossil intensive and non-fossil energy sources. In addition to the many different scenarios, each SRES scenario's level of effect on atmospheric temperature depends on the sensitivity of Earth's climate system, for which there is a degree of uncertainty. In response to a doubling of CO_2 from 280 to 560 ppm, the commonly accepted range for atmospheric temperature increases is 1.5 to 4.5°C (Houghton et al. 2001). Climate models are run with a set sensitivity, and the IPCC uses 1.7°C for a model that assumes a low level of sensitivity of the climate system in response to a doubling of atmospheric GHG, and 4.2°C for a high level of sensitivity (Houghton et al. 2001). A medium-level sensitivity of 2.6°C was used in this study, common to the medium-level sensitivity used by OzClim (CSIRO 1996). Comparison maps of Australian October to April temperature anomalies, modelled using SRES scenario A1B and the three different climate sensitivities of 1.7, 2.6 and 4.3°C, are illustrated in Figure 1 for the years 2030, 2050 and 2070. The maps feature common attributes in terms of the spatial differences in response to increasing GHG concentrations. The general pattern is greater warming inland and to the north and west, with less warming close to the coasts and in the south, particularly coastal South Australia, southwest Victoria and Tasmania. The mean warming experienced for each combination of climate sensitivity and year is included in the upper left of each panel of Figure 1. The three combinations selected in this study can be compared against other possible combinations using this chart. For example, assuming similarity in the spatial rate of change in temperatures, the models produced using a medium sensitivity for 2050 would be similar to those produced with a low sensitivity for 2070.

Average GST (mean average daily temperature from 1 October to 30 April) used in this study is similar to that used by Jones et al. (2005) (which used average temperatures of April to October for Northern Hemisphere studies). How the groupings of Jones et al. (2005) relate to those used in this study is shown in Table 1. Jones

Table 1. Growing season temperature categories of Jones et al. (2005) and those used in this study.

Growing season temperature categories	Growing season temperature category ranges used by (Jones et al. 2005)	Growing season temperature category ranges used in this study
Cool	13–15°C	13–15°C
Intermediate	15–17°C	15–17°C
Warm	17–19°C	17–19°C
Hot	19–24°C	19–21°C
Very Hot	Unused	21–24°C

(2006) orders grapegrowing climates into cool, intermediate, warm and hot groupings based on average GST, a simpler climate classification method but analogous to that developed by Winkler et al. (1974) based on heat accumulation.

A common measure of heat accumulation is GDD, which is used to determine the growth rate and phenological development of many crops. The GDD for a single day (GDD_i) is calculated using

$$GDD_i = \max\left[\left(\frac{T_{max} + T_{min}}{2} - b\right), 0\right] \quad (1)$$

where T_{max} and T_{min} are the daily maximum and minimum recorded air temperatures (in °C) and b is the base temperature, below which there will be no significant growth of a particular plant (10°C is typically used for grapevines). GDD is often used to determine climatic regions for grapevine suitability, following the work of Winkler et al. (1974) who present seasonal summations of GDD to classify five viticultural climatic regions for California.

For grapevines, a linearly increasing phenological response to mean daily temperature between 10 and 19°C can be used to find approximate maturity dates (Gladstones 1992). Below a temperature of 10°C, no growth occurs, and above 19°C, the growth rate flattens out so that no further increase in temperature results in an increase in growth rate (Gladstones 2004). When calculating GDD, setting b to 10°C accounts for the temperatures below which no growth will occur, and restricting the maximum GDD_i to 9°Cdays accounts for no further growth above an average temperature of 19°C. This leads to lower heat accumulation units than those produced using a method with no upper limit to GDD_i (Winkler et al. 1974). Heat accumulation units calculated with a maximum GDD_i cap of 9°Cdays per day are termed *biologically effective °Cdays* (Gladstones 1992). Cumulative biologically effective °Cdays (BEDD) calculated for this study are the sum of GDD_i for a number of days (n) in a particular period restricted to a maximum accumulation of 9°C on any 1 day, i.e.

$$\text{BEDD} = \sum_{i=1}^{n} \min[GDD_i, 9] \quad (2)$$

Gladstones's (1992) *biologically effective °Cdays* calculations, like Winkler et al. (1974), uses averaged monthly temperature data (rather than daily average temperature as described in Eqns 1,2), and a 7-month growing period, but instead of using April to October, the months of October to April are used to suit the Southern Hemisphere summer.

The day on which BEDD reaches a target heat accumulation level can be taken as the season-end date (Coops et al. 2001). To enable comparisons of BEDD to be made with accumulated heat unit calculations in previous research and publications, the season start date has been assumed to be 1 October. In phenological terms, 1 October is an arbitrary date for the season start date. Many factors, mainly early spring temperatures, can affect the season start date; it varies from year to year, and for warmer temperatures, the season start date is likely to be earlier. Nevertheless, previous research and publications use data from 1 October, and classification of climates or varietal suitability using accumulated heat units has proceeded based on this assumption. Therefore, in this study, the length of the growing season is considered to be the number of days it takes for accumulated BEDD to reach a target value after 1 October.

RPT was estimated in this study using the estimate of the harvest date and then calculating the average temperature of the preceding 30 days. To determine the harvest date, a target BEDD of 1300°Cdays accumulated since 1 October was chosen, which is the boundary between maturity groups 5 and 6 defined by Gladstones (2004). Group 5 contains Shiraz and group 6 contains Cabernet Sauvignon; these two varieties made up 39% of the Australian winemaking grape crop in 2006 (Australian Bureau of Statistics 2006).

Production of base daily temperature surfaces

Meteorological stations with a continuous record (above 95% complete) of maximum temperature (T_{max}) and minimum temperature (T_{min}) for the years 1971 to 2000 (the same base period used in the CSIRO Mk3.0 climate model) were identified (238 stations). The geographic distribution of the stations that met the above criteria is illustrated in Figure 2. Although there is not an overall good level of coverage for Australia as a whole, the southern and eastern areas in which Australia's viticultural regions are located are represented well by temporally continuous climate data, suggesting that spatial interpolations of climate for the wine growing regions will be more accurate in the south and east than that for Australia as a whole.

Daily mean temperatures (T) were calculated from the maximum and minimum daily temperatures for each station, i.e.

$$T = \frac{T_{max} + T_{min}}{2} \quad (3)$$

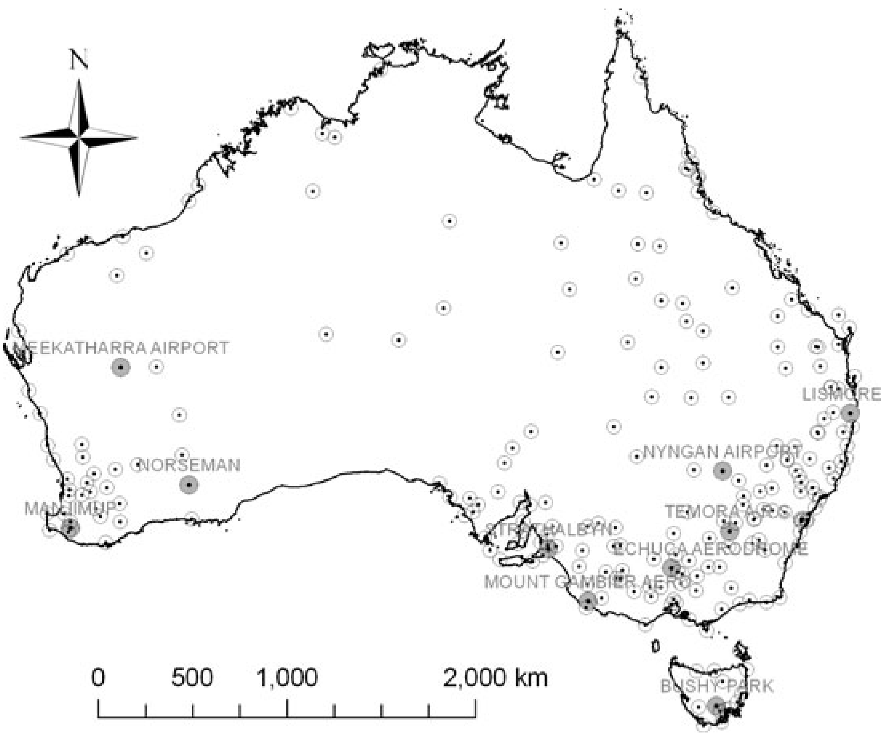

Figure 2. Spatial distribution of meteorological stations used to derive the daily mean average temperature maps (Stations Used in Model, ⊙) and those used to validate the maps (Stations Used in Validation, ◉).

Daily mean temperatures were then altered to take into account the elevation of the meteorological stations, producing sea-level-equivalent temperatures (T_{sle}). An environmental lapse rate of 6.5°C/km, which is widely accepted as the average rate of change of temperature with elevation (Donn 1975, Sturman and Tapper 1996), was applied to the daily mean temperature data (T), i.e.

$$T_{sle} = T + 6.5h \quad (4)$$

where h is the elevation above sea level of the meteorological station in kilometres.

There are many interpolation functions available for producing continuous maps of point data. In a comparison of different interpolation techniques, kriging was shown to be the most accurate method in interpolating climatic data over the UK (Luo et al. 2008). Therefore, the daily sea-level-equivalent temperature data were interpolated at a spatial resolution of 0.05 decimal degrees for the Australian continent using the ordinary kriging function of ArcGIS 9.2 Spatial Analyst (Environmental Systems Research Institute 2006). A spherical variogram model was employed, with the range, sill and nugget parameters calculated internally by ArcGIS separately for each set of daily temperature data. This resulted in a series of 365 maps of mean daily sea-level-equivalent temperature with a pixel size of 0.05 decimal degrees (approximately 5.6 km latitude by 4.6 km longitude at 35°S). Note that the longitudinal length of the pixels varies with latitude, so that south of 35°S the area covered by a pixel is slightly smaller and north of 35°S the area is slightly larger.

Each mean daily sea-level-equivalent temperature map was then adjusted for elevation using a 3-s (<0.001 decimal degrees) DEM of Australia (Jet Propulsion Laboratory 2004). The DEM was converted to a temperature adjustment map (6.5 h_{DEM}), which was subtracted from the sea-level-equivalent temperature maps, i.e.

$$T_p = T_{sle_p} - 6.5h_{DEM} \quad (5)$$

The 0.05-decimal degree pixel size was retained for the resultant maps, which are termed *temperature surfaces*. Regions of missing data in the DEM, due to areas of shadow or low radar backscatter, where an elevation solution could not be resolved by the remote sensing device (Rosen et al. 2000), resulted in a small number of pixels with no data in the temperature surfaces.

Ten meteorological stations were selected for use in the validation of the interpolated temperature surfaces (Figure 2). These stations were removed from the data set before the interpolation process described in the last section was completed. Data were extracted from the resulting interpolated map files in a 0.08-decimal degree radius around the location of the validation stations (delivering six to eight pixels). The average of the extracted pixels (the modelled temperature) was calculated for each validation station, and compared against the actual recorded temperature by calculating both the mean error ($\bar{\varepsilon}$) and the mean absolute error ($\bar{\varepsilon}_{abs}$).

Production of modelled maps of temperature indices

Separate maps for each of the three temperature indices (BEDD, GST and RPT) and season-end date for the four different time periods (1971–2000, 2030, 2050 and 2070) were produced. For the maps that describe the indices for the three future time periods, a map of temperature increases for the corresponding month was added to the daily modelled temperature surfaces before calculating the maps. To produce BEDD maps, each daily modelled temperature surface for the period 1 October to 30 April was converted to maps of GDD_i using Equation 1. BEDD was then calculated for each pixel using Equation 2 and was recorded as the value of the co-located pixel in a new map. To produce maps of the season-end date (the day on which 1300 BEDD is reached), maps of GDD_i were converted to maps of daily BEDD for each day in the period 1 October to 30 April using Equation 2. Each daily BEDD map was then assessed in sequence. The day on which each pixel's BEDD reached 1300°Cdays was recorded as the value of the co-located pixel in a new map. To produce *maps* of RPT, for each pixel, the mean of the temperature records between the day on which 1300°Cdays was reached and the day 30 days before the day on which 1300°Cdays was reached was calculated. The value determined for each pixel was assigned to the co-located pixel in a new map.

Unlike the other three maps of temperature indices produced in this study, the daily modelled temperature surfaces were not used in the production of the GST maps. Instead, the daily average temperatures for the period 1 October to 30 April for the years 1971–2000 were averaged to produce point data, which were then interpolated. The interpolation method was the same as that used to produce the daily modelled temperature surfaces, i.e. sea-level-equivalent temperatures were calculated; the data was interpolated using the ordinary kriging function of ArcGIS 9.2 Spatial Analyst (Environmental Systems Research Institute 2006), and then the DEM was used to correct the temperature surfaces for elevation. Separate maps for the different future time periods were produced by adding the temperature anomaly for the SRES scenario A1B for 2030, 2050 and 2070 (with medium climate system sensitivity) to the GST maps calculated for the 1971–2000 average temperatures.

Wine region summaries

Using the modelled maps, summary data were produced to describe each Australian wine region. The wine regions used in this study are those that are officially described by the Australian Wine and Brandy Corporation (2008), called Geographical Indications (GIs), which are the official descriptions of Australian wine zones, regions or subregions (Figure 3). In addition, two unofficial regions in northern and southern Tasmania were added to account for the growing industry there, which in combination with the official GIs resulted in 63 wine regions being used (Figure 3). Elevational differences result in many regions containing highland areas with climates that are obviously too cool for winegrape production. Statistics generated using data for the whole of such regions are therefore not representative of the areas in which grapes are produced. To account for this issue, those regions that had mean seasonal BEDD totals of less than 1400 (approximately the mean BEDD of all regions), along with two further regions that have large elevational ranges (Hunter and New England), were processed to remove those pixels that were below the median BEDD for the base period 1971–2000 within each region. Using these criteria, the regions that were processed were Alpine Valleys, Beechworth, Canberra District, Geelong, Grampians, Henty, Hunter Valley, Macedon Ranges, New England, North Tasmania, Orange, Pyrenees, South Tasmania, Southern Highlands, Strathbogie Ranges, Sunbury, Tumbarumba, Upper Goulburn and Yarra Valley. The remaining pixels of the climate index maps, whose centres were within each region, were extracted and summarised by generating the median, maximum, minimum, first quartile and third quartile of the index values of each region for the four time periods.

Results

Validation of temperature surfaces

The validation process indicated that the modelled temperature surfaces were close to the actual recorded temperatures for the 10 validation stations and varied by amounts less than what would be expected through instrumental error alone. For example, for the station at Meekatharra Airport, which has the greatest $\bar{\varepsilon}_{abs}$ of the validation stations (1.04°C), the 95% confidence interval of the expected cumulative error over 365 days is −1.0 ± 1.2°C. For the 10 stations as a whole, $\bar{\varepsilon} = -0.26°\text{C}$ and $\bar{\varepsilon}_{abs} = 0.47°\text{C}$, which shows that the model underestimated temperatures for the 10 validation stations by an average of 0.26°C, and the accuracy on any one particular day was on average 0.47°C different from the actual recorded temperature. The absolute mean error is highest for stations at Lismore, Bushy Park, Meekatharra Airport and Norseman, all with $\bar{\varepsilon}_{abs} > 0.5°\text{C}$. For areas that have few meteorological stations nearby, extrapolated data will be less accurate, thus explaining the high errors for these locations. For the six validation climate stations within the viticultural regions, mean $\bar{\varepsilon}_{abs} = 0.31°\text{C}$. It may be reasonably assumed therefore that errors in the modelled temperature surface are little more than 0.3°C for those regions of interest to this study.

Modelled temperature indices

Each temperature index map for each time period is presented in Figure 4. The general spatial trends of each of the temperature indices show latitudinal shifts southward and/or upward in elevation. The maps show that for all locations, increasing temperatures lead to warmer GST, more accumulated BEDD, earlier ripening and warmer RPT. The rate of the increases in the temperature indices varies spatially mainly with respect to the degree of continentality; generally, for locations closer to the coast, projected temperature increases are lower than those inland.

A visual comparison of the maps of GST with maps of BEDD and RPT (Figure 4) suggests that the spatial patterns are very similar. However, correlation coefficients describing the spatial correlation between the different temperature index maps suggest that there are some large spatial differences between the indices. For example, the correlation coefficient (r) for BEDD and GST is 0.75 for 1971–2000 decreasing to 0.60 for 2070. This shows that the two indices describe different climatic characteristics,

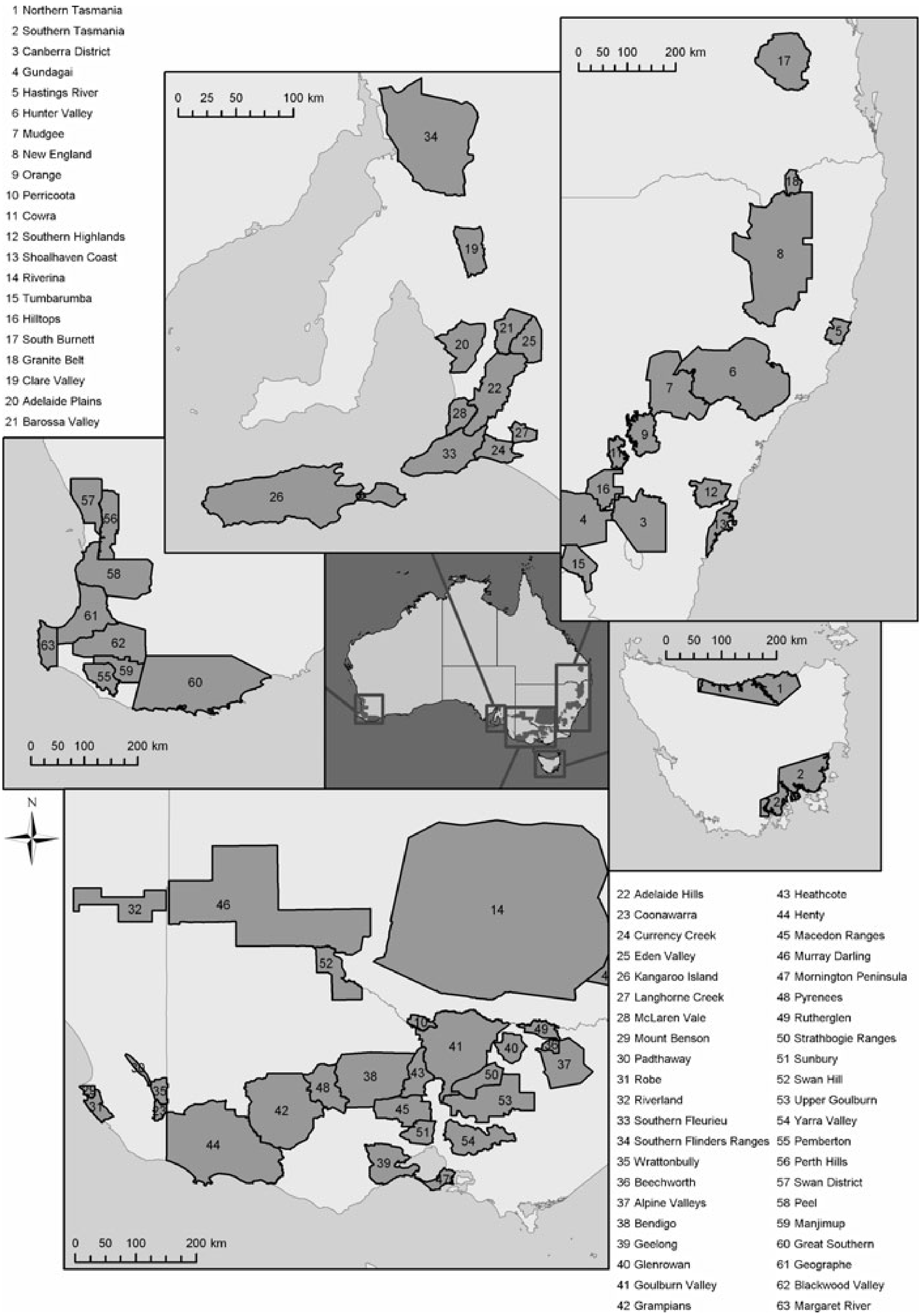

Figure 3. Australian wine regions used in this study. Regions labelled 3–63 are derived from data supplied by the Australian Wine and Brandy Corporation describing official regions (Geographic Indications). Regions labelled 1–2 are regions produced by the authors to include Tasmania.

each being affected differently by increasing atmospheric temperatures. RPT is also shown to be a different climatic descriptor to GST, although the correlation coefficient (r = 0.80 for 1971–2000) indicates that these indices are more similar to each other than BEDD is to GST.

Summary data for the baseline period (1971–2000) and change in index values for 2030, 2050 and 2070 are presented for each region in Table 2. For 1971–2000, GST averages 18.0°C across all 63 wine regions but varies from 13.6°C in Southern Tasmania to 23.7°C in South Burnett.

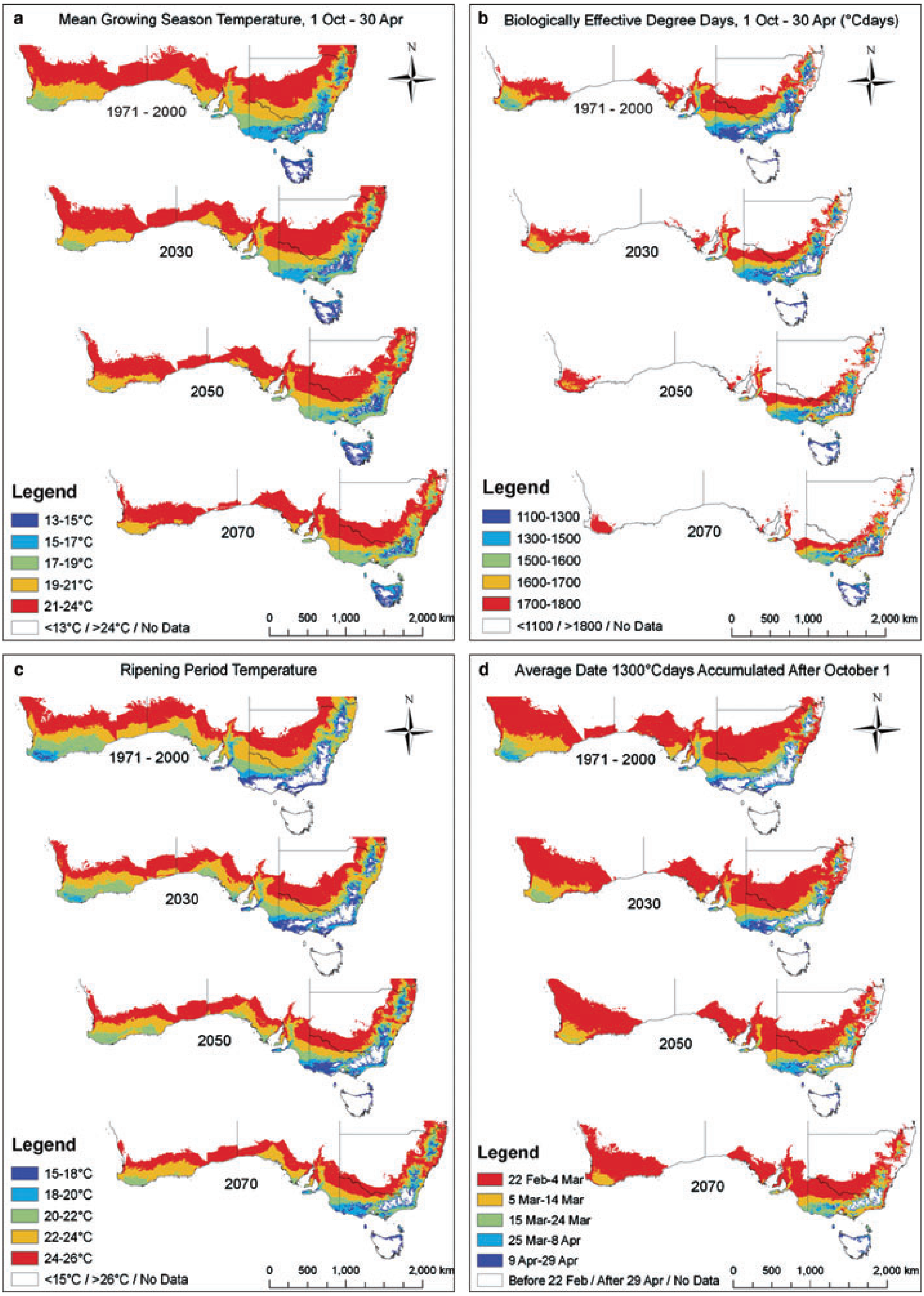

Figure 4. Winegrape growing conditions for the period 1971–2000 and projected for 2030, 2050 and 2070 described by: (a) mean temperature for the period 1 October to 30 April; (b) total biologically effective degree days for the period 1 October to 30 April; (c) estimated mean ripening period temperature (air temperature of the 30 days preceding day on which target heat unit accumulation reached) experienced for a grapevine cultivar that has a target heat accumulation of 1300 biologically effective °Cdays assuming a start date of 1 October (note areas of no data are present in regions where 1300 biologically effective °Cdays are not reached); and (d) estimated season-end dates based on a start date of 1 October and a target heat accumulation of 1300 biologically effective °Cdays.

Table 2. Index summaries (minimum (Min), first quartile (Q1), median, third quartile (Q3) and maximum (Max) values) of the pixel sets inside each Australian wine region for the base period (1971–2000) and the projection years of 2030, 2050 and 2070 (excluding pixels representing high elevation areas as described under Wine region summaries of the Methods section).

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
WA	Perth Hills	Base	18.4	20.0	20.3	20.8	21.8	1546	1702	1734	1763	1821	20.0	22.3	22.8	23.3	24.4	2-Mar	7-Mar	10-Mar	12-Mar	23-Mar
		2030	19.4	21.0	21.3	21.8	22.8	1649	1774	1798	1819	1856	21.5	23.5	23.9	24.4	25.5	27-Feb	2-Mar	4-Mar	6-Mar	16-Mar
		2050	20.2	21.9	22.2	22.7	23.7	1723	1819	1837	1850	1873	22.5	24.5	24.8	25.3	26.4	25-Feb	27-Feb	1-Mar	2-Mar	10-Mar
		2070	21.1	22.7	23.1	23.5	24.6	1779	1851	1861	1870	1889	23.4	25.3	25.7	26.1	27.1	23-Feb	25-Feb	26-Feb	27-Feb	6-Mar
		2030-Base	1.0	1.0	1.0	1.0	1.0	103	72	64	56	35	1.5	1.2	1.1	1.1	1.1	−4	−5	−6	−6	−7
		2050-Base	1.8	1.9	1.9	1.9	1.9	177	117	103	87	52	2.5	2.2	2.0	2.0	2.0	−6	−9	−9	−10	−13
		2070-Base	2.7	2.7	2.8	2.7	2.8	233	149	127	107	68	3.4	3.0	2.9	2.8	2.7	−8	−11	−13	−14	−17
QLD	Granite Belt	Base	16.6	17.6	17.9	18.3	19.0	1387	1559	1591	1647	1709	16.1	18.0	18.4	19.1	20.1	6-Mar	10-Mar	14-Mar	16-Mar	5-Apr
		2030	17.6	18.6	18.9	19.3	20.0	1551	1683	1706	1746	1790	18.0	19.4	19.7	20.3	21.2	28-Feb	3-Mar	5-Mar	6-Mar	16-Mar
		2050	18.4	19.4	19.7	20.2	20.9	1658	1761	1777	1806	1838	19.1	20.3	20.6	21.2	22.0	25-Feb	27-Feb	28-Feb	1-Mar	8-Mar
		2070	19.3	20.3	20.6	21.0	21.7	1742	1816	1827	1849	1873	20.1†	21.2	21.5	22.1	22.9	22-Feb†	24-Feb	25-Feb	25-Feb	2-Mar
		2030-Base	1.0	1.0	1.0	1.0	1.0	164	124	115	99	81	1.9	1.4	1.3	1.2	1.1	−7	−7	−9	−10	−20
		2050-Base	1.8	1.8	1.8	1.9	1.9	271	202	186	159	129	3.0	2.3	2.2	2.1	1.9	−10	−12	−15	−15	−28
		2070-Base	2.7	2.7	2.7	2.7	2.7	355	257	236	202	164	4.0†	3.2	3.1	3.0	2.8	−13†	−15	−18	−20	−34
NSW	New England	Base	17.0	17.8	18.6	19.4	21.7	1467	1553	1629	1709	1873	17.1	18.5	19.6	20.8	23.3	24-Feb	6-Mar	12-Mar	17-Mar	26-Mar
		2030	18.0	18.8	19.6	20.4	22.7	1595	1666	1725	1785	1897	18.5†	19.9	20.9	21.9	24.2	22-Feb†	28-Feb	4-Mar	9-Mar	14-Mar
		2050	18.8	19.7	20.4	21.3	23.6	1681	1745	1789	1834	1899†	19.6†	20.8	21.8	22.8	24.9	22-Feb†	25-Feb	28-Feb	2-Mar	7-Mar
		2070	19.6	20.5	21.3	22.1	24.4	1749	1800	1836	1869	1899†	20.6†	21.8	22.6	23.6	25.7	22-Feb†	23-Feb	25-Feb	27-Feb	1-Mar
		2030-Base	1.0	1.0	1.0	1.0	1.0	128	113	96	76	24	1.4†	1.4	1.3	1.1	0.9	−2†	−7	−8	−8	−12
		2050-Base	1.8	1.9	1.8	1.9	1.9	214	192	160	125	26†	2.5†	2.3	2.2	2.0	1.6	−2†	−10	−13	−15	−19
		2070-Base	2.6	2.7	2.7	2.7	2.7	282	247	207	160	26†	3.5†	3.3	3.0	2.8	2.4	−2†	−12	−16	−19	−25
QLD	South Burnett	Base	20.0	21.6	22.0	22.5	23.7	1787	1875	1888	1895	1899†	21.0†	22.6†	23.1†	23.5	24.6	22-Feb†	22-Feb†	22-Feb†	23-Feb	28-Feb
		2030	21.0	22.6	23.0	23.5	24.7	1841	1894	1898	1898	1899†	21.9†	23.5†	24.0†	24.4†	25.5	22-Feb†	22-Feb†	22-Feb†	22-Feb†	24-Feb
		2050	21.9	23.5	23.9	24.4	25.5	1876	1898	1899†	1899†	1899†	22.8†	24.3†	24.8†	25.2†	26.3†	22-Feb†	22-Feb†	22-Feb†	22-Feb†	22-Feb†
		2070	22.7	24.3	24.7	25.2	26.3	1890	1899†	1899†	1899†	1899†	23.6†	25.1†	25.5†	26.0†	27.0†	22-Feb†	22-Feb†	22-Feb†	22-Feb†	22-Feb†
		2030-Base	1.0	1.0	1.0	1.0	1.0	54	19	10	3	0†	0.9†	0.9†	0.9†	0.9†	0.9	0†	0†	0†	−1†	−4
		2050-Base	1.9	1.9	1.9	1.9	1.8	89	23	11†	4†	0†	1.8†	1.7†	1.7†	1.7†	1.7†	0†	0†	0†	−1†	−6†
		2070-Base	2.7	2.7	2.7	2.7	2.6	103	24†	11†	4†	0†	2.6†	2.5†	2.4†	2.5†	2.4†	0†	0†	0†	−1†	−6†
WA	Peel	Base	18.1	19.0	19.3	19.8	21.4	1531	1611	1640	1680	1806	19.5	20.9	21.4	22.0	24.0	4-Mar	13-Mar	16-Mar	18-Mar	24-Mar
		2030	19.1	20.0	20.3	20.8	22.3	1632	1703	1724	1754	1848	21.1	22.1	22.5	23.1	24.9	28-Feb	8-Mar	10-Mar	12-Mar	17-Mar
		2050	19.9	20.8	21.1	21.7	23.2	1710	1763	1782	1806	1868	22.1	23.1	23.5	24.0	25.8	25-Feb	3-Mar	5-Mar	7-Mar	11-Mar
		2070	20.7	21.6	21.9	22.5	24.0	1769	1811	1826	1842	1884	23.0	24.0	24.3	24.9	26.5	24-Feb	28-Feb	2-Mar	3-Mar	7-Mar
		2030-Base	1.0	1.0	1.0	1.0	0.9	101	92	84	74	42	1.6	1.2	1.1	1.1	0.9	−5	−5	−6	−6	−7
		2050-Base	1.8	1.8	1.8	1.9	1.8	179	152	142	126	62	2.6	2.2	2.1	2.0	1.8	−8	−10	−11	−11	−13
		2070-Base	2.6	2.6	2.6	2.7	2.6	238	200	186	162	78	3.5	3.1	2.9	2.9	2.5	−9	−14	−14	−15	−17
NSW	Mudgee	Base	15.2	17.7	19.1	20.1	21.0	1104	1512	1650	1722	1798	12.6	18.6	20.5	21.7	23.0†	28-Feb	6-Mar	11-Mar	20-Mar	30-Apr†
		2030	16.1	18.7	20.1	21.1	22.0	1287	1616	1737	1794	1849	14.8	19.8	21.8	23.0	24.0†	25-Feb	28-Feb	4-Mar	12-Mar	30-Apr†
		2050	17.0	19.5	20.9	21.9	22.8	1417	1697	1795	1837	1881	16.8†	21.0	22.9	23.8	24.8	22-Feb†	25-Feb	28-Feb	6-Mar	28-Mar
		2070	17.7	20.3	21.7	22.7	23.6	1522	1761	1835	1870	1893	18.4†	22.1	23.7	24.6	25.6	22-Feb†	23-Feb	25-Feb	1-Mar	17-Mar
		2030-Base	0.9	1.0	1.0	1.0	1.0	183	104	87	72	51	2.2	1.2	1.3	1.3	1.0†	−3	−7	−7	−8	0†
		2050-Base	1.8	1.8	1.8	1.8	1.8	313	185	145	115	83	4.2†	2.4	2.4	2.1	1.8†	−6†	−10	−12	−14	−33†
		2070-Base	2.5	2.6	2.6	2.6	2.6	418	249	185	148	95	5.8†	3.5	3.2	2.9	2.6†	−6†	−12	−15	−19	−44†

Table 2. *Continued*

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
NSW	Hunter	Base	16.1	20.5	20.8	21.1	21.6	1288	1792	1818	1840	1863	16.9	21.9	22.3	22.6	23.4†	24-Feb	26-Feb	27-Feb	1-Mar	30-Apr†
		2030	17.1	21.4	21.8	22.0	22.6	1437	1844	1866	1882	1893	17.2†	22.8	23.2	23.6	24.4	22-Feb†	23-Feb	24-Feb	25-Feb	27-Mar
		2050	17.9	22.3	22.6	22.8	23.4	1545	1879	1890	1896	1898	18.6†	23.6†	24.0†	24.4	25.1	22-Feb†	22-Feb†	22-Feb†	23-Feb	16-Mar
		2070	18.7	23.0	23.4	23.6	24.2	1632	1893	1897	1898	1899†	19.8†	24.4†	24.8†	25.1†	25.8	22-Feb†	22-Feb†	22-Feb†	22-Feb†	9-Mar
		2030-Base	1.0	0.9	1.0	0.9	1.0	149	52	48	42	30	0.3†	0.9	0.9	1.0	1.0†	−2†	−3	−3	−5	−34†
		2050-Base	1.8	1.8	1.8	1.7	1.8	257	87	72	56	35	0.7†	1.7†	1.7†	1.8	1.7†	−2†	−4†	−5†	−7	−45†
		2070-Base	2.6	2.5	2.6	2.5	2.6	344	101	79	58	36†	1.9†	2.5†	2.5†	2.5†	2.4†	−2†	−4†	−5†	−8†	−52†
WA	Swan District	Base	20.3	21.2	21.3	21.5	21.7	1737	1806	1814	1823	1835	22.8	23.6	23.8	23.9	24.4	1-Mar	2-Mar	3-Mar	4-Mar	10-Mar
		2030	21.3	22.1	22.3	22.4	22.7	1799	1845	1850	1855	1863	23.9	24.6	24.8	25.0	25.3	26-Feb	27-Feb	27-Feb	28-Feb	4-Mar
		2050	22.2	23.0	23.1	23.3	23.6	1838	1867	1871	1875	1881	24.8	25.4	25.6	25.8	26.2	24-Feb	25-Feb	25-Feb	25-Feb	1-Mar
		2070	23.0	23.8	23.9	24.1	24.4	1862	1884	1886	1889	1893	25.5	26.1	26.3	26.5	26.9	23-Feb	23-Feb	23-Feb	24-Feb	26-Feb
		2030-Base	1.0	0.9	1.0	0.9	1.0	62	39	36	32	28	1.1	1.0	1.0	1.1	0.9	−4	−4	−5	−5	−6
		2050-Base	1.9	1.8	1.8	1.8	1.9	101	61	57	52	46	2.0	1.8	1.8	1.9	1.8	−6	−6	−7	−8	−9
		2070-Base	2.7	2.6	2.6	2.6	2.7	125	78	72	66	58	2.7	2.5	2.5	2.6	2.5	−7	−8	−9	−9	−13
NSW	Orange	Base	16.3	16.8	17.2	17.6	18.6	1293	1361	1414	1464	1587	12.7	16.0	17.3	18.3	20.0†	15-Mar	25-Mar	31-Mar	8-Apr	30-Apr†
		2030	17.2	17.7	18.1	18.5	19.6	1427	1487	1532	1573	1678	17.4	18.5	19.2	19.8	21.2	9-Mar	16-Mar	19-Mar	22-Mar	28-Mar
		2050	18.1	18.5	18.9	19.3	20.4	1532	1581	1620	1655	1749	19.1	19.8	20.5	21.1	22.4	3-Mar	9-Mar	12-Mar	14-Mar	18-Mar
		2070	18.8	19.3	19.7	20.1	21.2	1615	1659	1693	1728	1805	20.3	21.0	21.6	22.2	23.5	27-Feb	4-Mar	7-Mar	9-Mar	12-Mar
		2030-Base	0.9	0.9	0.9	0.9	1.0	134	126	118	109	91	4.7	2.5	1.9	1.5	1.2†	−6	−9	−12	−17	−33†
		2050-Base	1.8	1.7	1.7	1.7	1.8	239	220	206	191	162	6.4	3.8	3.2	2.8	2.4†	−12	−16	−19	−25	−43†
		2070-Base	2.5	2.5	2.5	2.5	2.6	322	298	279	264	218	7.6	5.0	4.3	3.9	3.5†	−17	−21	−24	−30	−49†
VIC	Beechworth	Base	16.7	16.7	17.1	17.2	17.7	1316	1322	1369	1382	1450	14.2	14.7	16.3	16.7	18.4	27-Mar	4-Apr	6-Apr	16-Apr	19-Apr
		2030	17.6	17.6	18.0	18.1	18.6	1435	1440	1481	1492	1550	18.0	18.2	19.1	19.3	20.2	18-Mar	22-Mar	23-Mar	27-Mar	28-Mar
		2050	18.4	18.4	18.8	18.9	19.4	1527	1532	1568	1578	1628	19.8	19.9	20.5	20.6	21.6	12-Mar	16-Mar	16-Mar	19-Mar	19-Mar
		2070	19.1	19.2	19.6	19.7	20.2	1604	1608	1639	1649	1693	21.1	21.3	21.8	21.9	22.7	8-Mar	11-Mar	11-Mar	13-Mar	14-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	119	118	112	110	100	3.8	3.5	2.8	2.6	1.8	−9	−13	−14	−20	−22
		2050-Base	1.7	1.7	1.7	1.7	1.7	211	210	199	196	178	5.6	5.2	4.2	3.9	3.2	−15	−19	−21	−28	−31
		2070-Base	2.4	2.5	2.5	2.5	2.5	288	286	270	267	243	6.9	6.6	5.5	5.2	4.3	−19	−24	−26	−34	−36
VIC	Rutherglen	Base	17.4	18.2	18.6	18.8	19.0	1404	1498	1540	1557	1580	17.3	19.5	20.2	20.4	20.8	16-Mar	18-Mar	19-Mar	22-Mar	1-Apr
		2030	18.3	19.1	19.5	19.7	19.9	1511	1590	1627	1642	1662	19.6	21.0	21.8	22.0	22.3	10-Mar	12-Mar	13-Mar	15-Mar	21-Mar
		2050	19.1	19.9	20.3	20.5	20.7	1594	1663	1694	1708	1726	20.9	22.3	22.9	23.1	23.5	6-Mar	7-Mar	8-Mar	10-Mar	15-Mar
		2070	19.8	20.7	21.1	21.2	21.5	1663	1723	1750	1763	1779	22.1	23.4	24.0	24.2	24.5	2-Mar	3-Mar	4-Mar	6-Mar	10-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	107	92	87	85	82	2.3	1.5	1.6	1.6	1.5	−6	−6	−6	−7	−11
		2050-Base	1.7	1.7	1.7	1.7	1.7	190	165	154	151	146	3.6	2.8	2.7	2.7	2.7	−10	−11	−11	−12	−17
		2070-Base	2.4	2.5	2.5	2.4	2.5	259	225	210	206	199	4.8	3.9	3.8	3.8	3.7	−14	−15	−15	−16	−22
VIC	Glenrowan	Base	17.1	18.5	18.7	18.9	19.1	1378	1543	1567	1587	1607	16.5	20.0	20.4	20.7	21.2	14-Mar	16-Mar	17-Mar	19-Mar	5-Apr
		2030	18.0	19.4	19.7	19.8	20.0	1490	1631	1651	1668	1685	19.2	21.6	21.9	22.1	22.5	8-Mar	10-Mar	11-Mar	12-Mar	22-Mar
		2050	18.8	20.2	20.4	20.6	20.8	1574	1697	1715	1729	1745	20.5	22.6	23.0	23.2	23.6	4-Mar	5-Mar	6-Mar	8-Mar	16-Mar
		2070	19.6	21.0	21.2	21.3	21.6	1644	1754	1770	1782	1797	21.7	23.7	24.0	24.2	24.5	1-Mar	2-Mar	2-Mar	4-Mar	11-Mar
		2030-Base	0.9	0.9	1.0	0.9	0.9	112	88	84	81	78	2.7	1.6	1.5	1.4	1.3	−6	−6	−6	−7	−14
		2050-Base	1.7	1.7	1.7	1.7	1.7	196	154	148	142	138	4.0	2.6	2.6	2.5	2.4	−10	−11	−11	−11	−20
		2070-Base	2.5	2.5	2.5	2.4	2.5	266	211	203	195	190	5.2	3.7	3.6	3.5	3.3	−13	−14	−15	−15	−25

Table 2. *Continued*

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
VIC	Goulburn Valley	Base	17.1	18.4	18.8	19.3	20.0	1396	1558	1594	1631	1688	16.7	19.9	20.6	21.4	22.4	8-Mar	12-Mar	15-Mar	17-Mar	4-Apr
		2030	17.9	19.3	19.7	20.2	20.9	1506	1645	1675	1707	1757	19.1	21.4	21.9	22.7	23.6	3-Mar	7-Mar	9-Mar	11-Mar	22-Mar
		2050	18.7	20.1	20.5	21.0	21.7	1585	1710	1736	1764	1805	20.3	22.4	22.9	23.7	24.6	28-Feb	3-Mar	5-Mar	7-Mar	16-Mar
		2070	19.4	20.8	21.3	21.8	22.5	1654	1765	1789	1809	1839	21.5	23.4	24.0	24.6	25.4	26-Feb	28-Feb	1-Mar	3-Mar	11-Mar
		2030-Base	0.8	0.9	0.9	0.9	0.9	110	87	81	76	69	2.4	1.5	1.3	1.3	1.2	−5	−5	−6	−6	−13
		2050-Base	1.6	1.7	1.7	1.7	1.7	189	152	142	133	117	3.6	2.5	2.3	2.3	2.2	−9	−9	−10	−10	−19
		2070-Base	2.3	2.4	2.5	2.5	2.5	258	207	195	178	151	4.8	3.5	3.4	3.2	3.0	−11	−13	−14	−14	−24
NSW	Pericoota	Base	19.2	19.3	19.4	19.5	19.6	1616	1628	1639	1645	1659	21.1	21.3	21.4	21.5	21.7	10-Mar	11-Mar	12-Mar	12-Mar	13-Mar
		2030	20.1	20.2	20.3	20.4	20.5	1693	1703	1713	1718	1730	22.3	22.5	22.6	22.7	23.0	5-Mar	6-Mar	6-Mar	7-Mar	8-Mar
		2050	20.9	21.0	21.1	21.2	21.3	1752	1761	1769	1773	1784	23.4	23.5	23.7	23.8	24.0	1-Mar	2-Mar	2-Mar	3-Mar	3-Mar
		2070	21.6	21.8	21.9	21.9	22.1	1801	1808	1813	1816	1824	24.3	24.4	24.6	24.7	24.9	27-Feb	27-Feb	27-Feb	28-Feb	28-Feb
		2030-Base	0.9	0.9	0.9	0.9	0.9	77	75	74	73	71	1.2	1.2	1.2	1.2	1.3	−5	−5	−6	−5	−5
		2050-Base	1.7	1.7	1.7	1.7	1.7	136	133	130	128	125	2.3	2.2	2.3	2.3	2.3	−9	−9	−10	−9	−10
		2070-Base	2.4	2.5	2.5	2.4	2.5	185	180	174	171	165	3.2	3.1	3.2	3.2	3.2	−12	−13	−14	−13	−14
NSW	Cowra	Base	18.7	19.7	20.0	20.3	20.6	1554	1655	1685	1705	1730	20.1	21.6	22.0	22.4	22.8	6-Mar	8-Mar	9-Mar	11-Mar	18-Mar
		2030	19.6	20.6	20.9	21.2	21.5	1644	1733	1760	1776	1796	21.5	22.9	23.3	23.6	24.0	1-Mar	2-Mar	3-Mar	5-Mar	11-Mar
		2050	20.4	21.4	21.7	22.0	22.3	1712	1789	1812	1824	1839	22.7	24.0	24.4	24.7	24.9	26-Feb	27-Feb	27-Feb	1-Mar	6-Mar
		2070	21.1	22.2	22.5	22.8	23.1	1770	1829	1848	1858	1870	23.7	24.9	25.1	25.4	25.6	23-Feb	24-Feb	25-Feb	26-Feb	2-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	90	78	75	71	66	1.4	1.3	1.3	1.2	1.2	−5	−6	−6	−6	−7
		2050-Base	1.7	1.7	1.7	1.7	1.7	158	134	127	119	109	2.6	2.4	2.4	2.3	2.1	−9	−10	−11	−10	−12
		2070-Base	2.4	2.5	2.5	2.5	2.5	216	174	163	153	140	3.6	3.3	3.1	3.0	2.8	−12	−13	−13	−14	−16
NSW	Riverina	Base	18.1	20.5	21.1	21.6	22.6	1486	1720	1759	1790	1836	19.3	23.1	23.8	24.4	25.4	25-Feb	1-Mar	3-Mar	6-Mar	23-Mar
		2030	19.1	21.5	22.0	22.5	23.6	1579	1783	1813	1836	1873	20.9	24.3	24.9	25.4	26.3	23-Feb	26-Feb	27-Feb	1-Mar	16-Mar
		2050	19.8	22.3	22.8	23.4	24.4	1651	1825	1849	1868	1890	22.2†	25.3	25.7	26.2	27.2	22-Feb†	23-Feb	25-Feb	26-Feb	10-Mar
		2070	20.6	23.1	23.6	24.2	25.2	1715	1857	1877	1888	1895	23.3†	26.0†	26.5	27.0	27.9	22-Feb†	22-Feb†	23-Feb	24-Feb	6-Mar
		2030-Base	1.0	1.0	0.9	0.9	1.0	93	63	54	46	37	1.6	1.2	1.1	1.0	0.9	−2	−4	−5	−5	−7
		2050-Base	1.7	1.8	1.7	1.8	1.8	165	105	90	78	54	2.9†	2.2	1.9	1.8	1.8	−3†	−7	−7	−9	−13
		2070-Base	2.5	2.6	2.5	2.6	2.6	229	137	118	98	59	4.0†	2.9†	2.7	2.6	2.5	−3†	−8†	−9	−11	−17
NSW	Hastings River	Base	18.7	20.5	20.9	21.0	21.1	1699	1840	1860	1865	1871	19.7	21.8	22.2	22.3	22.5	25-Feb	25-Feb	26-Feb	27-Feb	8-Mar
		2030	19.7	21.5	21.8	22.0	22.1	1784	1885	1893	1895	1896	20.8†	22.7†	23.1†	23.2	23.4	22-Feb†	22-Feb†	22-Feb†	23-Feb	2-Mar
		2050	20.5	22.3	22.6	22.8	22.9	1839	1898	1899†	1899†	1899†	21.7†	23.5†	23.8†	24.0†	24.2	22-Feb†	22-Feb†	22-Feb†	22-Feb†	26-Feb
		2070	21.3	23.0	23.4	23.5	23.6	1874	1899†	1899†	1899†	1899†	22.5†	24.3†	24.6†	24.7†	24.9	22-Feb†	22-Feb†	22-Feb†	22-Feb†	23-Feb
		2030-Base	1.0	1.0	0.9	1.0	1.0	85	45	33	30	25	1.1†	0.9†	0.9†	0.9	0.9	−3†	−3†	−4†	−4	−6
		2050-Base	1.8	1.8	1.7	1.8	1.8	140	58	39†	34†	28†	2.0†	1.7†	1.6†	1.7†	1.7	−3†	−3†	−4†	−5†	−11
		2070-Base	2.6	2.5	2.5	2.5	2.5	175	59†	39†	34†	28†	2.8†	2.5†	2.4†	2.4†	2.4	−3†	−3†	−4†	−5†	−14
NSW	Southern Highlands	Base	16.4	16.7	17.1	17.7	19.0	1340	1405	1477	1575	1717	15.0	16.5	17.4	18.4	20.3	8-Mar	18-Mar	27-Mar	5-Apr	16-Apr
		2030	17.2	17.6	18.0	18.6	19.9	1482	1541	1601	1680	1795	17.6	18.2	18.9	19.6	21.5	2-Mar	10-Mar	15-Mar	20-Mar	25-Mar
		2050	18.0	18.4	18.8	19.4	20.7	1588	1649	1689	1756	1851	18.9	19.4	20.0	20.7	22.5	26-Feb	4-Mar	9-Mar	12-Mar	15-Mar
		2070	18.8	19.1	19.5	20.1	21.4	1672	1727	1760	1818	1883	19.9	20.4	20.9	21.7	23.2	23-Feb	27-Feb	3-Mar	6-Mar	9-Mar
		2030-Base	0.8	0.9	0.9	0.9	0.9	142	136	124	105	78	2.6	1.7	1.5	1.2	1.2	−6	−8	−12	−16	−22
		2050-Base	1.6	1.7	1.7	1.7	1.7	248	244	212	181	134	3.9	2.9	2.6	2.3	2.2	−11	−14	−18	−24	−32
		2070-Base	2.4	2.4	2.4	2.4	2.4	332	322	283	243	166	4.9	3.9	3.5	3.3	2.9	−14	−20	−24	−30	−38

Table 2. *Continued*

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
NSW	Canberra District	Base	16.8	17.0	17.4	17.7	19.1	1361	1392	1422	1468	1614	16.1	16.9	17.7	18.7	21.0	14-Mar	24-Mar	29-Mar	2-Apr	7-Apr
		2030	17.7	17.9	18.2	18.6	20.0	1475	1504	1530	1566	1694	18.5	18.9	19.5	20.2	22.3	8-Mar	16-Mar	19-Mar	20-Mar	23-Mar
		2050	18.4	18.7	19.0	19.4	20.8	1564	1590	1610	1643	1756	19.8	20.3	20.7	21.3	23.3	3-Mar	11-Mar	13-Mar	14-Mar	16-Mar
		2070	19.2	19.4	19.8	20.2	21.5	1637	1662	1682	1712	1805	20.8	21.4	21.8	22.4	24.3	28-Feb	6-Mar	8-Mar	9-Mar	11-Mar
		2030-Base	0.9	0.9	0.8	0.9	0.9	114	112	108	98	80	2.4	2.0	1.8	1.5	1.3	−6	−8	−10	−13	−15
		2050-Base	1.6	1.7	1.6	1.7	1.7	203	198	188	175	142	3.7	3.4	3.0	2.6	2.3	−11	−13	−16	−19	−22
		2070-Base	2.4	2.4	2.4	2.5	2.4	276	270	260	244	191	4.7	4.5	4.1	3.7	3.3	−15	−18	−21	−24	−27
VIC	Strathbogie Ranges	Base	16.4	16.9	17.3	17.8	18.5	1310	1374	1433	1498	1560	13.6	16.1	17.7	19.0	20.2	17-Mar	22-Mar	29-Mar	6-Apr	23-Apr
		2030	17.3	17.8	18.2	18.7	19.4	1432	1486	1540	1594	1645	17.6	18.9	19.6	20.5	21.7	11-Mar	15-Mar	19-Mar	22-Mar	29-Mar
		2050	18.1	18.6	19.0	19.5	20.2	1525	1573	1617	1665	1710	19.4	20.2	21.0	21.6	22.6	7-Mar	10-Mar	13-Mar	16-Mar	19-Mar
		2070	18.8	19.3	19.7	20.2	21.0	1601	1642	1683	1723	1765	20.6	21.4	21.9	22.6	23.7	3-Mar	6-Mar	8-Mar	11-Mar	14-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	122	112	107	96	85	4.0	2.8	1.9	1.5	1.5	−6	−7	−10	−15	−25
		2050-Base	1.7	1.7	1.7	1.7	1.7	215	199	184	167	150	5.8	4.1	3.3	2.6	2.4	−10	−12	−16	−21	−35
		2070-Base	2.4	2.4	2.4	2.4	2.5	291	268	250	225	205	7.0	5.3	4.2	3.6	3.5	−14	−16	−21	−26	−40
VIC	Alpine Valleys	Base	16.3	17.0	17.6	18.2	19.2	1275	1379	1450	1523	1614	13.0	16.8	18.2	19.7	21.3†	14-Mar	20-Mar	27-Mar	5-Apr	30-Apr†
		2030	17.2	17.9	18.5	19.1	20.1	1400	1492	1554	1614	1692	17.0	19.0	19.9	21.2	22.7	8-Mar	13-Mar	18-Mar	22-Mar	1-Apr
		2050	18.0	18.7	19.2	19.9	20.9	1497	1578	1632	1683	1752	19.1	20.3	21.3	22.3	23.7	4-Mar	8-Mar	12-Mar	15-Mar	21-Mar
		2070	18.7	19.4	20.0	20.6	21.7	1578	1650	1698	1742	1803	20.4	21.5	22.3	23.2	24.6	28-Feb	4-Mar	7-Mar	10-Mar	15-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	125	113	104	91	78	4.0	2.2	1.7	1.5	1.4†	−6	−7	−9	−14	−29†
		2050-Base	1.7	1.7	1.6	1.7	1.7	222	199	182	160	138	6.1	3.5	3.1	2.6	2.4†	−10	−12	−15	−21	−40†
		2070-Base	2.4	2.4	2.4	2.4	2.5	303	271	248	219	189	7.4	4.7	4.1	3.5	3.3†	−15	−16	−20	−26	−46†
WA	Blackwood Valley	Base	17.1	17.7	18.0	18.3	18.8	1415	1494	1521	1556	1655	16.7	18.4	19.1	19.8	20.6	16-Mar	22-Mar	24-Mar	28-Mar	6-Apr
		2030	18.0	18.6	18.9	19.2	19.7	1532	1596	1620	1652	1736	19.2	20.1	20.5	20.9	21.6	10-Mar	15-Mar	17-Mar	19-Mar	24-Mar
		2050	18.7	19.3	19.7	19.9	20.4	1618	1676	1698	1724	1789	20.4	20.9	21.4	21.8	22.5	6-Mar	10-Mar	12-Mar	14-Mar	18-Mar
		2070	19.4	20.0	20.4	20.7	21.2	1692	1739	1758	1780	1828	21.1	21.8	22.3	22.7	23.3	2-Mar	6-Mar	7-Mar	9-Mar	13-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	117	102	99	96	81	2.5	1.7	1.4	1.1	1.0	−6	−7	−7	−9	−13
		2050-Base	1.6	1.6	1.7	1.6	1.6	203	182	177	168	134	3.7	2.5	2.3	2.0	1.9	−10	−12	−12	−14	−19
		2070-Base	2.3	2.3	2.4	2.4	2.4	277	245	237	224	173	4.4	3.4	3.2	2.9	2.7	−14	−16	−17	−19	−24
NSW	Tumbarumba	Base	17.0	17.5	17.9	18.3	19.0	1377	1441	1480	1541	1584	16.5	18.1	18.9	19.7	20.8	16-Mar	19-Mar	24-Mar	27-Mar	5-Apr
		2030	17.9	18.4	18.8	19.2	19.9	1493	1544	1577	1634	1666	19.0	19.9	20.4	21.2	22.2	10-Mar	12-Mar	16-Mar	18-Mar	22-Mar
		2050	18.7	19.2	19.5	20.0	20.7	1576	1619	1649	1703	1729	20.3	21.1	21.7	22.2	23.2	5-Mar	7-Mar	11-Mar	13-Mar	16-Mar
		2070	19.4	19.9	20.3	20.7	21.4	1650	1688	1714	1763	1785	21.4	22.1	22.8	23.4	24.4	1-Mar	3-Mar	6-Mar	8-Mar	10-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	116	103	97	93	82	2.5	1.8	1.5	1.5	1.4	−6	−-7	−8	−9	−14
		2050-Base	1.7	1.7	1.6	1.7	1.7	199	178	169	162	145	3.8	3.0	2.8	2.5	2.4	−11	−12	−13	−14	−20
		2070-Base	2.4	2.4	2.4	2.4	2.4	273	247	234	222	201	4.9	4.0	3.9	3.7	3.6	−15	−16	−18	−19	−26
VIC	Heathcote	Base	16.3	17.4	17.8	18.2	18.7	1292	1444	1490	1528	1585	14.1	18.1	18.9	19.5	20.3†	16-Mar	20-Mar	23-Mar	28-Mar	30-Apr†
		2030	17.2	18.3	18.7	19.1	19.6	1417	1549	1588	1618	1666	17.3	19.7	20.4	21.1	21.8	10-Mar	13-Mar	15-Mar	18-Mar	31-Mar
		2050	17.9	19.0	19.5	19.8	20.4	1505	1622	1656	1685	1728	19.0	21.1	21.6	22.1	22.8	5-Mar	8-Mar	11-Mar	13-Mar	22-Mar
		2070	18.6	19.7	20.2	20.6	21.2	1583	1687	1716	1741	1780	20.4	22.0	22.5	23.1	23.8	2-Mar	4-Mar	6-Mar	8-Mar	15-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	125	105	98	90	81	3.2	1.6	1.5	1.6	1.5†	−6	−7	−8	−10	−30†
		2050-Base	1.6	1.6	1.7	1.6	1.7	213	178	166	157	143	4.9	3.0	2.7	2.6	2.5†	−11	−12	−12	−15	−39†
		2070-Base	2.3	2.3	2.4	2.4	2.5	291	243	226	213	195	6.3	3.9	3.6	3.6	3.5†	−14	−16	−17	−20	−46†

Table 2. *Continued*

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
NSW	Young	Base	17.5	18.3	18.6	18.9	19.9	1424	1521	1550	1577	1673	17.9	19.7	20.2	20.6	22.2	10-Mar	17-Mar	18-Mar	20-Mar	29-Mar
		2030	18.4	19.2	19.5	19.8	20.8	1530	1612	1637	1662	1746	19.7	21.1	21.6	22.0	23.4	5-Mar	10-Mar	12-Mar	13-Mar	19-Mar
		2050	19.2	20.0	20.3	20.6	21.6	1609	1683	1707	1728	1799	21.0	22.3	22.7	23.2	24.4	1-Mar	5-Mar	7-Mar	8-Mar	13-Mar
		2070	19.9	20.7	21.0	21.4	22.3	1681	1745	1766	1783	1836	22.1	23.3	23.8	24.2	25.3	26-Feb	1-Mar	2-Mar	4-Mar	8-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	106	91	87	85	73	1.8	1.4	1.4	1.4	1.2	−5	−7	−6	−7	−10
		2050-Base	1.7	1.7	1.7	1.7	1.7	185	162	157	151	126	3.1	2.6	2.5	2.6	2.2	−9	−12	−11	−12	−16
		2070-Base	2.4	2.4	2.4	2.5	2.4	257	224	216	206	163	4.2	3.6	3.6	3.6	3.1	−13	−16	−16	−16	−21
NSW	Gundagai	Base	15.7	18.4	19.0	19.4	20.0	1188	1535	1587	1626	1675	13.1	20.0	20.9	21.7	22.4†	10-Mar	13-Mar	16-Mar	20-Mar	30-Apr†
		2030	16.6	19.3	19.9	20.3	20.8	1322	1622	1668	1704	1747	14.6	21.4	22.2	22.9	23.7	4-Mar	7-Mar	10-Mar	13-Mar	16-Apr
		2050	17.4	20.1	20.7	21.1	21.6	1431	1692	1733	1764	1799	17.9	22.5	23.3	24.0	24.8	1-Mar	3-Mar	5-Mar	8-Mar	27-Mar
		2070	18.1	20.9	21.4	21.9	22.4	1521	1751	1787	1810	1837	19.4	23.6	24.4	25.0	25.6	26-Feb	28-Feb	1-Mar	4-Mar	19-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.8	134	87	81	78	72	1.5	1.4	1.3	1.2	1.3†	−6	−6	−6	−7	−14†
		2050-Base	1.7	1.7	1.7	1.7	1.6	243	157	146	138	124	4.8	2.5	2.4	2.3	2.4†	−9	−10	−11	−12	−34†
		2070-Base	2.4	2.5	2.4	2.5	2.4	333	216	200	184	162	6.3	3.6	3.5	3.3	3.2†	−13	−14	−15	−16	−42†
NSW	Shoalhaven Coast	Base	17.1	18.9	19.3	19.6	19.9	1486	1718	1756	1780	1809	17.5	20.1	20.6	20.9	21.3	2-Mar	4-Mar	6-Mar	9-Mar	28-Mar
		2030	18.0	19.8	20.2	20.5	20.8	1617	1795	1828	1849	1869	19.0	21.2	21.7	21.9	22.3	25-Feb	26-Feb	28-Feb	2-Mar	15-Mar
		2050	18.8	20.6	21.0	21.3	21.6	1705	1853	1874	1885	1894	20.0†	22.1	22.4	22.7	23.0	22-Feb†	23-Feb	24-Feb	26-Feb	9-Mar
		2070	19.5	21.3	21.7	22.0	22.3	1776	1885	1895	1897	1898	20.9†	22.8†	23.1†	23.4	23.7	22-Feb†	22-Feb†	22-Feb†	23-Feb	3-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	131	77	72	69	60	1.5	1.1	1.1	1.0	1.0	−6	−7	−7	−7	−13
		2050-Base	1.7	1.7	1.7	1.7	1.7	219	135	118	105	85	2.5†	2.0	1.8	1.8	1.7	−9†	−10	−11	−12	−19
		2070-Base	2.4	2.4	2.4	2.4	2.4	290	167	139	117	89	3.4†	2.7†	2.5†	2.5	2.4	−9†	−11†	−13†	−15	−25
VIC	Swan Hill	Base	19.7	20.1	20.3	20.5	20.6	1682	1711	1725	1736	1747	21.9	22.4	22.7	22.9	23.1	3-Mar	4-Mar	5-Mar	6-Mar	8-Mar
		2030	20.5	21.0	21.2	21.3	21.5	1749	1774	1785	1794	1802	23.1	23.6	23.8	24.1	24.2	28-Feb	28-Feb	1-Mar	2-Mar	4-Mar
		2050	21.3	21.7	21.9	22.1	22.3	1799	1817	1825	1832	1840	24.0	24.5	24.7	24.9	25.0	25-Feb	26-Feb	26-Feb	27-Feb	28-Feb
		2070	22.0	22.5	22.7	22.9	23.1	1835	1850	1856	1861	1867	24.8	25.2	25.4	25.6	25.8	23-Feb	24-Feb	24-Feb	25-Feb	26-Feb
		2030-Base	0.8	0.9	0.9	0.8	0.9	67	63	60	58	55	1.2	1.2	1.1	1.2	1.1	−4	−5	−4	−4	−4
		2050-Base	1.6	1.6	1.6	1.6	1.7	117	106	100	96	93	2.1	2.1	2.0	2.0	1.9	−7	−7	−8	−8	−9
		2070-Base	2.3	2.4	2.4	2.4	2.5	153	139	131	125	120	2.9	2.8	2.7	2.7	2.7	−9	−9	−10	−10	−11
VIC	Murray Darling	Base	20.4	20.7	20.8	21.0	22.0	1733	1753	1763	1780	1822	22.8	23.1	23.3	23.6	24.7	26-Feb	1-Mar	2-Mar	3-Mar	4-Mar
		2030	21.3	21.5	21.7	21.9	22.9	1791	1806	1814	1826	1860	23.8	24.2	24.4	24.6	25.6	24-Feb	26-Feb	27-Feb	27-Feb	28-Feb
		2050	22.0	22.3	22.5	22.7	23.7	1829	1841	1848	1857	1883	24.5†	24.9	25.1	25.3	26.4	22-Feb†	24-Feb	25-Feb	25-Feb	26-Feb
		2070	22.7	23.0	23.2	23.4	24.5	1859	1870	1876	1882	1893	25.2†	25.6†	25.8	26.0	27.1	22-Feb†	22-Feb†	23-Feb	23-Feb	24-Feb
		2030-Base	0.9	0.8	0.9	0.9	0.9	58	53	51	46	38	1.0	1.1	1.1	1.0	0.9	−2	−4	−4	−5	−5
		2050-Base	1.6	1.6	1.7	1.7	1.7	96	88	85	77	61	1.7†	1.8	1.8	1.7	1.7	−4†	−6	−6	−7	−7
		2070-Base	2.3	2.3	2.4	2.4	2.5	126	117	113	102	71	2.4†	2.5†	2.5	2.4	2.4	−4†	−8†	−8	−9	−9
VIC	Upper Goulburn	Base	16.4	16.7	17.0	17.3	18.0	1308	1360	1397	1435	1526	13.4	15.5	16.7	17.6	19.2	21-Mar	29-Mar	3-Apr	10-Apr	24-Apr
		2030	17.2	17.6	17.9	18.1	18.9	1431	1476	1509	1543	1619	17.5	18.5	19.0	19.5	20.7	14-Mar	19-Mar	21-Mar	24-Mar	29-Mar
		2050	17.9	18.3	18.6	18.9	19.6	1525	1563	1591	1621	1683	19.1	19.8	20.4	20.8	21.8	9-Mar	13-Mar	15-Mar	17-Mar	20-Mar
		2070	18.7	19.1	19.3	19.6	20.3	1601	1637	1661	1687	1740	20.4	21.1	21.4	21.8	22.7	5-Mar	8-Mar	10-Mar	11-Mar	14-Mar
		2030-Base	0.8	0.9	0.9	0.8	0.9	123	116	112	108	93	4.1	3.0	2.3	1.9	1.5	−7	−10	−13	−17	−26
		2050-Base	1.5	1.6	1.6	1.6	1.6	217	203	194	186	157	5.7	4.3	3.7	3.2	2.6	−12	−16	−19	−24	−35
		2070-Base	2.3	2.4	2.3	2.3	2.3	293	277	264	252	214	7.0	5.6	4.7	4.2	3.5	−16	−21	−24	−30	−41

Table 2. *Continued*

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
WA	Manjimup	Base	17.3	17.6	17.8	17.9	18.3	1411	1481	1501	1521	1559	16.6	17.9	18.3	18.6	19.4	22-Mar	26-Mar	28-Mar	30-Mar	8-Apr
		2030	18.2	18.5	18.7	18.8	19.2	1534	1589	1605	1621	1657	18.9	19.7	19.9	20.1	20.5	15-Mar	18-Mar	19-Mar	20-Mar	25-Mar
		2050	18.9	19.2	19.4	19.5	19.9	1619	1669	1683	1698	1729	20.1	20.5	20.7	20.9	21.3	10-Mar	12-Mar	14-Mar	15-Mar	18-Mar
		2070	19.6	19.9	20.1	20.2	20.6	1693	1736	1748	1760	1786	20.9	21.3	21.5	21.7	22.0	6-Mar	8-Mar	9-Mar	10-Mar	13-Mar
		2030-Base	0.9	0.9	0.9	0.9	0.9	123	108	104	100	98	2.3	1.8	1.6	1.5	1.1	−7	−8	−9	−10	−14
		2050-Base	1.6	1.6	1.6	1.6	1.6	208	188	182	177	170	3.5	2.6	2.4	2.3	1.9	−12	−14	−14	−15	−21
		2070-Base	2.3	2.3	2.3	2.3	2.3	282	255	247	239	227	4.3	3.4	3.2	3.1	2.6	−16	−18	−19	−20	−26
WA	Pemberton	Base	17.4	17.6	17.8	18.0	18.5	1436	1505	1531	1566	1632	17.1	18.2	18.7	19.1	19.9	18-Mar	23-Mar	25-Mar	28-Mar	4-Apr
		2030	18.2	18.5	18.6	18.8	19.3	1554	1612	1633	1663	1719	19.3	19.8	20.1	20.2	20.8	11-Mar	15-Mar	17-Mar	19-Mar	23-Mar
		2050	18.9	19.2	19.4	19.5	20.1	1638	1692	1710	1736	1780	20.2	20.5	20.8	21.0	21.6	6-Mar	10-Mar	12-Mar	13-Mar	17-Mar
		2070	19.6	19.8	20.1	20.2	20.8	1710	1755	1771	1790	1821	21.0	21.4	21.6	21.7	22.3	3-Mar	6-Mar	7-Mar	8-Mar	12-Mar
		2030-Base	0.8	0.9	0.8	0.8	0.8	118	107	102	97	87	2.2	1.6	1.4	1.1	0.9	−7	−8	−8	−9	−12
		2050-Base	1.5	1.6	1.6	1.5	1.6	202	187	179	170	148	3.1	2.3	2.1	1.9	1.7	−12	−13	−13	−15	−18
		2070-Base	2.2	2.2	2.3	2.2	2.3	274	250	240	224	189	3.9	3.2	2.9	2.6	2.4	−15	−17	−18	−20	−23
VIC	Bendigo	Base	16.2	17.5	18.0	18.5	19.0	1264	1457	1512	1560	1613	12.9	18.3	19.3	20.0	20.9†	14-Mar	17-Mar	21-Mar	27-Mar	30-Apr†
		2030	17.1	18.3	18.9	19.3	19.9	1392	1556	1606	1646	1690	16.6	19.8	20.8	21.5	22.2	8-Mar	11-Mar	14-Mar	18-Mar	3-Apr
		2050	17.8	19.1	19.6	20.1	20.6	1481	1630	1672	1708	1749	18.8	21.2	21.8	22.4	23.1	4-Mar	7-Mar	9-Mar	13-Mar	23-Mar
		2070	18.5	19.8	20.3	20.8	21.4	1561	1691	1728	1761	1795	20.0	22.1	22.7	23.4	24.1	1-Mar	3-Mar	6-Mar	8-Mar	17-Mar
		2030-Base	0.9	0.8	0.9	0.8	0.9	128	99	94	86	77	3.7	1.5	1.5	1.5	1.3†	−6	−6	−7	−9	−27†
		2050-Base	1.6	1.6	1.6	1.6	1.6	217	173	160	148	136	5.9	2.9	2.5	2.4	2.2†	−10	−10	−12	−14	−38†
		2070-Base	2.3	2.3	2.3	2.3	2.4	297	234	216	201	182	7.1	3.8	3.4	3.4	3.2†	−13	−14	−15	−19	−44†
WA	Geographe	Base	17.4	18.5	18.9	19.6	20.4	1466	1590	1636	1714	1763	17.9	20.3	20.9	21.6	22.8	7-Mar	11-Mar	17-Mar	20-Mar	31-Mar
		2030	18.3	19.4	19.7	20.4	21.3	1571	1683	1720	1779	1817	19.9	21.4	21.8	22.7	23.7	3-Mar	6-Mar	11-Mar	13-Mar	22-Mar
		2050	19.0	20.1	20.5	21.2	22.1	1651	1748	1777	1822	1851	20.9	22.3	22.7	23.4	24.5	27-Feb	2-Mar	6-Mar	8-Mar	16-Mar
		2070	19.7	20.9	21.2	21.9	22.9	1719	1798	1818	1852	1870	21.7	23.1	23.5	24.2	25.2	25-Feb	27-Feb	3-Mar	4-Mar	11-Mar
		2030-Base	0.9	0.9	0.8	0.8	0.9	105	93	84	65	54	2.0	1.1	0.9	1.1	0.9	−4	−5	−6	−7	−9
		2050-Base	1.6	1.6	1.6	1.6	1.7	185	158	141	108	88	3.0	2.0	1.8	1.8	1.7	−9	−9	−11	−12	−15
		2070-Base	2.3	2.4	2.3	2.3	2.5	253	208	182	138	107	3.8	2.8	2.6	2.6	2.4	−11	−13	−14	−16	−20
VIC	Macedon Ranges	Base	15.3	15.6	15.9	16.3	17.2	1118	1162	1226	1287	1416	12.0	14.0†	14.8†	15.3†	17.2†	1-Apr	30-Apr†	30-Apr†	30-Apr†	30-Apr†
		2030	16.1	16.4	16.7	17.1	18.0	1268	1307	1360	1411	1518	12.9	14.8	16.2	17.2	19.3†	21-Mar	1-Apr	11-Apr	25-Apr	30-Apr†
		2050	16.8	17.1	17.5	17.9	18.7	1384	1414	1457	1502	1599	16.1	17.0	18.1	19.0	20.6	15-Mar	22-Mar	26-Mar	1-Apr	7-Apr
		2070	17.5	17.8	18.1	18.6	19.4	1475	1504	1541	1581	1663	18.3	18.8	19.3	20.2	21.6	10-Mar	16-Mar	19-Mar	22-Mar	25-Mar
		2030-Base	0.8	0.8	0.8	0.8	0.8	150	145	134	124	102	0.9	0.8†	1.4†	1.9†	2.1†	−11	−29†	−19†	−5†	0†
		2050-Base	1.5	1.5	1.6	1.6	1.5	266	252	231	215	183	3.1	3.0†	3.3†	3.7†	3.4†	−17	−39†	−35†	−29†	−23†
		2070-Base	2.2	2.2	2.2	2.3	2.2	357	342	315	294	247	5.3	4.8†	4.5†	4.9†	4.4†	−22	−45†	−42†	−39†	−36†
VIC	Sunbury	Base	16.9	17.0	17.1	17.4	18.0	1402	1423	1446	1493	1575	16.6	16.9	17.4	18.2	19.2	18-Mar	26-Mar	31-Mar	3-Apr	5-Apr
		2030	17.7	17.8	17.9	18.2	18.8	1516	1534	1553	1592	1662	18.6	18.8	19.0	19.5	20.5	12-Mar	17-Mar	20-Mar	22-Mar	23-Mar
		2050	18.4	18.5	18.6	18.9	19.5	1602	1616	1632	1667	1727	19.8	20.0	20.3	20.7	21.4	7-Mar	11-Mar	14-Mar	15-Mar	16-Mar
		2070	19.0	19.1	19.3	19.6	20.2	1668	1683	1697	1728	1780	20.9	21.0	21.1	21.6	22.2	3-Mar	7-Mar	9-Mar	10-Mar	11-Mar
		2030-Base	0.8	0.8	0.8	0.8	0.8	114	111	107	99	87	2.0	1.9	1.6	1.3	1.3	−6	−9	−11	−12	−13
		2050-Base	1.5	1.5	1.5	1.5	1.5	200	193	186	174	152	3.2	3.1	2.9	2.5	2.2	−11	−15	−17	−19	−20
		2070-Base	2.1	2.1	2.2	2.2	2.2	266	260	251	235	205	4.3	4.1	3.7	3.4	3.0	−15	−19	−22	−24	−25

Table 2. *Continued*

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
VIC	Yarra Valley	Base	16.3	17.1	17.3	17.4	18.0	1322	1438	1479	1497	1578	14.4	17.3	17.9	18.2	19.3	18-Mar	25-Mar	27-Mar	31-Mar	22-Apr
		2030	17.1	17.8	18.1	18.3	18.8	1453	1549	1581	1599	1663	17.4	18.9	19.3	19.7	20.6	11-Mar	16-Mar	17-Mar	20-Mar	30-Mar
		2050	17.8	18.6	18.8	19.0	19.6	1553	1634	1660	1673	1729	18.9	20.2	20.6	20.8	21.5	6-Mar	10-Mar	11-Mar	13-Mar	19-Mar
		2070	18.5	19.2	19.5	19.7	20.2	1632	1699	1721	1734	1780	20.1	21.1	21.5	21.7	22.3	3-Mar	6-Mar	7-Mar	8-Mar	13-Mar
		2030-Base	0.8	0.7	0.8	0.9	0.8	131	111	102	102	85	3.0	1.6	1.4	1.5	1.3	−7	−9	−10	−11	−23
		2050-Base	1.5	1.5	1.5	1.6	1.6	231	196	181	176	151	4.5	2.9	2.7	2.6	2.2	−12	−15	−16	−18	−34
		2070-Base	2.2	2.1	2.2	2.3	2.2	310	261	242	237	202	5.7	3.8	3.6	3.5	3.0	−15	−19	−20	−23	−40
VIC	Pyrenees	Base	16.1	17.1	17.4	17.6	18.1	1259	1406	1448	1474	1534	14.4	16.8	17.9	18.5	19.5†	20-Mar	25-Mar	28-Mar	3-Apr	30-Apr†
		2030	16.9	17.8	18.2	18.4	19.0	1381	1506	1545	1569	1624	16.1	19.0	19.6	20.0	21.0	13-Mar	17-Mar	19-Mar	22-Mar	7-Apr
		2050	17.5	18.6	18.9	19.1	19.7	1473	1587	1621	1640	1686	18.2	20.2	20.9	21.2	21.9	9-Mar	12-Mar	14-Mar	16-Mar	26-Mar
		2070	18.2	19.2	19.6	19.8	20.4	1552	1653	1683	1700	1741	19.4	21.3	21.7	22.1	22.8	5-Mar	8-Mar	9-Mar	11-Mar	19-Mar
		2030-Base	0.8	0.7	0.8	0.8	0.9	122	100	97	95	90	1.7	2.2	1.7	1.5	1.5†	−7	−8	−9	−12	−23†
		2050-Base	1.4	1.5	1.5	1.5	1.6	214	181	173	166	152	3.8	3.4	3.0	2.7	2.4†	−11	−13	−14	−18	−35†
		2070-Base	2.1	2.1	2.2	2.2	2.3	293	247	235	226	207	5.0	4.5	3.8	3.6	3.3†	−15	−17	−19	−23	−42†
SA	Riverland	Base	20.5	20.8	20.9	21.0	21.3	1767	1779	1787	1793	1807	22.9	23.1	23.3	23.5	23.9	27-Feb	28-Feb	1-Mar	2-Mar	3-Mar
		2030	21.3	21.6	21.7	21.8	22.1	1817	1826	1832	1836	1846	23.8	24.1	24.2	24.3	24.6	25-Feb	26-Feb	26-Feb	27-Feb	28-Feb
		2050	22.0	22.2	22.4	22.5	22.9	1847	1854	1860	1864	1874	24.4	24.6	24.8	24.9	25.2	23-Feb	24-Feb	24-Feb	25-Feb	26-Feb
		2070	22.7	22.9	23.1	23.2	23.5	1873	1880	1884	1886	1890	24.9†	25.2†	25.4	25.6	25.9	22-Feb†	22-Feb†	23-Feb	23-Feb	24-Feb
		2030-Base	0.8	0.8	0.8	0.8	0.8	50	47	45	43	39	0.9	1.0	0.9	0.8	0.7	−2	−2	−4	−4	−4
		2050-Base	1.5	1.4	1.5	1.5	1.6	80	75	73	71	67	1.5	1.5	1.5	1.4	1.3	−4	−4	−6	−6	−6
		2070-Base	2.2	2.1	2.2	2.2	2.2	106	101	97	93	83	2.0†	2.1†	2.1	2.1	2.0	−5†	−6†	−7	−8	−8
VIC	Mornington Peninsula	Base	15.7	16.4	16.7	17.0	17.3	1197	1339	1402	1446	1499	15.0	16.0	16.9	17.3	18.0†	26-Mar	1-Apr	8-Apr	19-Apr	30-Apr†
		2030	16.5	17.2	17.5	17.8	18.1	1350	1475	1526	1563	1607	15.5	17.6	18.3	18.8	19.4	16-Mar	20-Mar	23-Mar	29-Mar	16-Apr
		2050	17.1	17.8	18.2	18.4	18.8	1461	1568	1614	1645	1681	17.4	18.8	19.4	20.0	20.4	11-Mar	13-Mar	16-Mar	19-Mar	30-Mar
		2070	17.7	18.4	18.8	19.1	19.4	1551	1646	1682	1708	1740	18.6	19.9	20.4	20.8	21.3	6-Mar	8-Mar	11-Mar	13-Mar	21-Mar
		2030-Base	0.8	0.8	0.8	0.8	0.8	153	136	124	117	108	0.5	1.6	1.4	1.5	1.4†	−10	−12	−16	−21	−14†
		2050-Base	1.4	1.4	1.5	1.4	1.5	264	229	212	199	182	2.4	2.8	2.5	2.7	2.4†	−15	−19	−23	−31	−31†
		2070-Base	2.0	2.0	2.1	2.1	2.1	354	307	280	262	241	3.6	3.9	3.5	3.5	3.3†	−20	−24	−28	−37	−40†
VIC	Geelong	Base	16.4	16.6	16.7	16.9	17.1	1334	1366	1388	1417	1451	15.0	15.7	16.0	16.8	17.4	31-Mar	5-Apr	10-Apr	13-Apr	19-Apr
		2030	17.2	17.4	17.5	17.7	17.9	1459	1489	1508	1533	1561	17.6	18.0	18.3	18.6	19.0	20-Mar	23-Mar	25-Mar	27-Mar	30-Mar
		2050	17.8	18.0	18.1	18.3	18.5	1548	1575	1592	1615	1637	18.8	19.2	19.4	19.7	20.2	14-Mar	16-Mar	18-Mar	19-Mar	21-Mar
		2070	18.4	18.6	18.8	18.9	19.2	1620	1646	1661	1683	1702	20.0	20.3	20.5	20.7	21.0	9-Mar	11-Mar	12-Mar	13-Mar	15-Mar
		2030-Base	0.8	0.8	0.8	0.8	0.8	125	123	120	116	110	2.6	2.3	2.3	1.8	1.6	−11	−13	−16	−17	−20
		2050-Base	1.4	1.4	1.4	1.4	1.4	214	209	204	198	186	3.8	3.5	3.4	2.9	2.8	−17	−20	−23	−25	−29
		2070-Base	2.0	2.0	2.1	2.0	2.1	286	280	273	266	251	5.0	4.6	4.5	3.9	3.6	−22	−25	−29	−31	−35
VIC	Grampians	Base	15.8	16.1	16.7	17.2	17.8	1212	1267	1361	1423	1497	13.1	15.5	16.6	17.7†	18.9†	23-Mar	1-Apr	12-Apr	30-Apr†	30-Apr†
		2030	16.5	16.9	17.5	17.9	18.6	1340	1389	1464	1520	1585	15.1	16.2	18.1	19.1	20.2	16-Mar	21-Mar	27-Mar	6-Apr	17-Apr
		2050	17.1	17.5	18.1	18.6	19.3	1429	1475	1544	1596	1655	17.1	18.2	19.4	20.4	21.4	11-Mar	15-Mar	20-Mar	26-Mar	1-Apr
		2070	17.7	18.2	18.8	19.3	19.9	1512	1554	1613	1660	1712	18.6	19.4	20.6	21.4	22.2	7-Mar	11-Mar	14-Mar	19-Mar	23-Mar
		2030-Base	0.7	0.8	0.8	0.7	0.8	128	122	103	97	88	2.0	0.7	1.5	1.4†	1.3†	−7	−11	−16	−24†	−13†
		2050-Base	1.3	1.4	1.4	1.4	1.5	217	208	183	173	158	4.0	2.7	2.8	2.7†	2.5†	−12	−17	−23	−35†	−29†
		2070-Base	1.9	2.1	2.1	2.1	2.1	300	287	252	237	215	5.5	3.9	4.0	3.7†	3.3†	−16	−21	−29	−42†	−38†

Table 2. *Continued*

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
WA	Great Southern	Base	15.7	17.5	17.8	18.1	19.5	1210	1510	1548	1589	1740	14.7	18.3	18.9	19.4	21.1†	9-Mar	21-Mar	24-Mar	27-Mar	30-Apr†
		2030	16.5	18.3	18.6	18.9	20.3	1366	1610	1643	1676	1797	15.7	19.7	19.9	20.2	21.8	5-Mar	15-Mar	17-Mar	19-Mar	16-Apr
		2050	17.2	19.0	19.2	19.6	20.9	1482	1687	1714	1740	1832	17.6	20.4	20.6	21.0	22.6	1-Mar	10-Mar	12-Mar	14-Mar	31-Mar
		2070	17.8	19.6	19.9	20.2	21.5	1571	1748	1768	1788	1857	19.0	21.1	21.4	21.7	23.1	27-Feb	6-Mar	8-Mar	9-Mar	22-Mar
		2030-Base	0.8	0.8	0.8	0.8	0.8	156	100	95	87	57	1.0	1.4	1.0	0.8	0.7†	−4	−6	−7	−8	−14†
		2050-Base	1.5	1.5	1.4	1.5	1.4	272	177	166	151	92	2.9	2.1	1.7	1.6	1.5†	−8	−11	−12	−13	−30†
		2070-Base	2.1	2.1	2.1	2.1	2.0	361	238	220	199	117	4.3	2.8	2.5	2.3	2.0†	−11	−15	−16	−18	−39†
SA	Southern Flinders Ranges	Base	17.1	18.9	19.5	20.0	21.8	1402	1606	1665	1722	1839	17.1	20.8	21.6	22.3	24.3	26-Feb	6-Mar	10-Mar	14-Mar	31-Mar
		2030	17.9	19.6	20.2	20.8	22.6	1502	1680	1734	1782	1871	19.0	21.7	22.4	23.1	24.8	24-Feb	2-Mar	5-Mar	9-Mar	21-Mar
		2050	18.6	20.4	20.9	21.5	23.2	1581	1739	1783	1821	1890	20.3	22.5	23.2	23.9	25.3	23-Feb	27-Feb	2-Mar	5-Mar	15-Mar
		2070	19.3	21.0	21.6	22.1	23.9	1643	1787	1821	1850	1898	21.2†	23.2	24.0	24.4	25.9	22-Feb†	25-Feb	27-Feb	1-Mar	11-Mar
		2030-Base	0.8	0.7	0.7	0.8	0.8	100	74	69	60	32	1.9	0.9	0.8	0.8	0.5	−2	−4	−5	−5	−10
		2050-Base	1.5	1.5	1.4	1.5	1.4	179	133	118	99	51	3.2	1.7	1.6	1.6	1.0	−3	−8	−8	−9	−16
		2070-Base	2.2	2.1	2.1	2.1	2.1	241	181	156	128	59	4.1†	2.4	2.4	2.1	1.6	−4†	−10	−12	−13	−20
WA	Margaret River	Base	18.1	18.6	18.7	18.8	19.4	1639	1674	1692	1710	1742	19.4	20.0	20.1	20.2	21.1	10-Mar	13-Mar	14-Mar	15-Mar	18-Mar
		2030	18.9	19.3	19.5	19.6	20.2	1722	1750	1765	1778	1801	20.2	20.8	20.9	21.0	22.0	5-Mar	7-Mar	8-Mar	9-Mar	12-Mar
		2050	19.6	20.0	20.1	20.3	20.9	1780	1800	1810	1820	1836	20.9	21.5	21.6	21.7	22.7	1-Mar	3-Mar	4-Mar	5-Mar	7-Mar
		2070	20.2	20.7	20.8	20.9	21.6	1819	1833	1841	1849	1862	21.5	22.1	22.2	22.3	23.3	26-Feb	27-Feb	28-Feb	1-Mar	3-Mar
		2030-Base	0.8	0.7	0.8	0.8	0.8	83	76	73	68	59	0.8	0.8	0.8	0.8	0.9	−5	−6	−6	−6	−6
		2050-Base	1.5	1.4	1.4	1.5	1.5	141	126	118	110	94	1.5	1.5	1.5	1.5	1.6	−9	−10	−10	−10	−11
		2070-Base	2.1	2.1	2.1	2.1	2.2	180	159	149	139	120	2.1	2.1	2.1	2.1	2.2	−13	−15	−15	−14	−15
SA	Eden Valley	Base	16.9	17.1	17.6	17.9	18.2	1390	1427	1493	1527	1567	16.3	17.1	18.5	19.0	19.6	18-Mar	21-Mar	24-Mar	1-Apr	6-Apr
		2030	17.6	17.8	18.3	18.6	19.0	1488	1520	1579	1609	1645	18.3	18.9	19.7	20.3	20.9	12-Mar	14-Mar	17-Mar	22-Mar	25-Mar
		2050	18.2	18.4	19.0	19.2	19.6	1562	1593	1645	1671	1702	19.5	19.9	20.9	21.1	21.6	8-Mar	10-Mar	12-Mar	16-Mar	18-Mar
		2070	18.8	19.0	19.6	19.8	20.2	1628	1654	1702	1725	1753	20.5	20.9	21.5	21.8	22.2	5-Mar	7-Mar	8-Mar	11-Mar	13-Mar
		2030-Base	0.7	0.7	0.7	0.7	0.8	98	93	86	82	78	2.0	1.8	1.2	1.3	1.3	−6	−7	−7	−10	−12
		2050-Base	1.3	1.3	1.4	1.3	1.4	172	166	152	144	135	3.2	2.8	2.4	2.1	2.0	−10	−11	−12	−16	−19
		2070-Base	1.9	1.9	2.0	1.9	2.0	238	227	209	198	186	4.2	3.8	3.0	2.8	2.6	−13	−14	−16	−21	−24
SA	Clare Valley	Base	17.4	18.3	18.5	18.8	19.0	1454	1559	1580	1606	1629	18.0	19.8	20.1	20.6	21.0	13-Mar	15-Mar	16-Mar	18-Mar	27-Mar
		2030	18.2	19.0	19.2	19.5	19.7	1546	1636	1655	1677	1696	19.5	21.1	21.3	21.5	21.8	8-Mar	10-Mar	11-Mar	12-Mar	19-Mar
		2050	18.8	19.7	19.9	20.2	20.4	1618	1698	1713	1736	1751	20.7	21.7	22.0	22.3	22.5	5-Mar	6-Mar	7-Mar	8-Mar	13-Mar
		2070	19.4	20.3	20.5	20.8	21.0	1677	1748	1762	1780	1794	21.3	22.4	22.7	23.0	23.3	1-Mar	2-Mar	4-Mar	5-Mar	9-Mar
		2030-Base	0.8	0.7	0.7	0.7	0.7	92	77	75	71	67	1.5	1.3	1.2	0.9	0.8	−5	−5	−5	−6	−8
		2050-Base	1.4	1.4	1.4	1.4	1.4	164	139	133	130	122	2.7	1.9	1.9	1.7	1.5	−8	−9	−9	−10	−14
		2070-Base	2.0	2.0	2.0	2.0	2.0	223	189	182	174	165	3.3	2.6	2.6	2.4	2.3	−12	−13	−12	−13	−18
SA	Barossa Valley	Base	17.5	18.3	18.6	18.8	19.3	1472	1568	1597	1610	1657	18.2	19.7	20.3	20.5	21.5	12-Mar	15-Mar	16-Mar	18-Mar	26-Mar
		2030	18.2	19.0	19.3	19.5	20.0	1558	1645	1669	1680	1718	19.5	21.0	21.4	21.6	22.3	8-Mar	10-Mar	11-Mar	12-Mar	19-Mar
		2050	18.8	19.7	20.0	20.1	20.6	1626	1703	1722	1732	1765	20.6	21.7	22.1	22.3	23.0	4-Mar	7-Mar	7-Mar	8-Mar	14-Mar
		2070	19.4	20.3	20.6	20.7	21.2	1682	1753	1769	1777	1804	21.3	22.3	22.8	22.9	23.7	1-Mar	3-Mar	4-Mar	5-Mar	10-Mar
		2030-Base	0.7	0.7	0.7	0.7	0.7	86	77	72	70	61	1.3	1.3	1.1	1.1	0.8	−4	−5	−5	−6	−7
		2050-Base	1.3	1.4	1.4	1.3	1.3	154	135	125	122	108	2.4	2.0	1.8	1.8	1.5	−8	−8	−9	−10	−12
		2070-Base	1.9	2.0	2.0	1.9	1.9	210	185	172	167	147	3.1	2.6	2.5	2.4	2.2	−11	−12	−12	−13	−16

Table 2. *Continued*

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
TAS	South Tasmania	Base	13.6	13.9	14.2	14.7	15.3	756	825	890	994	1111	N/A^	N/A^	N/A^	N/A^	N/A^	30-Apr*	30-Apr*	30-Apr*	30-Apr*	30-Apr*
		2030	14.2	14.6	14.9	15.4	15.9	895	972	1037	1136	1255	N/A^	N/A^	N/A^	N/A^	N/A^	30-Apr*	30-Apr*	30-Apr*	30-Apr*	30-Apr*
		2050	14.8	15.2	15.5	16.0	16.5	1016	1100	1161	1267	1363	14.0	14.2*	15.0*	15.2*	15.5*	15-Apr	30-Apr*	30-Apr*	30-Apr*	30-Apr*
		2070	15.4	15.8	16.1	16.6	17.1	1133	1218	1280	1381	1464	14.3	15.3	15.8*	16.4*	17.0*	31-Mar	12-Apr	30-Apr*	30-Apr*	30-Apr*
		2030-Base	0.6	0.7	0.7	0.7	0.6	139	147	147	142	144	N/A^	N/A^	N/A^	N/A^	N/A^	0*	0*	0*	0*	0*
		2050-Base	1.2	1.3	1.3	1.3	1.2	260	275	271	273	252	N/A^	N/A^	N/A^	N/A^	N/A^	−15*	0*	0*	0*	0*
		2070-Base	1.8	1.9	1.9	1.9	1.8	377	393	390	387	353	N/A^	N/A^	N/A^	N/A^	N/A^	−30*	−18*	0*	0*	0*
TAS	North Tasmania	Base	14.6	14.8	15.0	15.2	15.6	966	1020	1055	1105	1180	N/A^	N/A^	N/A^	N/A^	N/A^	30-Apr*	30-Apr*	30-Apr*	30-Apr*	30-Apr*
		2030	15.2	15.5	15.7	15.9	16.3	1103	1161	1198	1249	1323	14.0	14.5*	14.6*	14.7*	14.9*	24-Apr	30-Apr*	30-Apr*	30-Apr*	30-Apr*
		2050	15.8	16.1	16.3	16.5	16.9	1216	1284	1321	1370	1434	13.9	14.8	15.6	16.1*	16.9*	4-Apr	14-Apr	24-Apr	30-Apr*	30-Apr*
		2070	16.3	16.7	16.9	17.1	17.5	1326	1388	1420	1466	1527	15.1	16.1	16.7	17.4	18.3	25-Mar	1-Apr	6-Apr	12-Apr	23-Apr
		2030-Base	0.6	0.7	0.7	0.7	0.7	137	141	143	144	143	N/A^	N/A^	N/A^	N/A^	N/A^	−6*	0*	0*	0*	0*
		2050-Base	1.2	1.3	1.3	1.3	1.3	250	264	266	265	254	N/A^	N/A^	N/A^	N/A^	N/A^	−26*	−16*	−6*	0*	0*
		2070-Base	1.7	1.9	1.9	1.9	1.9	360	368	365	361	347	N/A^	N/A^	N/A^	N/A^	N/A^	−36*	−29*	−24*	−18*	−7*
SA	Adelaide Plains	Base	19.1	19.7	19.9	20.0	20.1	1645	1712	1721	1729	1746	21.1	21.9	22.1	22.2	22.4	6-Mar	7-Mar	8-Mar	8-Mar	13-Mar
		2030	19.7	20.4	20.6	20.7	20.8	1709	1768	1775	1782	1797	21.9	22.7	22.9	23.0	23.1	2-Mar	3-Mar	4-Mar	4-Mar	8-Mar
		2050	20.3	21.0	21.2	21.3	21.4	1756	1807	1813	1820	1831	22.5	23.3	23.6	23.7	23.8	27-Feb	28-Feb	1-Mar	1-Mar	5-Mar
		2070	20.9	21.6	21.8	21.8	21.9	1797	1837	1842	1846	1855	23.2	23.9	24.2	24.3	24.4	26-Feb	26-Feb	27-Feb	27-Feb	2-Mar
		2030-Base	0.6	0.7	0.7	0.7	0.7	64	56	54	53	51	0.8	0.8	0.8	0.8	0.7	−4	−4	−4	−4	−5
		2050-Base	1.2	1.3	1.3	1.3	1.3	111	95	92	91	85	1.4	1.4	1.5	1.5	1.4	−8	−8	−7	−7	−8
		2070-Base	1.8	1.9	1.9	1.8	1.8	152	125	121	117	109	2.1	2.0	2.1	2.1	2.0	−9	−10	−10	−10	−11
SA	Adelaide Hills	Base	16.2	16.7	16.9	17.2	18.2	1303	1386	1423	1451	1558	13.6	15.9	16.7	17.4	19.5	19-Mar	29-Mar	3-Apr	8-Apr	28-Apr
		2030	16.8	17.4	17.5	17.8	18.9	1418	1485	1518	1542	1635	16.5	17.9	18.3	18.8	20.8	13-Mar	20-Mar	22-Mar	25-Mar	3-Apr
		2050	17.3	17.9	18.1	18.4	19.5	1501	1561	1588	1611	1693	18.0	18.9	19.3	19.9	21.5	9-Mar	14-Mar	16-Mar	18-Mar	23-Mar
		2070	17.9	18.4	18.7	19.0	20.1	1570	1625	1650	1670	1741	18.8	19.9	20.2	20.8	22.1	6-Mar	10-Mar	12-Mar	13-Mar	18-Mar
		2030-Base	0.6	0.7	0.6	0.6	0.7	115	99	95	91	77	2.9	2.0	1.6	1.4	1.3	−6	−9	−12	−14	−25
		2050-Base	1.1	1.2	1.2	1.2	1.3	198	175	165	160	135	4.4	3.0	2.6	2.5	2.0	−10	−15	−18	−21	−36
		2070-Base	1.7	1.7	1.8	1.8	1.9	267	239	227	219	183	5.2	4.0	3.5	3.4	2.6	−13	−19	−22	−26	−41
SA	Wrattonbully	Base	16.7	17.1	17.2	17.4	17.5	1379	1446	1456	1470	1484	15.8	17.4	17.7	18.0	18.2	26-Mar	27-Mar	29-Mar	31-Mar	10-Apr
		2030	17.3	17.8	17.9	18.0	18.1	1472	1531	1542	1556	1567	17.8	18.8	19.0	19.2	19.4	19-Mar	20-Mar	21-Mar	22-Mar	28-Mar
		2050	17.9	18.3	18.4	18.6	18.7	1546	1599	1608	1621	1631	18.9	19.7	19.9	20.2	20.5	14-Mar	15-Mar	16-Mar	17-Mar	21-Mar
		2070	18.4	18.8	19.0	19.1	19.2	1609	1657	1666	1676	1685	19.8	20.7	21.0	21.1	21.2	10-Mar	11-Mar	11-Mar	12-Mar	16-Mar
		2030-Base	0.6	0.7	0.7	0.6	0.6	93	85	86	86	83	2.0	1.4	1.3	1.2	1.2	−7	−7	−8	−9	−13
		2050-Base	1.2	1.2	1.2	1.2	1.2	167	153	152	151	147	3.1	2.3	2.2	2.2	2.3	−12	−12	−13	−14	−20
		2070-Base	1.7	1.7	1.8	1.7	1.7	230	211	210	206	201	4.0	3.3	3.3	3.1	3.0	−16	−16	−18	−19	−25
SA	Padthaway	Base	17.4	17.7	17.8	18.0	18.1	1479	1517	1533	1552	1569	18.2	18.7	18.9	19.1	19.4	18-Mar	19-Mar	21-Mar	22-Mar	26-Mar
		2030	18.0	18.4	18.5	18.6	18.8	1561	1598	1613	1630	1645	19.3	19.8	20.1	20.4	20.6	12-Mar	13-Mar	15-Mar	16-Mar	19-Mar
		2050	18.6	18.9	19.1	19.2	19.4	1626	1659	1673	1689	1703	20.4	20.9	21.0	21.1	21.3	8-Mar	9-Mar	11-Mar	11-Mar	14-Mar
		2070	19.1	19.5	19.6	19.8	19.9	1681	1712	1725	1738	1751	21.1	21.4	21.6	21.8	21.9	5-Mar	5-Mar	7-Mar	7-Mar	10-Mar
		2030-Base	0.6	0.7	0.7	0.6	0.7	82	81	80	78	76	1.1	1.1	1.2	1.3	1.2	−6	−6	−6	−6	−7
		2050-Base	1.2	1.2	1.3	1.2	1.3	147	142	140	137	134	2.2	2.2	2.1	2.0	1.9	−10	−10	−10	−11	−12
		2070-Base	1.7	1.8	1.8	1.8	1.8	202	195	192	186	182	2.9	2.7	2.7	2.7	2.5	−13	−14	−14	−15	−16

Table 2. *Continued*

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
SA	Langhorne Creek	Base	18.7	18.7	18.7	18.8	18.9	1676	1680	1682	1685	1694	20.3	20.3	20.4	20.4	20.5	9-Mar	9-Mar	10-Mar	10-Mar	10-Mar
		2030	19.3	19.4	19.4	19.4	19.5	1739	1742	1744	1746	1754	21.0	21.0	21.1	21.1	21.2	5-Mar	5-Mar	5-Mar	5-Mar	6-Mar
		2050	19.9	19.9	19.9	20.0	20.1	1786	1789	1791	1792	1799	21.6	21.6	21.7	21.7	21.9	1-Mar	2-Mar	2-Mar	2-Mar	2-Mar
		2070	20.4	20.4	20.5	20.5	20.6	1823	1825	1826	1828	1833	22.1	22.2	22.3	22.3	22.4	27-Feb	27-Feb	27-Feb	27-Feb	27-Feb
		2030-Base	0.6	0.7	0.7	0.6	0.6	63	62	62	61	60	0.7	0.7	0.7	0.7	0.7	−4	−4	−5	−5	−4
		2050-Base	1.2	1.2	1.2	1.2	1.2	110	109	109	107	105	1.3	1.3	1.3	1.3	1.4	−8	−7	−8	−8	−8
		2070-Base	1.7	1.7	1.8	1.7	1.7	147	145	144	143	139	1.8	1.9	1.9	1.9	1.9	−11	−11	−12	−12	−12
SA	South Fleurieu	Base	15.8	16.5	16.9	17.3	18.1	1224	1374	1456	1514	1636	14.9	16.3	17.2	17.9	19.1*	14-Mar	25-Mar	31-Mar	12-Apr	30-Apr*
		2030	16.4	17.1	17.5	17.8	18.7	1343	1482	1554	1605	1706	15.3	17.3	18.2	18.7	19.9	9-Mar	16-Mar	21-Mar	28-Mar	20-Apr
		2050	16.9	17.6	18.1	18.3	19.2	1441	1566	1626	1672	1760	16.7	18.2	19.1	19.5	20.5	5-Mar	11-Mar	14-Mar	19-Mar	4-Apr
		2070	17.3	18.1	18.6	18.8	19.7	1525	1632	1684	1726	1803	17.6	19.0	19.6	20.0	21.0	2-Mar	7-Mar	10-Mar	14-Mar	25-Mar
		2030-Base	0.6	0.6	0.6	0.5	0.6	119	108	98	91	70	0.4	1.0	1.0	0.8	0.8*	−5	−9	−10	−15	−10*
		2050-Base	1.1	1.1	1.2	1.0	1.1	217	192	170	158	124	1.8	1.9	1.9	1.6	1.4*	−9	−14	−17	−24	−26*
		2070-Base	1.5	1.6	1.7	1.5	1.6	301	258	228	212	167	2.7	2.7	2.4	2.1	1.9*	−12	−18	−21	−29	−36*
SA	Coonawarra	Base	16.6	16.7	16.8	16.9	17.1	1377	1397	1406	1419	1446	15.8	16.2	16.5	16.7	17.4	31-Mar	4-Apr	6-Apr	7-Apr	11-Apr
		2030	17.2	17.3	17.4	17.5	17.7	1471	1489	1496	1507	1531	17.6	18.0	18.2	18.3	18.7	22-Mar	25-Mar	26-Mar	27-Mar	29-Mar
		2050	17.7	17.9	18.0	18.1	18.3	1543	1559	1567	1578	1599	18.7	18.9	19.2	19.3	19.6	17-Mar	18-Mar	19-Mar	20-Mar	22-Mar
		2070	18.2	18.4	18.5	18.6	18.8	1605	1620	1627	1637	1657	19.5	19.9	20.1	20.2	20.7	12-Mar	14-Mar	14-Mar	15-Mar	16-Mar
		2030-Base	0.6	0.6	0.6	0.6	0.6	94	92	90	88	85	1.8	1.8	1.7	1.6	1.3	−9	−10	−11	−11	−13
		2050-Base	1.1	1.2	1.2	1.2	1.2	166	162	161	159	153	2.9	2.7	2.7	2.6	2.2	−14	−17	−18	−18	−20
		2070-Base	1.6	1.7	1.7	1.7	1.7	228	223	221	218	211	3.7	3.7	3.6	3.5	3.3	−19	−21	−23	−23	−26
VIC	Henty	Base	16.0	16.2	16.3	16.4	16.9	1271	1291	1312	1338	1412	13.4	14.4	15.0	15.6*	16.7*	5-Apr	19-Apr	26-Apr	30-Apr*	30-Apr*
		2030	16.6	16.8	16.9	17.0	17.5	1377	1400	1419	1441	1501	15.8	16.2	16.7	17.0	18.4	25-Mar	2-Apr	5-Apr	8-Apr	13-Apr
		2050	17.0	17.3	17.4	17.6	18.1	1458	1483	1500	1519	1571	17.1	17.8	18.0	18.3	19.3	19-Mar	24-Mar	26-Mar	28-Mar	1-Apr
		2070	17.5	17.8	17.9	18.1	18.6	1526	1551	1567	1585	1631	18.1	18.7	19.0	19.2	20.4	15-Mar	19-Mar	20-Mar	21-Mar	24-Mar
		2030-Base	0.6	0.6	0.6	0.6	0.6	106	109	107	103	89	2.4	1.8	1.7	1.4*	1.7*	−11	−17	−21	−22*	−17*
		2050-Base	1.0	1.1	1.1	1.2	1.2	187	192	188	181	159	3.7	3.4	3.0	2.7*	2.6*	−17	−26	−31	−33*	−29*
		2070-Base	1.5	1.6	1.6	1.7	1.7	255	260	255	247	219	4.7	4.3	4.0	3.6*	3.7*	−21	−31	−37	−40*	−37*
SA	McLaren Vale	Base	16.9	17.6	18.0	18.2	18.5	1429	1527	1592	1609	1642	16.8	18.4	19.1	19.5	20.1	13-Mar	15-Mar	16-Mar	22-Mar	2-Apr
		2030	17.6	18.2	18.6	18.8	19.1	1524	1607	1665	1681	1709	18.4	19.5	20.1	20.3	20.7	8-Mar	10-Mar	11-Mar	15-Mar	21-Mar
		2050	18.1	18.7	19.1	19.3	19.6	1595	1670	1722	1736	1760	19.3	20.3	20.6	20.9	21.3	4-Mar	5-Mar	7-Mar	10-Mar	16-Mar
		2070	18.6	19.3	19.6	19.8	20.2	1656	1723	1767	1779	1799	20.0	20.8	21.2	21.4	21.9	2-Mar	3-Mar	4-Mar	7-Mar	11-Mar
		2030-Base	0.7	0.6	0.6	0.6	0.6	95	80	73	72	67	1.6	1.1	1.0	0.8	0.6	−5	−5	−5	−7	−12
		2050-Base	1.2	1.1	1.1	1.1	1.1	166	143	130	127	118	2.5	1.9	1.5	1.4	1.2	−9	−10	−9	−12	−17
		2070-Base	1.7	1.7	1.6	1.6	1.7	227	196	175	170	157	3.2	2.4	2.1	1.9	1.8	−11	−12	−12	−15	−22
SA	Currency Creek	Base	17.8	18.3	18.4	18.5	18.6	1597	1650	1666	1669	1680	18.7	19.7	19.8	19.9	20.1	10-Mar	11-Mar	11-Mar	12-Mar	17-Mar
		2030	18.4	18.9	19.0	19.1	19.2	1673	1719	1732	1734	1742	19.6	20.3	20.4	20.5	20.8	6-Mar	6-Mar	6-Mar	7-Mar	11-Mar
		2050	18.9	19.4	19.5	19.6	19.8	1729	1769	1780	1782	1789	20.2	20.9	21.0	21.1	21.4	2-Mar	3-Mar	3-Mar	4-Mar	7-Mar
		2070	19.4	19.9	20.0	20.1	20.3	1778	1810	1819	1820	1826	20.7	21.5	21.6	21.7	22.0	27-Feb	28-Feb	28-Feb	1-Mar	3-Mar
		2030-Base	0.6	0.6	0.6	0.6	0.6	76	69	66	65	62	0.9	0.6	0.6	0.6	0.7	−4	−5	−5	−5	−6
		2050-Base	1.1	1.1	1.1	1.1	1.2	132	119	114	113	109	1.5	1.2	1.2	1.2	1.3	−8	−8	−8	−8	−10
		2070-Base	1.6	1.6	1.6	1.6	1.7	181	160	153	151	146	2.0	1.8	1.8	1.8	1.9	−12	−12	−12	−11	−14

Table 2. *Continued*

		Time period	Growing season temperature					Biologically effective degree days					Ripening period temperature					Season-end date				
			Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max	Min	Q1	Median	Q3	Max
SA	Robe	Base	16.8	17.0	17.1	17.2	17.4	1413	1450	1477	1491	1513	16.3	16.9	17.4	17.6	18.0	25-Mar	27-Mar	29-Mar	1-Apr	7-Apr
		2030	17.4	17.6	17.7	17.8	18.0	1509	1541	1565	1576	1595	17.8	18.2	18.4	18.6	19.0	17-Mar	19-Mar	20-Mar	22-Mar	26-Mar
		2050	17.8	18.0	18.2	18.3	18.5	1580	1607	1629	1638	1654	18.6	19.0	19.3	19.5	19.8	13-Mar	14-Mar	15-Mar	16-Mar	19-Mar
		2070	18.3	18.5	18.6	18.7	18.9	1638	1662	1682	1690	1705	19.5	19.8	20.0	20.1	20.4	9-Mar	10-Mar	11-Mar	12-Mar	14-Mar
		2030-Base	0.6	0.6	0.6	0.6	0.6	96	91	88	85	82	1.5	1.3	1.0	1.0	1.0	−8	−8	−9	−10	−12
		2050-Base	1.0	1.0	1.1	1.1	1.1	167	157	152	147	141	2.3	2.1	1.9	1.9	1.8	−12	−13	−14	−16	−19
		2070-Base	1.5	1.5	1.5	1.5	1.5	225	212	205	199	192	3.2	2.9	2.6	2.5	2.4	−16	−17	−18	−20	−24
SA	Mount Benson	Base	17.0	17.2	17.3	17.4	17.5	1454	1488	1497	1511	1522	17.0	17.5	17.7	17.9	18.1	24-Mar	25-Mar	26-Mar	28-Mar	1-Apr
		2030	17.6	17.8	17.8	18.0	18.0	1546	1575	1582	1594	1602	18.2	18.6	18.7	18.9	19.1	17-Mar	17-Mar	18-Mar	19-Mar	22-Mar
		2050	18.1	18.3	18.3	18.4	18.5	1610	1636	1642	1653	1661	19.0	19.5	19.6	19.8	20.0	12-Mar	13-Mar	13-Mar	14-Mar	16-Mar
		2070	18.5	18.7	18.8	18.9	19.0	1666	1689	1695	1704	1712	19.9	20.1	20.2	20.3	20.4	9-Mar	9-Mar	10-Mar	10-Mar	12-Mar
		2030-Base	0.6	0.6	0.5	0.6	0.5	92	87	85	83	80	1.2	1.1	1.0	1.0	1.0	−7	−8	−8	−9	−10
		2050-Base	1.1	1.1	1.0	1.0	1.0	156	148	145	142	139	2.0	2.0	1.9	1.9	1.9	−12	−12	−13	−14	−16
		2070-Base	1.5	1.5	1.5	1.5	1.5	212	201	198	193	190	2.9	2.6	2.5	2.4	2.3	−15	−16	−16	−18	−20
SA	Kangaroo Island	Base	15.7	16.6	17.0	17.4	18.1	1213	1386	1468	1534	1626	14.6	16.3	17.4	18.0	19.1*	17-Mar	26-Mar	2-Apr	12-Apr	30-Apr*
		2030	16.2	17.0	17.5	17.9	18.5	1307	1469	1548	1609	1676	14.7	17.1	18.1	18.7	19.8	13-Mar	18-Mar	24-Mar	1-Apr	28-Apr
		2050	16.6	17.5	17.9	18.3	19.0	1387	1542	1612	1669	1738	16.1	18.1	18.8	19.4	20.3	8-Mar	14-Mar	18-Mar	24-Mar	13-Apr
		2070	17.0	17.9	18.3	18.7	19.5	1460	1603	1667	1719	1777	16.9	18.7	19.5	19.9	20.8	5-Mar	10-Mar	14-Mar	19-Mar	3-Apr
		2030-Base	0.5	0.4	0.5	0.5	0.4	94	83	80	75	50	0.1	0.8	0.7	0.7	0.7*	−4	−8	−9	−11	−2*
		2050-Base	0.9	0.9	0.9	0.9	0.9	174	156	144	135	112	1.5	1.8	1.4	1.4	1.2*	−9	−12	−15	−19	−17*
		2070-Base	1.3	1.3	1.3	1.3	1.4	247	217	199	185	151	2.3	2.4	2.1	1.9	1.7*	−12	−16	−19	−24	−27*

Differences in the index value from the base period are included below the summary data of each region. Regions are listed in order by the greatest change in median GST.
† The modelled index value exceeded the limits of the indexing system, resulting in changes that are likely to be underestimated or invalid.
‡ RPT could not be calculated because 1300 BEDD was not reached in that region.

BEDD values for the baseline period reveal a wine region average of 1540 with the lowest (756) and highest (1899, the maximum BEDD that can be accumulated for any region) values being seen in Southern Tasmania and South Burnett, respectively. For RPT, the wine region average is 19.1°C with the lowest observed found in Mudgee (12.6°C) and the highest in the Riverina (25.4°C) (note that the wine regions in Tasmania are cooler overall than Mudgee, but as 1300°Cdays was not reached in these regions, the RPT could not be calculated). The estimated season-end date averages 20 March over the wine regions, with the earliest in South Burnett (22 February, the earliest season start date that can be achieved with the indexing method) and the latest occurring after 30 April in many locations (Table 2).

Future projections for 2030 reveal an average GST wine region warming of 0.9°C with a range of 0.5°C in Henty and Kangaroo Island to 1.0°C in seven different regions (Table 2). By 2050, GST is projected to increase on average 1.6°C with the greatest warming of 1.9°C in New England, South Burnett and Perth Hills and the least in Kangaroo Island (0.9°C). GST warming by 2070 averages 2.3°C across all regions with a range from 1.3°C in Kangaroo Island to 2.8°C in Perth Hills. BEDD shows similar spatial changes to GST with average BEDD increases of 87, 152 and 207 units for the 2030, 2050 and 2070 projections, respectively. The capping of the heat accumulation to 9°Cdays per day results in heat accumulation totals not increasing on many days of the year for the already warm locations. The BEDD in regions with a cooler starting period, but with similarly large increases in GST, is modelled to increase at a faster rate. For example, the modelled BEDD increases for the Granite Belt region are 115, 186 and 236°Cdays for 2030, 2050 and 2070, respectively, even though the GCM forecasts a similar GST rise to that experienced by Perth Hills.

Furthermore, the maximum BEDD that can be accumulated for any region is 1899°Cdays, resulting from 9°Cdays being accumulated on every day of the 211 days between 1 October and 30 April. For those regions that have relatively high BEDD totals (especially South Burnett and Hastings River), increases in BEDD under different warming scenarios do not fully reflect the warmer conditions. Similarly, modelling increases in RPT and earlier season-end dates (assuming harvest takes place once 1300°Cdays is reached) are not appropriate for several regions because 1300°Cdays is reached at the earliest possible date (22 February), 9°Cdays being accumulated on every day after October 1. Any increase in temperature does not affect the BEDD accumulation and therefore cannot alter the season-end date under this modelling method.

Discussion

Maps of mean GST are the simplest of the climate maps produced (Figure 4). Jones et al. (2005) suggest that the 'simple' GST value effectively defines spatial variations in varietal potential and growing season climates. If a GST of 21°C is considered as the upper limit of quality winegrape production (based on Jones 2006), then, under the temperature increase scenario for 2070, large areas of the northern viticultural regions of Australia may not be suitable for quality winegrape production. For the period 1971–2000, South Burnett, Swan District and Riverina are above a mean GST of 21°C. By 2030, Perth Hills, Hunter, Hastings River, Swan Hill and Murray Darling are modelled to have a mean GST above 21°C. By 2050, Peel, Perricoota, Cowra and Adelaide Plains, and by 2070, New England, Mudgee, Rutherglen, Glenrowan, Goulburn Valley, Gundagai, Shoalhaven Coast, Geographe, and Southern Flinders Ranges join this group.

If ripening periods occur earlier in a season, then the RPT is more likely to be warmer, which may lead to a decrease in quality. The level of impact of temperature on harvested fruit quality varies for different grapevine cultivars (Webb et al. 2006). The extrapolated maps of RPT for the period 1971–2000 suggest that most viticultural regions experienced RPTs that were on average below 24°C for varieties that required an accumulated BEDD total of 1300°Cdays. Clearly, fruit of varieties that require a greater number of BEDD would ripen later in the season and in conditions that are more likely to be cooler. For a variety such as Cabernet Sauvignon that is managed to mature at 1300 BEDD, the maps in Figure 4 can be used as a guide. The series of RPT maps clearly show a greater level of increase in RPT in inland areas than those that are closer to the coast. The same regions that become unsuitable for quality wine production using the threshold criterion of a GST above 21°C were also shown to become similarly unsuitable using the criterion of above an RPT of 24°C for grapevine varieties that ripen after accumulating 1300 BEDD. Nevertheless, those varieties that require more BEDD will have ripening periods that will more likely take place during cooler conditions later in a season.

In contrast to GST and RPT, the BEDD total is a less useful value for defining a region as being unsuitable for viticultural production due to high temperatures, because once a requisite total of BEDD has been reached, the grapes may be harvested and any further heat accumulation after the harvest date is irrelevant. BEDD is more useful in determining suitability of different regions to different grapevine varieties (Gladstones 1992). A viable variety for a particular region is one that requires a lower number of BEDD to ripen fruit than the total number of BEDD experienced at that location during a season. Assuming that a cooler ripening period is desired, the region's BEDD total should be close to the BEDD total required to ripen fruit of that variety so that the ripening stage occurs during a cooler period. However, due to natural season-to-season variability in average temperatures, there will be cool years that would lead to requisite BEDD not being reached for varieties that have required BEDD totals close to the average BEDD of the region leading to fruit not ripening within the season. Therefore, varieties should be selected for regions with the degree of climatic variability of the region in mind. The key changes due to increases in BEDD in Australia (Figure 4) under increasing future projections is the increasing viability of Tasmania and along the slopes of the Great Dividing Range. For example, by 2070, the projected warming in

Northern Tasmania would likely result in more reliable viticultural production with a greater number of viable varieties. In particular, the modelling suggests that by 2070, Northern Tasmania would likely have a similar GST, BEDD, RPT and season-end date to that currently experienced in Coonawarra. Table 2 can be further used to compare regions' modelled future conditions with other regions' current conditions as indicated by the different indices similar to the way in which Northern Tasmania for 2070 can be compared with Coonawarra for 1971–2000.

Conclusion

This study has used interpolated elevation-corrected maps of daily temperature data (*temperature surfaces*) for Australia for the period 1971–2000 to produce maps of GST, BEDD, RPT and season-end date of viticultural production. An error analysis of the temperature surfaces resulted in an estimated maximum error of about 0.3°C in any one location within the winegrape growing regions. The temperature surfaces were then altered by adding spatially modelled temperature anomalies for the years 2030, 2050 and 2070 using the CSIRO Mk3.0 GCM with a SRES scenario of A1B and a sensitivity of atmospheric temperature increases in response to a doubling of GHG of 2.6°C. The modified temperature surfaces were in turn used to produce similar maps of the temperature indices projected for 2030, 2050 and 2070. A correlation analysis of the spatial variation in the temperature indices demonstrated that maps of BEDD, RPT (for a variety requiring 1300 BEDD to ripen, such as Cabernet Sauvignon) and GST were sufficiently different, to show that GST alone does not fully characterise temperature differences that may be experienced due to future warming.

Using a very different methodological approach, the results of this study broadly validate the results and conclusions drawn by Webb et al. (2007) in that for established viticultural regions under warmer atmospheric conditions, shorter seasons would likely be experienced and harvest would occur in warmer conditions earlier in the year. The latitudinal location of Australia, being close to the equatorial limit of winegrape production for the Southern Hemisphere and with little land mass poleward, means that the total area of viable viticultural climates of Australia would be reduced, the level of reduction being proportional to the magnitude of the increase in temperature. The area of Australia estimated by the modelling process to experience GSTs between 13 and 21°C reduces from 986 000 km^2 for the 1971–2000 base period to 736 000 km^2 by 2030, 576 000 km^2 by 2050 and 449 000 km^2 by 2070. Of the 61 recognised wine regions (GIs) and two others in Tasmania, the median GSTs were found to be above 21°C for three regions for the period 1971–2000, for eight regions by 2030, 12 regions by 2050 and 21 regions by 2070. The spatial variation in the rate of temperature increase as derived by the CSIRO Mk3.0 model resulted in greater levels of change to the temperature indices for inland regions and lower levels of change to the temperature indices for coastal regions with southern areas of South Australia and western Victoria experiencing the least change. In addition, some regions that are apparently not suitable under 1971–2000 conditions could be suitable winegrape production regions under warmer temperature scenarios, such as areas of Tasmania and higher elevation areas of south-eastern Australia. Not only can the suitability of quality winegrape production in some regions be affected by the temperature changes, the grapevine varieties that are best suited to a given region may also change. Warm climate varieties may become suited to viticultural regions that are currently considered too cool for those varieties.

It should be noted that the warming scenarios used in this paper are based on estimates for warming produced by the IPCC and the CSIRO for the near future. Actual forecasts have large ranges of temperature changes because there is much uncertainty in the forecasting methods and in future human behaviour (IPCC 2007). The indices used in this study were designed to describe average growing conditions for long-term wine growing suitability. Temporal variability in inter-annual average temperatures must therefore be considered when interpreting the results. Derived viticultural temperature indices would also vary as a consequence of the inter-annual variance in temperature and may vary to a greater degree for different regions. Finally, mesoclimatic variation may not have been fully characterised. Data were derived from climate stations that may not fully represent the surrounding region. There are therefore likely to be sub-regions that experience significantly warmer or cooler overall conditions due to local factors (such as aspect) that affect the average temperature.

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