Carl's Chardonnay Haridness Model
A guide on how it works

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Contents

1 Introduction to the model

Carl Bogdanoff is a viticulture researcher at AgCanada who has a particular interest in wine-grape cold hardiness. He has been taking LTE_{50} readings from various vineyards and varieties from 2012 to the present. With this data he has built models to track vine cold hardiness (in terms of LTE_{50}) in relation to air temperatures. With this model Carl is able to send growers predictions of how cold hardy their grapes are likely to be so the growers can better manage their activities.

A difficulty with the model is that it is coded in excel. This makes it difficulty to interact with the model. We would love to have work on this model but we need it in R. The first step with this model is therefore to get it working in R.

This document focuses on the Chardonnay model because this is the one Carl started with. There are other models for other varieties that are (maybe?) similar.

2   Past work

Faith coded up a previous version of the Chardonnay hardiness Carl sent us. Her code is in BCvin\hardiness\oldCarlModel\.

- hardiness_stab.r. This is the main script Lizzie and Faith worked on to run Carl's older model. It used the functions below to replicate the if else statements in columns CC to CG. This file will be useful when setting up the data and as a reference for coding the full model. The files mentioned below will also be useful when trying to code if/else statements because you can see how they work, but I think the actual if/else statements will be quite different.

- ColumnCC_function.R

- ColumnCE_function.R

- ColumnCF_function.R

- ColumnCG_function.R - this one does the rest of the columns. Because of the dynamic elements to these columns (the columns refer back to each other's values from the previous day) I had to make one giant loop.

- The old model is in BCvin\hardiness\fromCarl\older.

3   The new model

3.1   Overview of the model

Carl's model works quite a bit differently from how we tend to write models in our lab, both structurally and mechanistically. The model's mechanics are spread out over various excel columns with functions coded into cells and columns are often repeated. Also the model has two main parts to it: estimating hardiness based on the day of the season and tweaking average hardiness each year to reflect the how the temperatures experienced that year deviate from average. These "tweaks" basically look at how much colder or warmer it is on the year of interest than the historical data, and increase or decrease vine hardiness accordingly. There are many if/else statements involved in these tweaks, and Carl likes to update them a little every year to ensure optimum fit. Also the if/else statements for the tweaks are consistant between years.

3.2   The files

- Chard Model Instructions May 2020.docx. This is Carl's explanatory documents describing what he did and why. It is useful to refer to this document when coding the model in R.

- Chard Model May 2020.xlsx. This is the actual model. Carl is an Excel wizard so all of the calculations happen here as well as any plotting and raw data. The file is fully explained in sections below.

3.3 The data

The model requires three data sets:

1. Hardiness measured in LTE_{50} between 2012 and 2020. Various variety LTE_50, including for Chardonnay, were measured at several sites in the Okenagan Valley by Carl and his team. Data was taken biweekly from late October to April. There was not a full season of data recorded for 2020 due to Covid-19. Each winter season is a separate csv file, and data are stored in analyses\input\budhardinessXtoY.csv, where X and Y are the years the data cover. These data can also be found in columns BB, BD, BF, BH, BJ, BL, BN and BP. There are lots of empty cells in these columns because we do not have LTE_{50} data for most days nor the same day each year.

2. Mean 2 day temperature for between 2012 ans 2019, measured in °C, from Environment Canada's Penticton site. Stored in analyses\input\envcanada_penticton.csv. These data are also in columns A though J of the spreadsheet. They are also repeated in columns R, U, X, AA, AD, AG, AJ and AM.

3. Historical temperature data which we pulled from Carl's excel file. Stored in analyses\input\climhist_19812010.csv. These data are repeated many times in the spreadsheet so the mechanics of the model works. They first appear in column N (1981-2010 data: 2day), then they are repeated in columns CE, DB, DY onwards so they appear once for each year there is LTE_{50} data.

3.4 Preparing the data

The model does uses mean 2 day temperature data, so that needs estimating. There is also code in hardiness_stab.R that it estimates GDDs (Growing Degree Days) in case you need it. I do not think Carl's model uses GDDs though.

3.5 Estimating mean LTE_{50} from day of the season

This section of the model fits a 4th order polynomial curve to the LTE_{50} values against day of the season. Carl uses the average LTE_{50} values of Chardonnay, but we will want to use all the data instead so we can see how much variation there is between sites. This "day of the season" is the number of days since October 1st, which is the beginning of winter hardiness acclimation according to Carl (Figure 1). The purpose of this section is to get a "general" trend of how LTE_{50} changes throughout the dormant season. The columns where this takes place are BR to BZ. Note the previous model Carl sent that we coded up uses a very different approach to getting the average trend of LTE_{50} so there will be big chunks of hardiness_stab.R that are not relevant to the new model. I think the equation is:

$$PredLTE_{50} = 12.29 * cd^4 - 42 * cd^3 + 63 * cd^2 - 44 * cd - 13$$

where $PredLTE_{50}$ is the predicted hardiness that day (day since October 1st), and cd is the day since October 1st/100. $PredLTE_{50}$ is in column BY and cd is in column BX.
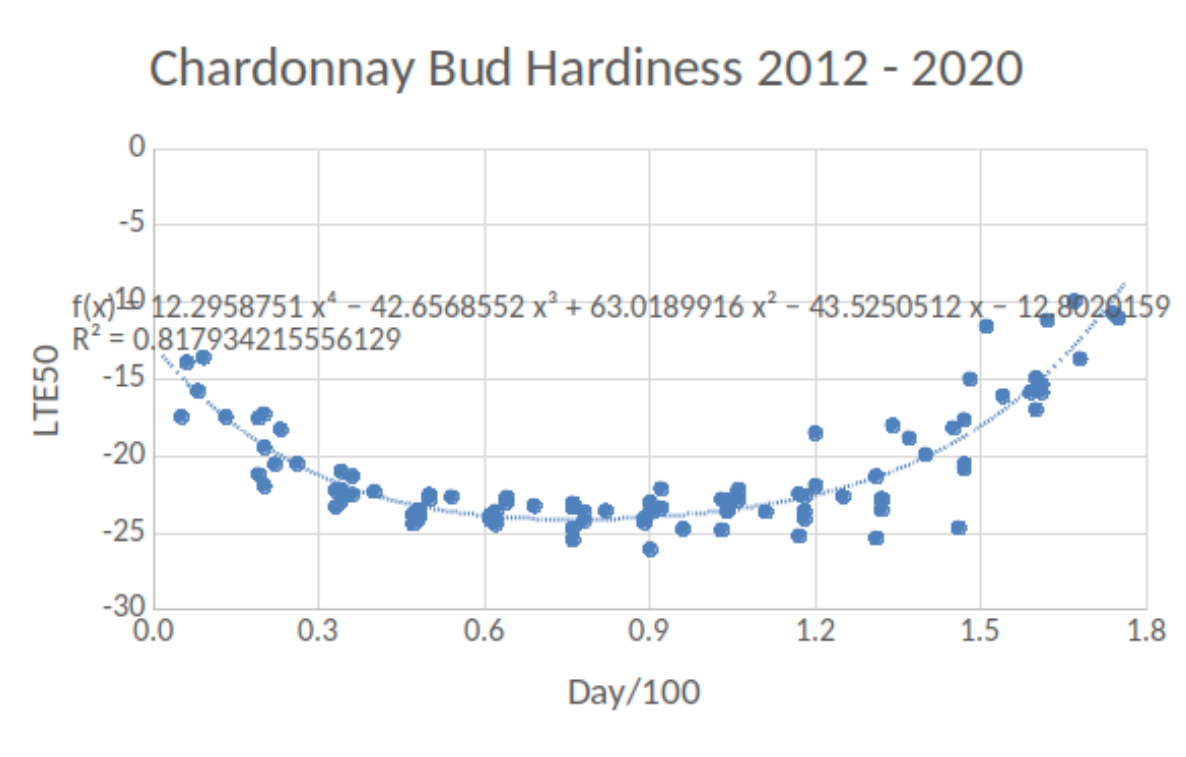
Figure 1: A plot taken from Carl's May 2020 Chardonnay excel model (Chard Model May 2020.xlsx). A polynomial 4th order curve is used to estimate LTE_{50} each day of the hardiness season.

The estimated LTE_{50} values are repeated for 2012/2013 in column CG (Estimate LTE), and the change between days is in column CG (Estimate LTE/day). They are also repeated are also repeated further to the right in the spreadsheet for every other year.

3.6 Tweaking hardiness or the year of interest

Once you have estimated LTE_{50} values for each day of the season then you can get predicted LTE_{50} values for a day of the season based on air temperatures that season.

The first step in this process is using the historical data as a baseline, and seeing how much colder it is on the day and year of interest than this historical value. These calculations happen in columns Q t AO. If the 2 day mean temperature for your day of interest (for example 28th Sep 2015) is 10.7 °C, and the average temperature for the 28th Sep in the historical data is 12.3 °C, then the difference is -1.6 °C. That is, in 2015 this day was a fair bit colder than the average for that day. This cell will be coloured blue on the spreadsheet, and warmer values will be coloured red. The basic idea is that the cold hardiness of a vine on the 28th of September 2015 will be colder than the average LTE_{50} predicted by the polynomial curve. Exactly how much colder is the next step of the model. The difference between historical temperatures and the day and year of interest is repeated later in the spreadsheet. For example, the difference between historical and 2012/2013 data is in column CH.

Carl estimates LTE_{50} each season separately. I will walk you through the 2012/13 data (see Figure 2). You will hopefully already be familiar with some of these columns from teh sections above, but I will repeat what each one contains to avoid confusion.

– CC: day of the year. Carl starts estimating hardiness from the 20th of September, but had temperature data before that and for some reason lists dates from September 1st).

– CD-CE: Historic temperatures. You only need concern yourself with the 2 day average (column CE).

– CF: Estimated LTE_{50}. Values are taken from the polynomial curve mentioned above.

– CG: Estimated LTE/day. This is how different each LTE_{50} value is from the value the previous day, so it is the rate of change of LTE_{50} per day. Values can increase or decrease.

– CH: A repeat of column S. This is difference between the temperature that day and the historical mean for that year.

– CI-CV: A selection of if/else statements that change the estimated LTE_{50} based on the polynomial curve to a specific estimated LTE_{50} for that specific date. Note that the statements change within a column, for example the statement in the autumn might be different from midwinter. Some of the later columns depend on each other a lot more so will need to be coded as one big function rather than a single function for each column. For more details on the statements in these columns see Chard Model Instructions May 2020.docx, and for how we previously tackled these type of columns see hardiness_stab.R.

– CW: Final predicted LTE_{50} values for that season based on temperatures that year.

These are constants used in the model every year and are determined from historical weather data and LTEs from the past 8 years. | Difference between 2012-13 & Historical data | IF and IF(AND) statements are used so that current years weather will closely match up to measured LTEs. The IF statements are grouped into 6 periods (2 for each acclimation, max hardiness and deacclimation phases of hardiness. These IF statements are the same for all eight years. | Setting upper limits to Final Predicted LTE. When near max LTE; cold temp effect on hardiness is small, warm temp effect is large. | Final predicted LTE & actual LTEs. See r² values below

Columns: initial IF statements | Results of initial IF statements | Initial limits based on the difference of Estimate LTE (CG) and results from initial IF statement (CK) | summed total LTE | Final limits based on the difference of early LTEs and Final Predicted LTE (CW)

date	Daily avg Tmean (step 2)	avg 2d Tmean (step 2)	Estimate LTE	Estimate LTE/day	avg T diff	initial IF (CI)	initial IF (CJ)	Initial Predicted LTE	Daily Change in LTE	CM	CN	CO	CP	Second Predicted LTE	CR	CS	CT	CU	CV	Final Predicted LTE	Actual Mean LTE
01-Sep																					
02-Sep																					
03-Sep																					
04-Sep																					
05-Sep																					
06-Sep																					
07-Sep																					
08-Sep																					
09-Sep																					
10-Sep																					
11-Sep																					
12-Sep					2012-13 GDD - 1333																
13-Sep																					
14-Sep					12.0																
15-Sep	15.1	15.2	-1.10	0.00	0.4																
16-Sep	14.9	15.0	-1.10	-0.03	1.6																
17-Sep	14.7	14.8	-1.13	-0.05	1.9																
18-Sep	14.4	14.5	-1.18	-0.08	0.5																
19-Sep	14.2	14.3	-1.25	-0.10	1.0																
20-Sep	14.0	14.1	-1.35	-0.13	2.9			0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	
21-Sep	13.8	13.9	-1.48	-0.15	2.7	0.00	0.90	0.16	-0.14	0.00	0.00	0.00	0.00	0.16	-0.14					0.16	
22-Sep	13.5	13.7	-1.63	-0.18	2.3	0.00	0.90	0.00	-0.16	0.00	0.00	0.00	0.00	0.00	-0.16					0.00	
23-Sep	13.3	13.4	-1.80	-0.20	2.6	0.00	0.90	-0.18	-0.18	0.00	0.00	0.00	0.00	-0.18	-0.18					-0.18	
24-Sep	13.1	13.2	-2.00	-0.23	2.8	0.00	0.90	-0.39	-0.20	0.00	0.00	0.00	0.00	-0.39	-0.20					-0.39	
25-Sep	12.9	13.0	-2.23	-0.25	4.4	0.00	0.60	-0.54	-0.15	0.00	0.00	0.00	0.00	-0.54	-0.15					-0.54	
26-Sep	12.7	12.8	-2.48	-0.28	3.8	0.00	0.75	-0.74	-0.21	0.00	0.00	0.00	0.00	-0.74	-0.21					-0.74	
27-Sep	12.4	12.6	-2.75	-0.30	1.4	0.00	0.95	-1.03	-0.29	0.00	0.00	0.00	0.00	-1.03	-0.29					-1.03	
28-Sep	12.2	12.3	-3.05	-0.33	1.6	0.00	0.95	-1.34	-0.31	0.00	0.00	0.00	0.00	-1.34	-0.31					-1.34	
29-Sep	12.0	12.1	-3.38	-0.35	3.5	0.00	0.75	-1.60	-0.26	0.00	0.00	0.00	0.00	-1.60	-0.26					-1.60	
30-Sep	11.8	11.9	-3.73	-0.38	3.5	0.00	0.75	-1.88	-0.28	0.00	0.00	0.00	0.00	-1.88	-0.28					-1.88	
01-Oct	11.6	11.7	-4.10	-0.40	2.5	0.00	0.90	-2.24	-0.36	0.00	0.00	0.00	0.00	-2.24	-0.36					-2.24	
02-Oct	11.4	11.5	-4.50	-0.43	2.0	0.00	0.90	-2.62	-0.38	0.00	0.00	0.00	0.00	-2.62	-0.38					-2.62	
03-Oct	11.2	11.3	-4.93	-0.45	-0.8	1.00	0.00	-3.07	-0.45	0.00	0.00	0.00	0.00	-3.07	-0.45					-3.07	
04-Oct	11.0	11.1	-5.38	-0.48	-3.0	1.20	0.00	-3.64	-0.57	0.00	0.00	0.00	0.00	-3.64	-0.57					-3.64	
05-Oct	10.8	10.9	-5.85	-0.50	-3.3	1.20	0.00	-4.24	-0.60	0.00	0.00	0.00	0.00	-4.24	-0.60					-4.24	
06-Oct	10.5	10.6	-6.35	-0.50	-2.6	1.15	0.00	-4.82	-0.58	0.00	0.00	0.00	0.00	-4.82	-0.58					-4.82	
07-Oct	10.3	10.4	-6.85	-0.50	-2.0	1.15	0.00	-5.39	-0.58	0.00	0.00	0.00	0.00	-5.39	-0.58					-5.39	
08-Oct	10.1	10.2	-7.35	-0.50	-1.2	1.10	0.00	-5.94	-0.55	0.00	0.00	0.00	0.00	-5.94	-0.55					-5.94	

Figure 2: A screen shot of the section of Carl's model spreadsheet (Chard Model May 2020.xlsx) where the tweaks for each year are calculated. This example is 2012/2013, and the same layout is repeated in columns to the right for the rest of the years.