A Model for estimating the bud hardiness of Merlot grown in the Okanagan Valley using Environment Canada's Penticton weather data.

Model (ver. 5) & Assumptions: This model is based on a 2-day average of daily mean temperature and its deviation from the 2-day average historical mean temperature. (note: model written on Excel)

1. Bud hardiness was measured biweekly from the late Oct to early Apr from 2012 to 2019.
   1. Observation 1 – Grapevine bud hardiness for all varieties follows a similar seasonal pattern where bud hardiness steadily increases in Oct & Nov, is at its maximum with some variation from Dec – Feb, and then steadily decreases in Mar & Apr.
2. A daily 2-day average Temperature Mean is generated (Sept 1 to April 30) from Environment Canada’s Penticton historical Average Temperature Graph.
3. For the variety of interest, common sample dates are chosen for all seven seasons and then the LTE50 are estimated for those dates from the nearest actual LTE50 value from all sites. In this model the LTE50 used is the average LTE50 from 3 (2012 – 2014) to 14 (2018 – 2019) Merlot sites in Okanagan Valley.
4. A curve is generated for each phase (acclimation, maximum hardiness, de-acclimation) of hardiness by plotting the historical daily average Tmean against the estimated actual LTE50 data from step 3.
   1. Assumption 1 – 3 separate curves (acclimation, max-hardiness & de-acclimation) are made to describe Merlot’s average hardiness for 7 winters.
5. Acclimation occurs from Oct to early Dec. (1015 – 1207)
6. Max-Hardiness occurs from late Nov to mid Feb. (1124 – 0215)
7. De-acclimation occurs from early Feb to the end of March. (0201 – 0330)
   1. Assumption 2 – the length/dates for each phase of hardiness are estimates and should overlap with adjoining phases.
8. Using the equations generated for each curve a single calculated LTE50 curve is created and is based on LTE50 values from 7 years. The curves are spliced together where the data from one curve intersects with the other and columns of Estimated LTE50 and Estimated LTE50/day are calculated for each day (October 15 – April 10) (Note: the Acclimation and Deacclimation curves do not overlap with the Max. Hardiness curve. This however is not important – the daily change in estimated LTE/day during the period of Max hardiness is set at 0.1 C/day)
   1. Assumption 3 – estimated LTE50 is based on 2-day Tmean.
   2. Assumption 4 – a maximum change in LTE is set at 0.5°C/day
   3. Assumption 5 – In the fall the change in LTE/day begins to decrease once LTE is ≤ -8.55°C
9. The LTE50/day ranges from -0.50 (Oct 24) to 0.50 (Apr 2) and are the primary values used to estimate the change in predicted hardiness.
   1. Assumption 6 – All LTE50/day that are <0.1 to >-0.1 are converted to -0.1 or +0.1. This more than covers the period of max-hardiness and is used as a multiplier for calculating changes in predicted hardiness.
10. For each year 2012-13 to 2018-19 a daily running 2-day temperature mean is calculated from Environment Canada’s Penticton historical weather (Sept 1 to April 30).
    1. Observation 2 – Modified calculations – the period of max hardiness is arbitrarily set and runs from Dec 8 to Feb 6. During this period the change in LTE50 is set at +0.1/day.
11. A daily difference between the historical 2-day average Tmean and the current season’s 2-day average Tmean is calculated.
12. From this point a series of chained IF(AND) statements and multipliers using primarily Predicted LTE/day and the Average Temp difference are used to estimate the daily change in LTE based on the past 2-day average Tmean.
13. September 21 (first day of Fall) was arbitrarily chosen as the starting point for Hardiness accumulation.
    1. Assumption 7 – Accumulation of hardiness begins Sept 21st and rate of change in LTE50/day from Sept 21 to Oct 14 was estimated using a 2nd order polynomial equation (note: hardiness data was not collected until late October or early November).
    2. Assumption 8 – Starting hardiness value is varied depending on total seasonal GDD accumulation (available Oct. 31st). For cool seasons the diff in GDD (GDD season – GDD average) is multiplied by -0.005. For warm seasons the diff in GDD is multiplied by -0.01.
14. IF statements and multipliers are next used so that current years weather will closely match up to measured LTEs. The IF statements are grouped into acclimation, max-hardiness and de-acclimation periods. These IF statements are the same for all seven years (Note: Modified IF statements are used the day before and the day after Feb 29 to account for Leap Years). The first 2 IF statements are used to predict LTE50 during acclimation (Sep 21 to Dec 7). (Note: calculations in the model are the same for each year. The workings of the model are described using columns (CD) to (CP) in the 2012 to 2013 winter season.)
    1. (CD) =IF(CC26<-8,2,IF(CC26<-5,1.6,IF(CC26<-4,1.5,IF(CC26<-3,1.3,IF(CC26<-2,1.2,IF(CC26<-1,1.15,IF(CC26<0,1.1,0)))))))
    2. (CE) =IF(CC26>5,0.8,IF(CC26>4,0.85,IF(CC26>3,0.9,IF(CC26>2,0.95,IF(CC26>1,0.98, IF(CC26>0,1,0))))))
    3. (CF) A multiplier is then applied to the daily predicted LTE as overall vine hardiness approaches its maximum
    4. (CI) =((CE26+CD26)\*CB26) Daily change in hardiness (to be used later)
    5. (CJ) =(CJ25+((CD26+CE26)\*CB26)\*CF26)…This is the initial estimate of hardiness
15. During the period of maximum hardiness (Dec 8 to Feb 6) there are 2 IF statements used to predict LTE50 from Dec 8 – Jan 6 and another 2 IF statements from Jan 7 – Feb 6.
    1. (CD) =IF(CC104<-7,-1.5,IF(CC104<-4,-1.4,IF(CC104<-3,-1.3,IF(CC104<-2,-1.25,IF(CC104<-1,-1.15,IF(CC104<0,-1.1,1))))))
    2. (CE) =IF(CC104>5,1.3,IF(CC104>4,1.1,IF(CC104>3,0.5,IF(CC104>2,-0.2,IF(CC104>1,-1,IF(CC104>0,-1.1,1))))))
    3. (CF & CG) An increasing or decreasing multiplier is then applied to the daily predicted
    4. (CI) =IF(CC104>2,(CB104\*CD104\*CE104\*CG104),(CB104\*CD104\*CE104\*CF104)) the loss or gain in daily hardiness based on estimated LTE/day, multiplier & correction factor
    5. (CD)=IF(CC134<-4,-1.7,IF(CC134<-3,-1.6,IF(CC134<-2,-1.5,IF(CC134<-1,-1.25,IF(CC134<0,-1,1)))))
    6. (CE)=IF(CC134>5,1.3,IF(CC134>4,1,IF(CC134>3,0.5,IF(CC134>2,0.2,IF(CC134>1,0,IF(CC134>0,-0.5,1))))))
    7. (CJ) =IF((CJ104+(CI105))<-24,-24,(CJ104+(CK105)))…This is the initial estimate of hardiness with a maximum bud hardiness value of -24°C
16. The next IF and IF(AND) statements are used to predict LTE50 during de-acclimation (Feb 8 to Apr 10).
    1. (CD) =IF(CC165<-9,CB165\*-1.5,IF(CC165<-7,CB165\*-1.3,IF(CC165<-5,CB165\*-1.1,IF(CC165<-4,CB165\*-1,IF(CC165<-3,CB165\*-0.5,IF(CC165<-2,CB165\*0.2,IF(CC165<-1,CB165\*1.1,1)))))))
    2. (CE)=IF(GY165>7,GX165\*2,IF(GY165>4,GX165\*1.8,IF(GY165>3,GX165\*1.5,IF(GY165>2,GX165\*1.3,IF(GY165>1,GX165\*1.1,IF(GY165>0,GX165\*1.05,IF(GY165>-1,GX165\*1,1)))))))
    3. (CF) =IF(AND(BY164>3,CD165<0),0.1,(CD165\*CE165)) a limit for after March 3 where hardiness cannot be gained
    4. (CG) =IF(AND(CO165<-23.5,CF166<0),CF166\*0.1,IF(AND(CO165<-22.5,CF166<0),CF166\*0.4,IF(AND(CO165<-21.5,CF166<0),CF166\*0.7,1))) a limit where gains in hardiness are reduced when bud hardiness is high
    5. (CH) =IF(AND(CO166<-23.5,CF167>0),CF167\*1.2,IF(AND(CO166<-22.5,CF167>0),CF167\*1.1,IF(AND(CO166<-21.5,CF167>0),CF167\*1.05,1))) an enhancement where losses in hardiness are increased when bud hardiness is high
    6. (CI) =IF(CH166\*CG166=1,CF166,(CG166\*CH166)) the loss or gain in daily hardiness that includes limits & correction factors
    7. (CJ) =IF((CJ104+(CI105))<-24,-24,(CJ104+(CK105)))…This is the initial estimate of hardiness with a maximum bud hardiness value of -24°C
17. This initial bud hardiness value is next followed by a set of equations that set an upper limit boundary for hardiness. As bud hardiness approaches this limit the gains in bud hardiness due to cold temperature exposure become less. See comments for explanations of IF(AND) statement in the next 2 columns (CK, CL & CM) in this model. Another limit is used that reduces the gain in de-acclimation when predicted LTE is more than -10°C (CN)
    1. Observation 3 – Each variety has a maximum hardiness. In this model the upper limit for Merlot is near -24.0˚C. If ambient temperatures fall below this point significant bud & phloem damage would occur.
    2. Assumption 9 – During de-acclimation the rate of change to predicted LTE decreases at -10 ˚C and warmer.
18. The Final Predicted LTE50 is compared to the actual measured LTE50 (For Merlot the actual measured LTE50 is a value that is averaged from 3 to 14 sites). The accuracy of this model is measured by the R-squared value and the slope (a 1.0 in both cases would be perfect).
19. This model can now be used in future years and will only need to use the current year’s 2-day average of daily mean temperature.