Nova Scotia Wine Grapes: Will a Changing Climate Mean a Change in Spring Frost Risk?

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In late May 2018, the Maritime provinces were enjoying unseasonably warm weather with daily highs reaching into the mid- to high twenties. Then, in the early hours of June 4, the Environment Canada thermometer at AAFC's Kentville Research and Development Centre registered -1.87 °C, a new record low temperature for June.[*] That record dates back to 1913. Young, rapidly growing grape leaves and shoots are especially susceptible to cold temperatures below 0 °C. The loss of the primary shoots to frost (**Figure 1**), which are typically far more fruitful than secondary and tertiary shoots, resulted in the loss of most of the crop that year at hard-hit vineyards. In the wake of this devestating event, one of the most common questions asked was, "Is this a sign of things to come?" Using regionally available data, this report examines: a) how the climate in the region has changed and b) the potential implications for bud break timing and spring frost risk.

Figure 1. A damaged primary shoot on a young Marquette vine 3 days post-frost in 2018. The apical meristem, inflorescence and leaves were damaged while the basal portion of the shoot remained viable.

A Changing Climate

An analysis of historical Kentville weather data (1913–2021) provides the following key findings:

- On average, the last spring frost now occurs 18 days earlier (**Figure 2A**).
- On average, the first fall frost now occurs 22 days later (**Figure 2B**).
- On average, the heat we receive in the form of base 10 °C growing degree days (GDD_{10}) (April 1 to October 31) has increased by 27% (**Figure 2C**).

These trends are all highly significant ($p < 0.001$). This means that the probability that the growing season is *not* getting both longer and warmer is less than 1 in 1,000. However, the timing of the last and first frosts, along with the amount of heat we receive, is *highly* variable, with large differences likely to occur between consecutive years. Let us use the last spring frost date—generally considered the beginning of the growing season—to explain. From our analysis (**Figure 2A**), we know that in 1913 the predicted last spring frost date was May 26. Fast forward to 2021, and we see that the date has shifted to May 8. It should be noted that it is difficult to accurately predict the exact last frost date for any given year. This is not something new. The data are

[*] While this was a record low temperature, even later spring frosts have been seen: 1943, 1944, 1945, 1947 and 1958.

so variable that we can only be 95% confident that the last spring frost will fall within ± 3 weeks of our predictions. This is because other factors aside from those being measured also greatly influence this date and these factors vary widely from year to year. The range of values for the last spring frost date is huge: the earliest occurrence was on April 16 in 2010 and the latest was on June 15 in 1943. While we can safely say that the variability of the last frost date has been high since 1913, whether this variability has increased in recent decades is open to interpretation. The most dramatic increase in atmospheric global CO_2 levels has occurred over a timeline (≈ 50 years) that is shorter than our historical weather data set (www.co2levels.org) (**Figure 2D**). Even considering the variability of this data set, the late frost in 2018 is an outlier as it fell outside the dates predicted with a 95% confidence level and this is already a wide margin (**Figure 2A**). In other words, we did not see it coming.

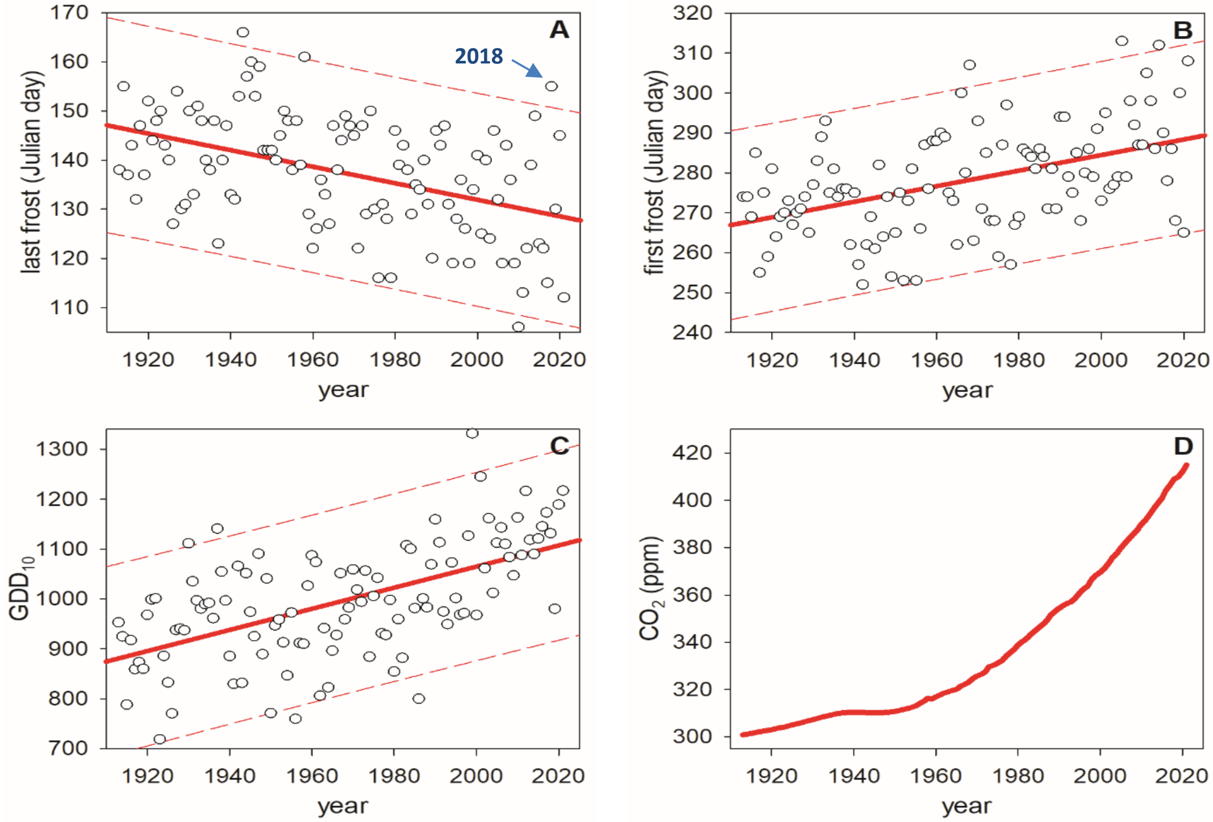


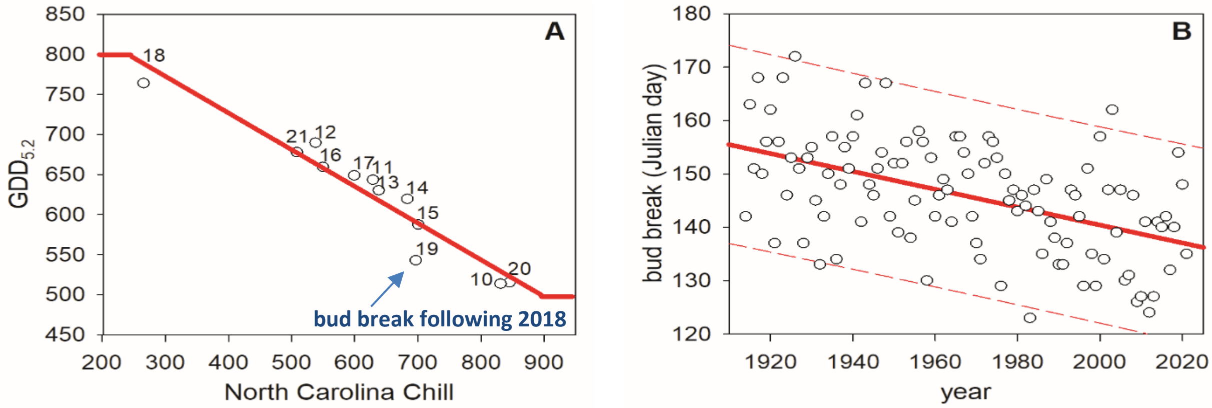
Figure 2. Plots showing the relationship between year and (A) the last spring frost date (i.e., the start of the growing season), blue arrow indicates 2018 frost; (B) the first fall frost date (i.e., the end of the growing season); (C) base 10 °C GDD_{10} between April 1 and October 31; (D) atmospheric CO_2 levels. All trends are highly significant ($p < 0.001$); dashed red lines indicate 95% prediction intervals.

Modelling Bud Break and Spring Frost Risk

The bud break modelling and spring frost risk analysis produced the following takeaways:

- Fall chilling units + heat units can be used to accurately predict bud break (**Figure 3A**).
- The predicted bud break (**Figure 3B**) and last spring frost (**Figure 2A**) dates have both advanced by 18 days, suggesting that there is no long-term trend in the spring frost damage risk (**Figure 3C**).

Chilling is required to release the buds from dormancy, while heat helps drive the metabolic mechanisms that lead to bud break. We obtained 12 years of phenology data for a Lucie Kuhlmann vineyard from Grand Pré Winery (Grand Pré, Nova Scotia). Lucie Kuhlmann, a red hybrid, is one of the earliest varieties to break bud in the region and therefore also has an elevated risk of spring frost damage. While the optimized model for Lucie Kuhlmann fits the data well (**Figure 3A**), there is one notable outlier year: the one following the 2018 spring frost. The model shows that the vines required less heat to achieve bud break in 2019 than the model predicted. How the physiology of the vines was impacted by the frost and produced this outcome would be an interesting research question but is currently a matter of speculation. When the historical weather data are plugged into the model, a trend in bud break dates similar to the trend observed for the last spring frost dates is generated (**Figures 2A, 3B**); the timing of both events advanced by approximately 18 days during the 1913–2021 period. Lastly, when the difference between the bud break date and the last spring frost date was plotted (i.e., the margin of safety measured in days between the last frost date and the bud break date), no significant trend was found (**Figure 3C**). This suggests that there has not been a long-term increase in the spring frost risk in terms of bud break in Lucie Kuhlmann, nor has there been a decrease (based on the limited data available). While this does provide some comfort, the complexity of the forces at play and possible repercussions of recent increases in atmospheric CO_2 levels (**Figure 2D**) are not reassuring: uncertainty is the only certainty there is.



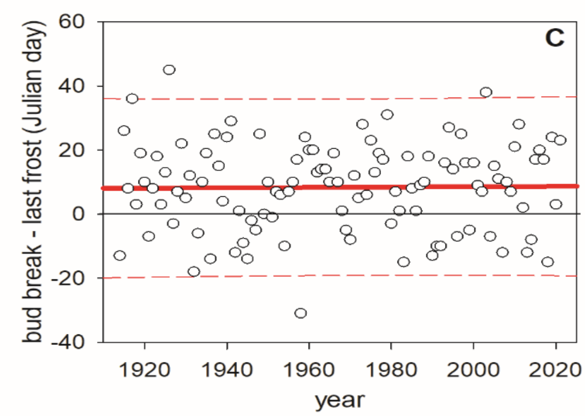


Figure 3. Plots showing (A) Lucie Kuhlmann bud break model based on North Carolina chilling units and base 5.2 °C $GDD_{5.2}$ ($R^2 = 0.91$, $p < 0.001$); asymptotes were fitted to the model at 500 and 800 GDD; (B) year versus the predicted bud break data (Julian day) based on the model ($p < 0.001$); (C) year versus the difference between the predicted bud break date and the last spring frost date (Julian day). Values < 0 (black line) suggest years when the last frost occurred after bud break for the early breaking Lucie Kuhlmann variety. Dashed red lines indicate 95% prediction intervals.

Acknowledgements

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