Weather INnovations Incorporated

# A STUDY OF STARTING DATES FOR CHU ACCUMULATION IN ONTARIO

## Prepared for the Ontario Corn Committee

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## INTRODUCTION

Ontario corn producers have been using the concept of Corn Heat Units (CHUs) to aid in the selection of corn hybrids; since the idea was first introduced by D.M. Brown, (1963) over forty years ago. This CHU system was the most widely used agroclimatic index for characterizing the suitability of corn hybrid maturity and zonation requirements in the northern United States until recently; and is still used today in Ontario. The CHU daily calculations assume that no development occurs at night temperatures below 4.4°C, or day temperatures below 10°C. It uses an optimal growth temperature for corn of 30°C; and growth declines at temperatures above this point. The formula is as follows:

$$CHU = \frac{(1.8(T_{min} - 4.4) + 3.33(T_{max} - 10) - 0.084(T_{max} - 10)^2)}{2}$$

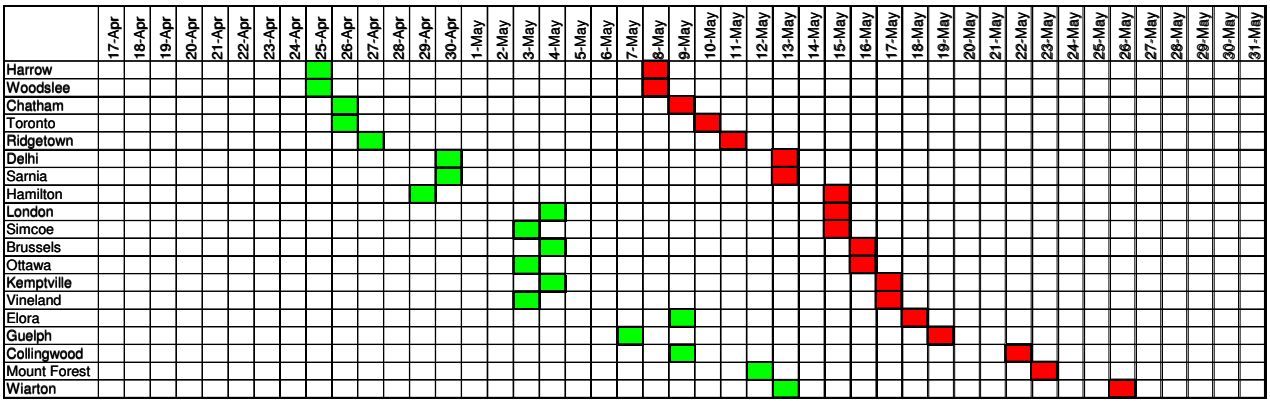
$T_{min}$ = daily minimum temperature (C)
$T_{max}$ = daily maximum temperature (C)

In a subsequent publication, 1995 (OMAF Factsheet 1993), D.M. Brown and A. Bootsma revised the CHU map by defining the season start based on a temperature formula and a season end based on either a killing frost (-2°C), or a calendar date when the 30-year average daily mean air temperature dropped to 12°C or lower. CHUs have been used since providing a reasonable estimate of the corn growing potential across Ontario.

The start date for accumulation of CHUs has been the subject of confusion and debate for some time. The rules for starting the season can create a wide range of seasonal start dates when they are applied correctly. However, many of the current CHU published information and the agencies that provide this information have modified or have not included all of the rules used in the starting date formulae. When growers or industry representatives go looking for information they may not realize the significance of the errors or omissions, only that the values do not match. If CHU accumulations are not calculated according to the same start method by everyone, comparisons between sets of data become inaccurate; and the value of such a tool is lost.

The start date rule is: “the last day of three consecutive days =>12.8°C, after the date the 30-year average daily mean air temperature has reached 10°C”.

**Table 1.** Variation in start time at various locations across Ontario




**10°C threshold (Fixed date of 30 Year daily average air temperature =>10C)**

**30 Year Average CHU start date**

It is often the 10°C rule that is omitted when calculating CHUs in Ontario.

When the start date temperature-based formula is not properly used, CHU accumulative values are incorrect and yearly comparisons are not possible. Also these early temperature formulas are somewhat antiquated; no longer reflecting the more recent changes in planting dates by growers, based on "soil fitness".

Corn production has changed in many ways in the last 40 years, not the least is the decision when corn is planted. Corn seed treatments are more effective and more widely used now, while corn genetics have given rise to more robust seedling vigour. There has been a tendency to plant when the ground is "ready", meaning dry enough for the planter. Less consideration has been given to waiting for ideal germination temperatures, which has been the basis of the CHU starting date determination. In light of these changes in grower preferences, a review of the methods used in calculating CHUs, (especially the period when to start accumulating corn heat units) has been a priority of the Ontario Corn Committee.

## EVALUATION COMPARISONS

Several factors were looked at in this study in an attempt to get a clearer picture of what happens with CHU accumulation in Ontario. The first objective, an "update" of the CHU map was made using the current method developed by Brown and Bootsma; but

using updated weather data to calculate the CHU accumulations. Brown and Bootsma used 1961-1990 data, while this study updated the CHU values using 1971-2000 data for the same (or nearest available) sites. Comparisons were then made between the two sets, to determine if there has been a significant change in seasonal CHU accumulation between the two time periods. The second objective was to determine the significance of changing the current starting date from a formula base, to a May 1 calendar starting date. The third objective was to compare Ontario's "modified starting date" CHU calculations to the US, Growing Degree Day system.

In studying seasonal CHU accumulation, Brown and Bootsma attempted to give a reasonable biofix for yearly start and end dates for corn growth. They fixed the annual start date as the third of three consecutive days with a mean daily temperature greater than 12.8$^{o}$C; provided that the three-day span occurred after the date where the thirty-year average daily mean air temperature exceeded 10$^{o}$C. The end of the growing season is taken as the first occurrence of a killing frost (-2$^{o}$C), or the date when the daily mean temperature has historically (30-year normals) fallen below 12$^{o}$C. Using these criteria, a map of the 30 year average (1961-1990) seasonal accumulation of CHUs was developed. The "updated" CHU values, using the newer dataset (1971-2000) based on Brown and Bootsma's method revealed some interesting changes overall; but particularly in the starting dates.

**i) Comparison in CHUs, using temperature datasets from 1961-1990 vs. 1971-2000.**

The first rule in the start date determination, that of the10$^{o}$C average in the spring moved ahead for most stations and behind for others, resulting in a no change average across all 50 sites. Sudbury's 10$^{o}$C date moved four days earlier, while Hamilton's moved 6 days later. Surprisingly, the season-ending 12$^{o}$C day, 30-year average was earlier using the most recent 1971-2000 dataset, than with the earlier dataset used by Bootsma and Brown. The growing season has actually gotten slightly shorter. The average of the 50 stations was a shorter season by two days, ranging from a loss of seven days at Walkerton, to a gain of three days at Earlton and Fort Frances. The average CHU accumulation for the fifty sites using Brown and Bootsma's accounting shows essentially no change between the 1961-1990 period and the 1971-2000 period (see Figure 1 and Figure 2). There is, however, considerable variation at some weather station locations; for example, the

maximum gain was 255 CHUs at Kingston, while Hamilton dropped 230 units (Figure 3). Hamilton's drop is likely due to WIN's use of a different weather-recording site at the top, rather than at the bottom of the escarpment as used by Brown and Bootsma. Part of the change may be attributable to changes in weather station citing; urban growth in the area around a station; or other unforeseen factors. Recorded values cannot be looked at without keeping these other factors in mind.

Given the current hype about global warming, it was interesting to not see a greater change in the accumulated CHU values between Brown and Bootsma's 1961-1990 dataset and the updated 1971-2000 dataset. The replacement of the weather data from the 1960's, with the data from the 1990's, made very little difference on the average CHUs. The regional differences are of significance to growers, however; and the apparent changes in seasonal CHU accumulation have likely changed farming practices in some areas.

**Figure 1.** Average seasonal CHU using the $10^{o}/12.8^{o}$ start date method and data from 1961-1990

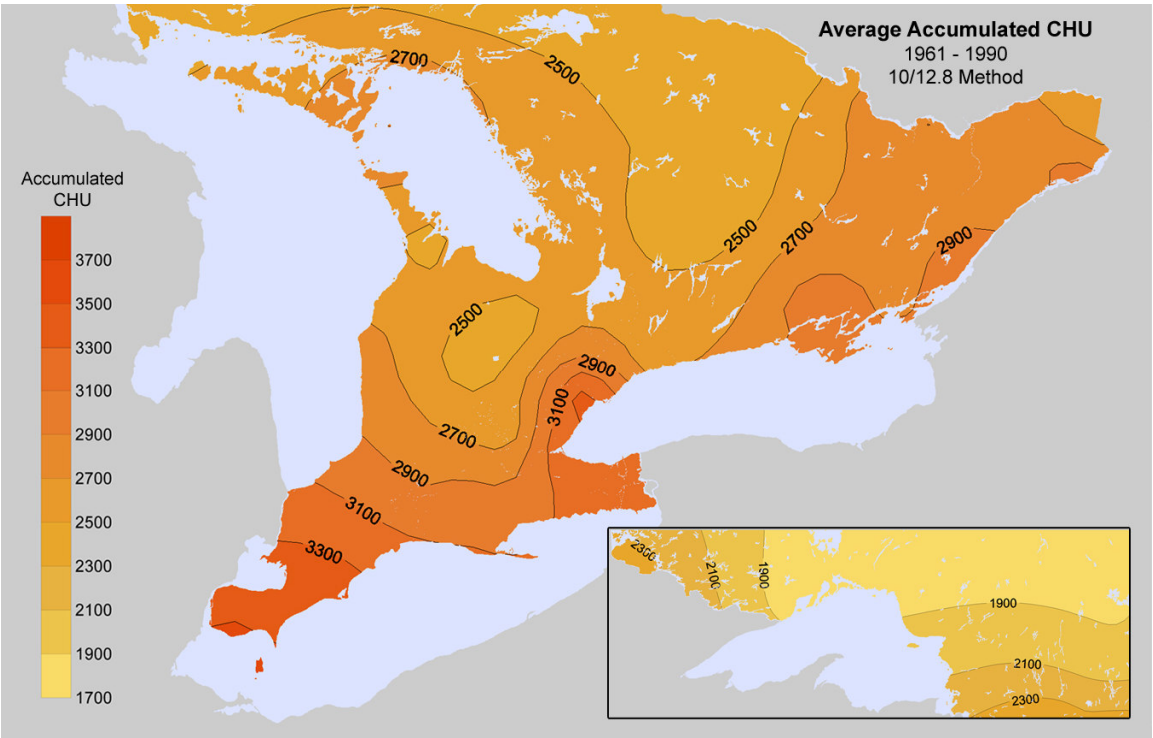


**Figure 2.** Average seasonal CHU using the 10°/12.8° start date method and data from 1971-2000.

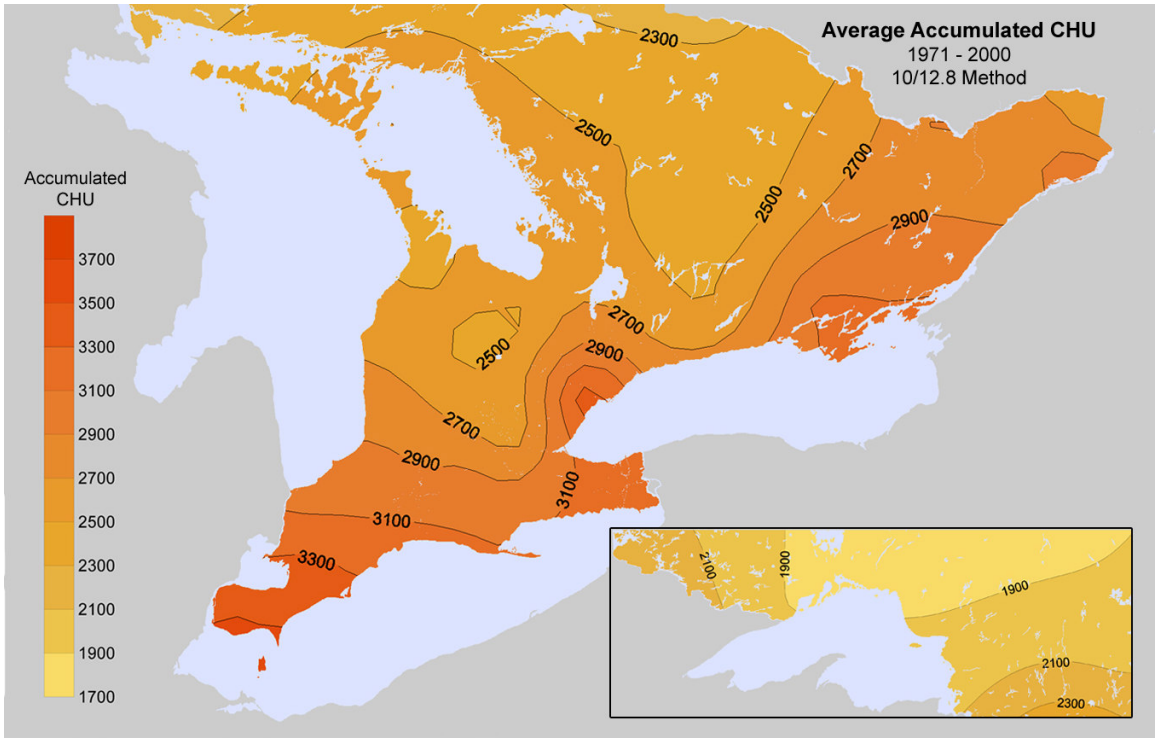
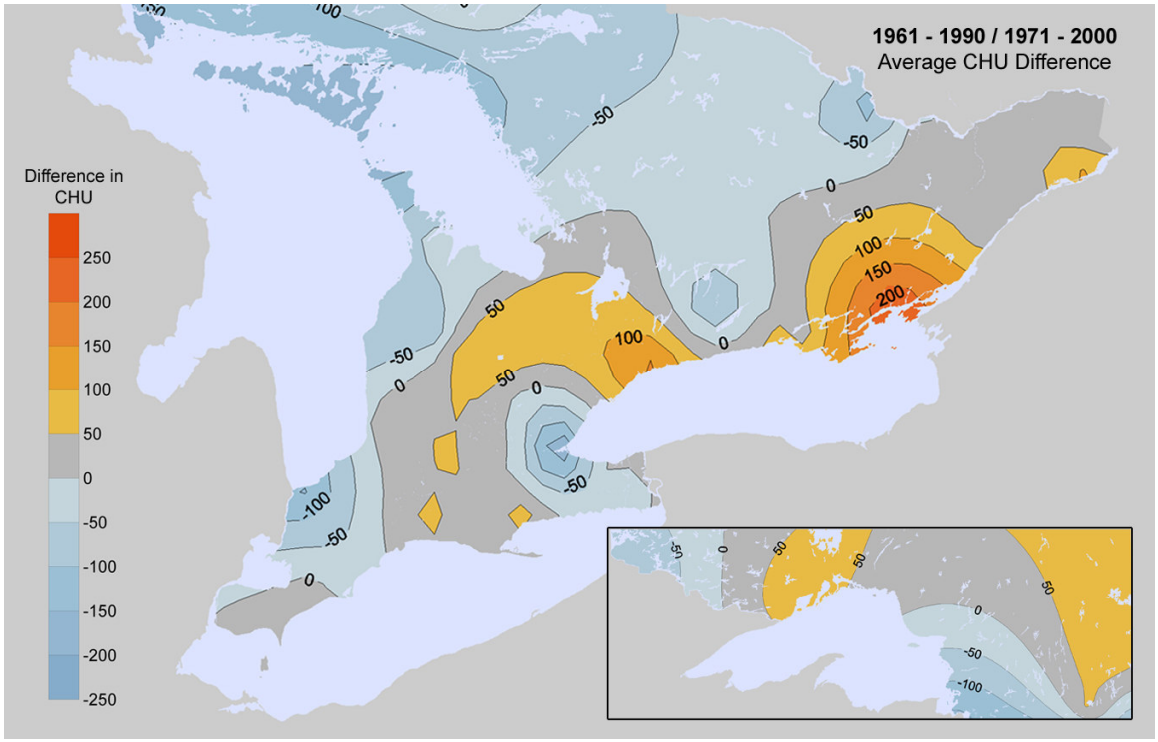



**Figure 3.** Difference in CHU accumulation between 1961-1990 dataset and 1971-2000 datasets.



Although the average CHUs have not changed significantly across Ontario since the time Brown and Boostma first developed the CHU maps; there have been significant, although relatively slight differences, in specific regions. In the Kingston, Toronto Simcoe and northern Ontario regions there has been an overall increase in CHUs, resulting in a slightly longer growing season (over 50-250 CHUs) over the years; while in the southwest, Georgian Bay, Sudbury and Ottawa, the seasons are just slightly shorter (less by 50-250 CHUs). If the daily maximum temperature is 25C and the minimum was 15C, then the daily CHU would equal 25. A 50-250 CHU change, as mentioned, converts to a 2 - 5 day difference. In the Hamilton area there was a change in the location of the weather station in the new data set, which resulted in a dramatic looking change in the map, Fig. 3.

**ii) CHU calculations using a May 1 start date**

Comparing seasonal CHU accumulation between the current method and the proposed calendar start date of May 1 (Figure 4) shows a fairly consistent, but slight, rise (6.2%) in CHU accumulation. The average increase in seasonal CHU using a May 1 start date, rather than the conventional formula, was 186; with a fairly tight standard deviation of ±21.

**Figure. 4.** CHU comparison between the currently used starting date vs. a May 1 proposed starting date.

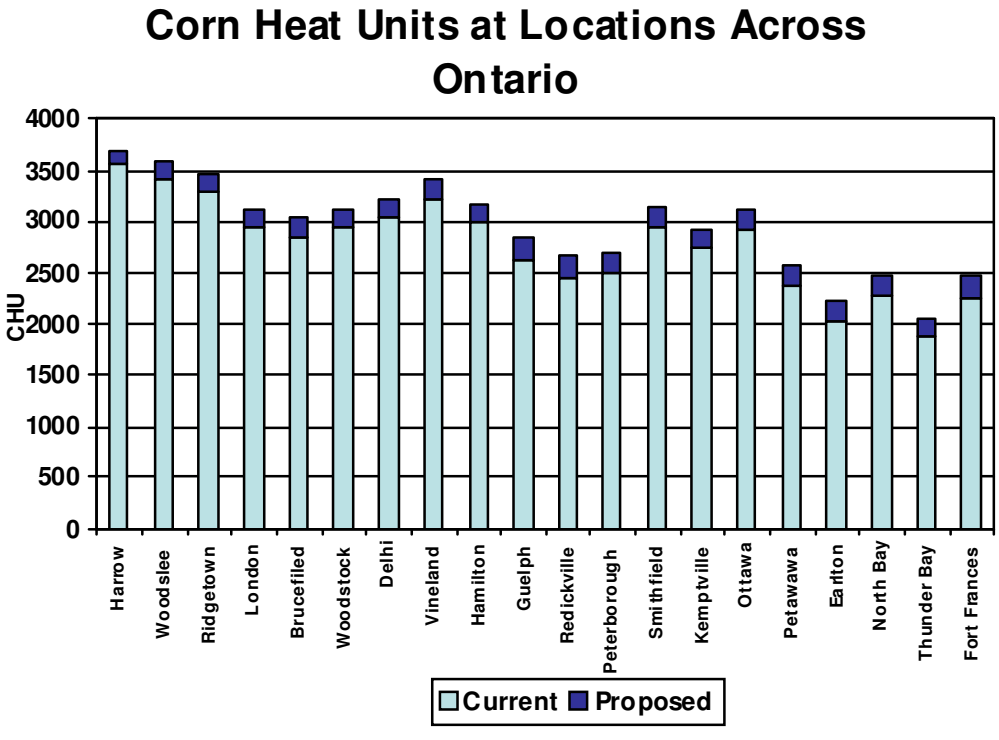


**Figure 5.** Average CHU throughout all 50 tested locations across Ontario. A slight 6.2% increase in CHUs.

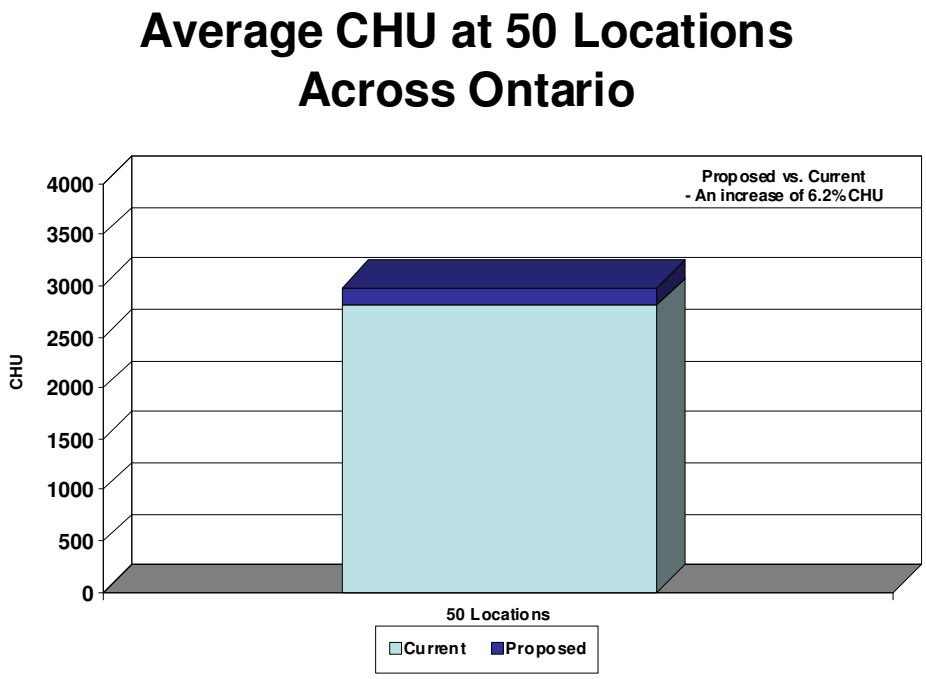



**Figure 6.** Differences in CHU accumulation comparing the current starting date to a May 1 starting date

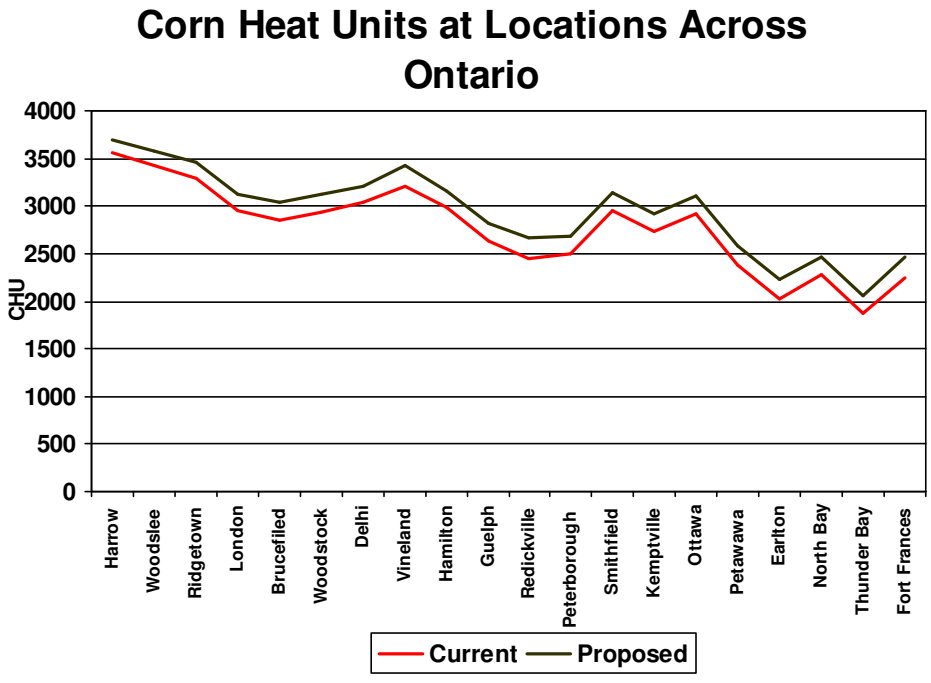
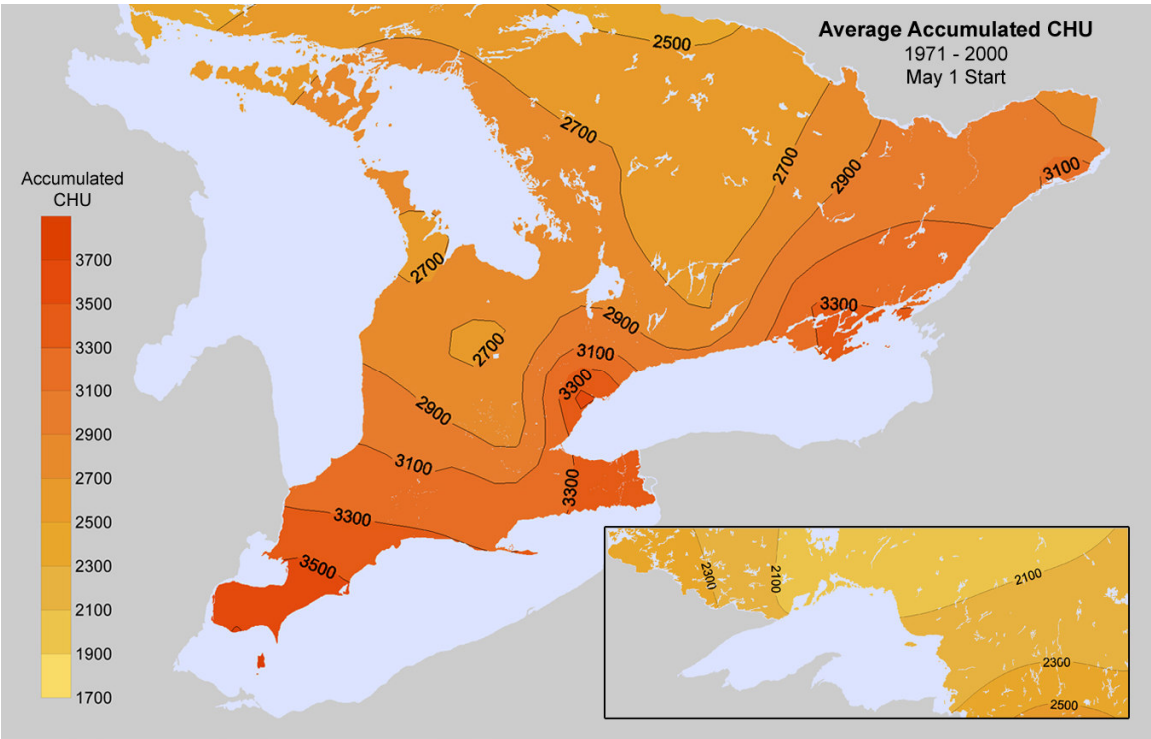


**Figure 7.** Average seasonal CHU from 1971-2000 data using a fixed May 1 start date.

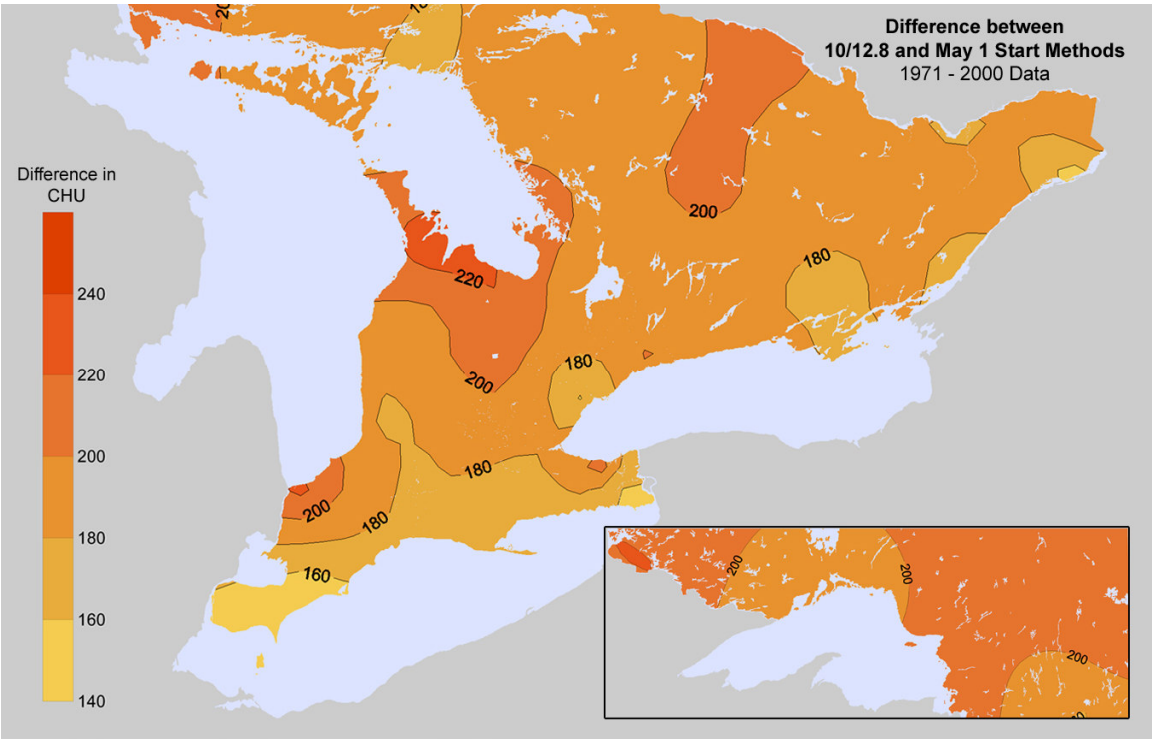



The increases were lowest in the warmest regions of Ontario - Kent and Essex counties and most of the Niagara Peninsula, while the largest increases tended to be along the colder lakes - the north shore of Lake Ontario, and along Lake Huron and Georgian Bay. Higher elevations and higher latitudes also gained many CHUs from the earlier start date. This appears reasonable, since the starting dates for many of the cooler sites were delayed when using the Bootsma and Brown formula compared to the warmer southern stations; and increased variability of weather at these places may set the 3 contiguous 12.8$^{o}$ days back farther.

This is not surprising as it has been speculated that growers are planting earlier, taking more advantage of the CHUs that are available during the Ontario summers. Growers have been planting longer season CHU hybrids in many regions and harvesting the crop on time. Assuming the CHU rating is correct for each corn hybrid, the current system may have been underestimating the total CHU available for many years. Growers have understood these differences; and have not hesitated in utilizing these longer season hybrids, thereby gaining yield all these years. Also, there appear to be regions that differ

in CHUs from their surrounding area - colder or warmer, longer vs. shorter season. Growers may have also perceived these differences and have learned the farm locations where longer season crops can safely be planted. See APPENDIX.

**Figure 8.** Difference in CHU accumulation between $10^{o}/12.8^{o}$ start and fixed May 1 start date (1971-2000 data).




The effect of using a standardized start date for CHU accumulation is to add a fairly uniform number of CHUs to all the growing areas in the province, with a slightly greater increase in colder areas. Adopting a May 1 start date has the effect of making across year comparisons easier; and possibly leading to a more standardized use of CHU accumulation, due to the simplified start method. In some areas and some years, it will give a more accurate reflection of actual accumulation of CHUs for the crop, which may be in the ground earlier than the traditional start date.

If growers are interested in determining the CHU that were accumulated per planting date, WIN could develop a program where a grower would enter his planting date, or better still the emergence date. A calculation could be made for each hybrid/field requested, based on the nearest weather station. Over time, this will allow a grower to better judge which corn hybrids are most suitable for his farm.

### iii) Corn Heat Units vs. Growing Degree Days

The northern US states have recently begun to use Growing Degree Days rather than CHUs. It is not clear to the authors the rationale for switching over to the GDD system. However, it is important that in Ontario we understand and compare the CHU system that we now use; and compare it with their system.

The most often used method for calculating GDD is to subtract 50 degree F (10C) from the mean daily temperature. The following adjustments are necessary:

1) temperatures below 50 F are set at 50 F
2) temperatures above 86 F (30C) are set at 86 F.

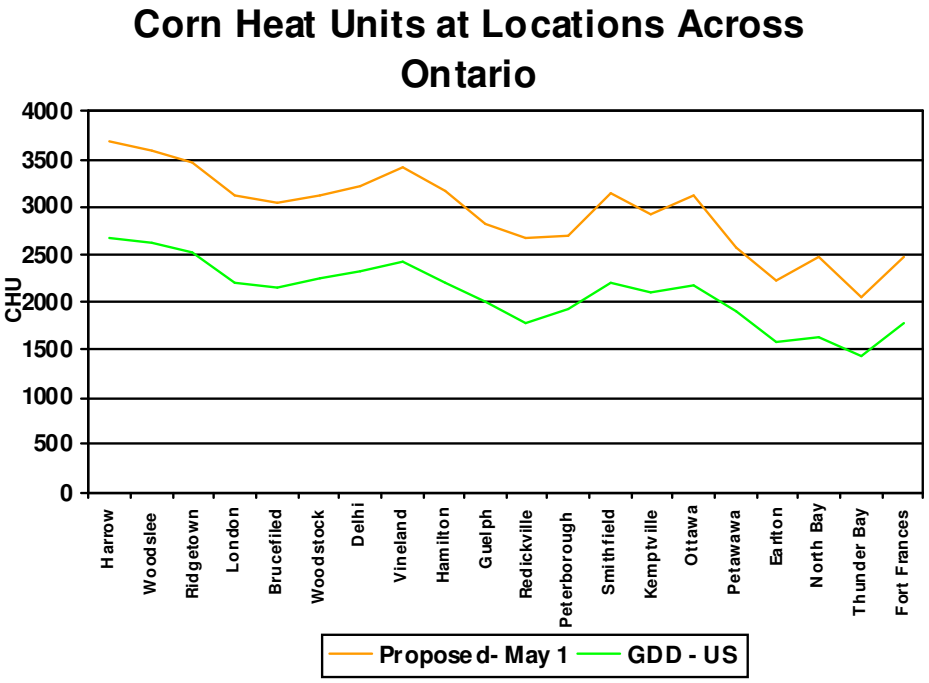
This method of calculating GDDs is often referred to as the (86,50) system. Some examples are as follows:

For High = 80F, Low 60F (80 + 60)/2 – 50 = 20 GDD
For High = 60F, Low 40F (60 + 50 (40))/2 – 50 = 5 GDD
For High = 90F, Low 70F (86(90) +70)/2 – 50 = 28 GDD

Growing Degree Days are calculated for each day; starting the day after planting and using the 10% frost date in the fall.

Using our proposed CHU with a starting date on May 1 and comparing the Growing Degree Day accumulative values at 20 locations across Ontario, Figure 9; the differences are not very large, but most important the patterns are very similar.

**Figure 9.** Comparing the US system of calculation GDD vs. the Ontario system using the new proposed CHU system




The units are considerably lower when using the US GDD system; than the modified and more realistic proposed CHU, with a starting date on May 1. Se APPENDIX.

## CONCLUSIONS

- The average starting date (temperatures >10C) did not change significantly between using the original temperature dataset used by Brown and Bootsma, 1961-1990 compared to using the more recent temperature dataset between 1971-2000
- There were differences at certain locations across Ontario, with some locations starting earlier and others with a later starting date; but on average there was no significant difference across the province
- On average, the ending date moved up by two days. The growing season has actually shortened slightly, but not to any great extent

- The average CHU accumulation for the fifty sites, using Brown and Bootsma's accounting, shows essentially no change between the 1961-1990 period and the 1971-2000 period
- Station site locations, e.g. in Hamilton can make a large difference in the CHU designations when representing a region
- The analysis of data suggests that modifying the starting date to a May 1 calendar date, the differences in actual CHU is not large; averaging an increase of 186 CHUs or 6.2% from the original Brown and Bootsma model
- The slight increase in CHU using a calendar start date on May 1 more accurately reflects what growers have known for years; that is that the current CHU model has been underestimating region CHUs for years. Growers have been successful in harvesting longer season hybrids than suggested by the CHU provincial maps
- An individual CHU calculator can be offered through Weather INnovations Incorporated for growers wanting to know the CHU values for their particular hybrid and planting date. A model could be developed where a grower would enter the emergence date; and the CHUs for that particular situation could be calculated
- In communication with the original author Dr. Murray Brown and his departmental colleague - Dr. Terry Gillespie, they have agreed with the need to modify the CHU to better reflect the farming practices of today
- It is important to recognize that the CHUs described on the Provincial map and the CHU listed on the bag of seed corn is not arrived at in the same way. The CHU rating on the bag is arrived at by careful observation of field trials; and is a measure of the actual number of CHUs needed by that hybrid to reach physiological maturity. The map uses CHU averages over a 30-year period, in an attempt to provide regional guidance to choosing corn hybrids that will mature in a location
- There has been some suggestion that perhaps Ontario should simply adopt the Growing Degree Day system used in the United States, as it "seems easier to use". The newly proposed CHU with a starting date on May 1

makes the Ontario system as easy to use as the US GDD; and provides values or CHU numbers that growers in Ontario currently are accustomed to using. The US GDD values are considerably lower than the CHU values, more familiar to the Ontario industry

## APPENDIX

The following chart is a list of selected sites across Ontario comparing total corn heat units calculated using the Brown, Boostma CHU formulae (**current**), the **new** modified formula using the initial starting date of May 1 and the average growing degree day calculation(**GDD Avg**) in the 30 year normals between either 1961-1990 or 1971-2000.

| Site | 1961-1990 CHU-Current | 1971-2000 CHU-Current | 1971-2000 CHU May1-New | 1971-2000 GDDAvg |
|---|---|---|---|---|
| Harrow | 3534 | 3555 | 3702 | 2673 |
| Woodslee | 3412 | 3424 | 3573 | 2610 |
| Ridgetown | 3342 | 3297 | 3462 | 2511 |
| London | 2899 | 2946 | 3120 | 2203 |
| Simcoe | 2939 | 3024 | 3190 | 2268 |
| St. Catharines | 3247 | 3251 | 3422 | 2445 |
| Guelph | 2682 | 2628 | 2828 | 2012 |
| Brucefield | 2823 | 2859 | 3034 | 2140 |
| WalkertonHanover | 2680 | 2575 | 2759 | 2000 |
| Redickville | 2342 | 2447 | 2665 | 1796 |
| Trenton | 2863 | 2837 | 3033 | 2100 |
| Belleville | 3139 | 3207 | 3369 | 2353 |
| Kemptville | 2731 | 2733 | 2926 | 2087 |
| Kemptville | 2731 | 2733 | 2926 | 2087 |
| Ottawa | 2885 | 2923 | 3099 | 2174 |
| Petawawa | 2379 | 2381 | 2583 | 1893 |
| North Bay | 2384 | 2275 | 2465 | 1622 |
| Sault Ste Marie | 2240 | 2081 | 2294 | 1578 |
| Earlton | 1934 | 2017 | 2228 | 1586 |
| Thunder Bay | 1789 | 1876 | 2058 | 1430 |
| Fort Frances | 2332 | 2251 | 2471 | 1777 |

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