Growing Degree Days Web Application

by

Tracy A. Hansen

A creative component submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Agronomy

Program of Study Committee:

Dr. Brian K. Hornbuckle	Major Professor
Dr. Allen D. Knapp	Committee Member
Dr. Andrew W. Lenssen	Committee Member

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And thank you to my family and friends for supporting me during the years of my studies and who offered encouragement and support along the way.

Introduction

Background

I was born and raised outside of Galesburg, Illinois in a rural area. While I didn't grow up on a farm, I spent much of my childhood surrounded by farmland and nature. I participated in 4-H showing horses, which meant long hours riding along field borders and training in the round pen. Unfortunately going off to college put my equestrian pursuits on hold.

In 2006, I graduated with my Bachelor of Science in Computer Science from Western Illinois University with a minor in Mathematics. In the years that followed, I worked at various financial and insurance companies. For some reason I always felt like something was missing, and so I decided to find a way to apply my computer science background in a field that I was more passionate about.

Why a Master's in Agronomy?

My job pursuits eventually landed me at DuPont Pioneer as a software test analyst, where I worked closely with laboratory workers and field researchers. As my job duties changed over time, I found myself having more conversations with agronomists and scientists. Their work fascinated me, but I couldn't speak their language.

After looking into continuing education opportunities that might help me bridge this gap, I found the Master of Agronomy distance program at Iowa State University. Within the first year I found that I was able to understand our users better and could have discussions with them regarding their day-to-day work. The end result was an improved user experience and enhanced quality built-in to the software applications that my team created.

Current Career

Unfortunately, the merging of large seed companies throughout the agriculture industry over the past few years resulted in many consolidations and layoffs. With my position eliminated, I found myself looking for a new job but unwilling to give up my desire to work in the agriculture sector. I soon found a job as a Software Engineer at John Deere. I currently work on the Enterprise Data Lake team in Analytics and Enablement, which is responsible for developing applications and services for users of Big Data. With terabytes of data coming from tractors, factories, warehouses, customers, and suppliers, it has proven to be a formidable yet worthwhile challenge to determine how to manage such large-scale data so it can be used by analysts and data scientists.

Today and Beyond

Today I live with my husband Brian and our dog Kito in Viola, Illinois. I was eventually able to circle back to my equestrian pursuits, and now live on a 35-acre horse farm with four miniature horses: Crash, Chrome, Joy, and Dazzle. I show them competitively in driving and in-hand classes at the local, regional, and national level. I have never lost my love of nature or being surrounded by farmland, and I look forward to using this degree to help agronomists and research scientists in the future.

Creative Component Background

Idea Generation: Combining Agronomy with Computer Science

I started the Master's in Agronomy program here at Iowa State University in the days of Blackboard, when the course materials were accessed through the msagron portal. For most of my classes, I was required to read the materials, post and participate on the discussion board, submit an assignment, and write a lesson reflection.

While I always looked forward to the new lesson readings, there were times when my eyes grew heavy reading after a long day at work and many subsequent hours of doing homework. But every now and then I came across one of my favorite features: "Try This!". These features usually opened up some small interactive graphic where I could click or drag some control and see the result. Being more of a visual learner myself, the impact of these small learning tools was great. Not only did I feel more engaged in the process of learning, but I actually felt like I retained the information longer.

The downside was that some of these "Try This!" interactive tools were Java applets, which often required the user to change security permissions in order for them to run ("How to Fix Java Applet Security Errors", 2019). There were some students in the class using Macs or certain browsers on PCs that couldn't get the applets to run, and using a mobile device such as an Android smartphone or tablet meant the applets could not be used at all ("Can Java Applets Run On Android?", 2019). With my background in computer science, I was almost always able to hack my laptop's browser security settings in such a way that the applets could run without exposing my computer to any outside threats, but there were other students that may have missed out on these learning opportunities.

By the time I enrolled in my first semester hour of AGRON 599, I knew exactly what I wanted to work on for my Creative Component. Taking the Climate and Crop Growth course (AGRON 503) fascinated me with the idea of growing degree days. The idea that a summation formula based on daily temperature and a planting start date was really all that was needed to predict plant stages didn't seem possible to me ("Growing Degree Days", 2019). I decided to see what tools were already available and see if I could create something that might fill a niche that wasn't already occupied. I began by researching available tools and putting them to the test in the spring of 2016.

Comparisons to Other Applications that are Currently Available

Corn Growing Degree Day Decision Support Tool [CGDDDST]

The CGDDDST from the High Plains Regional Climate Center [HPRCC] is a robust tool that offers the user to select their location and their GDD start date ("U2U Decision Support Tools - Corn GDD", 2019). It also allows the user to make comparisons to previous years, along with the

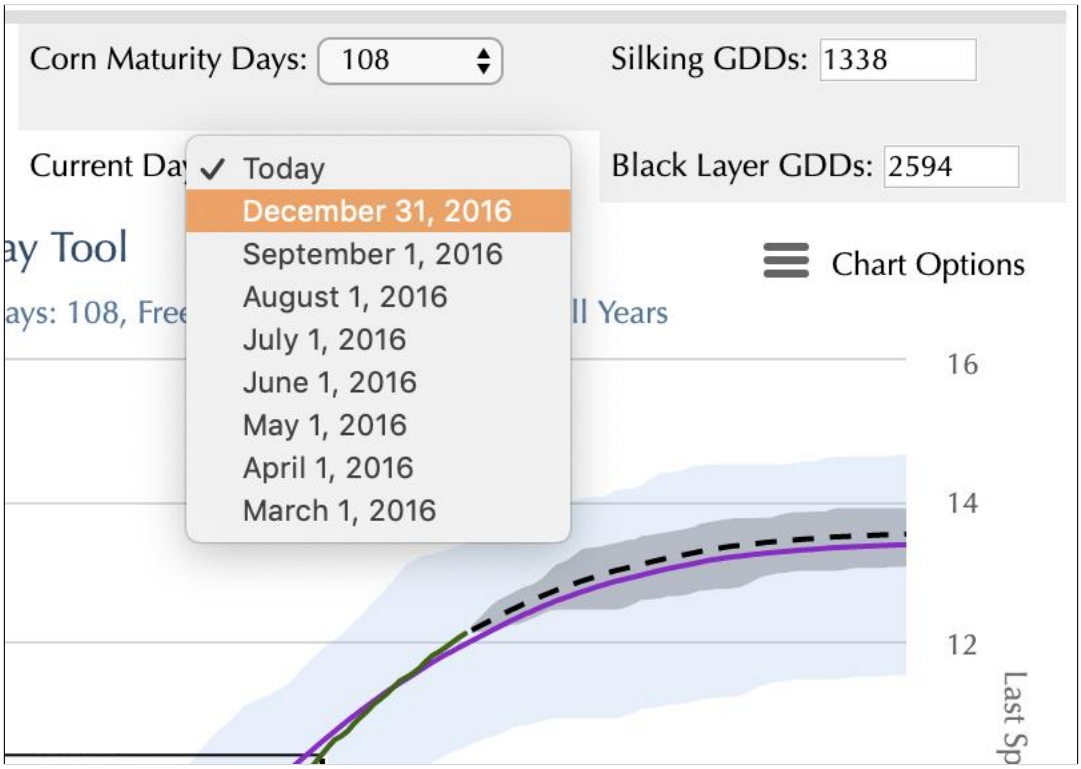
option to tweak some other values. For instance, the user can alter the number of “Corn Maturity Days”, “Silking GDDs”,” Black Layer GDDs”, “Freeze Temperature”, “Variation”, and “Current Day”. There are also options to change the information that is displayed on the graph. The user can also switch to the “Data” tab to see the data behind the scenes that help develop the graph.

Pros and cons of the CGDDDST application

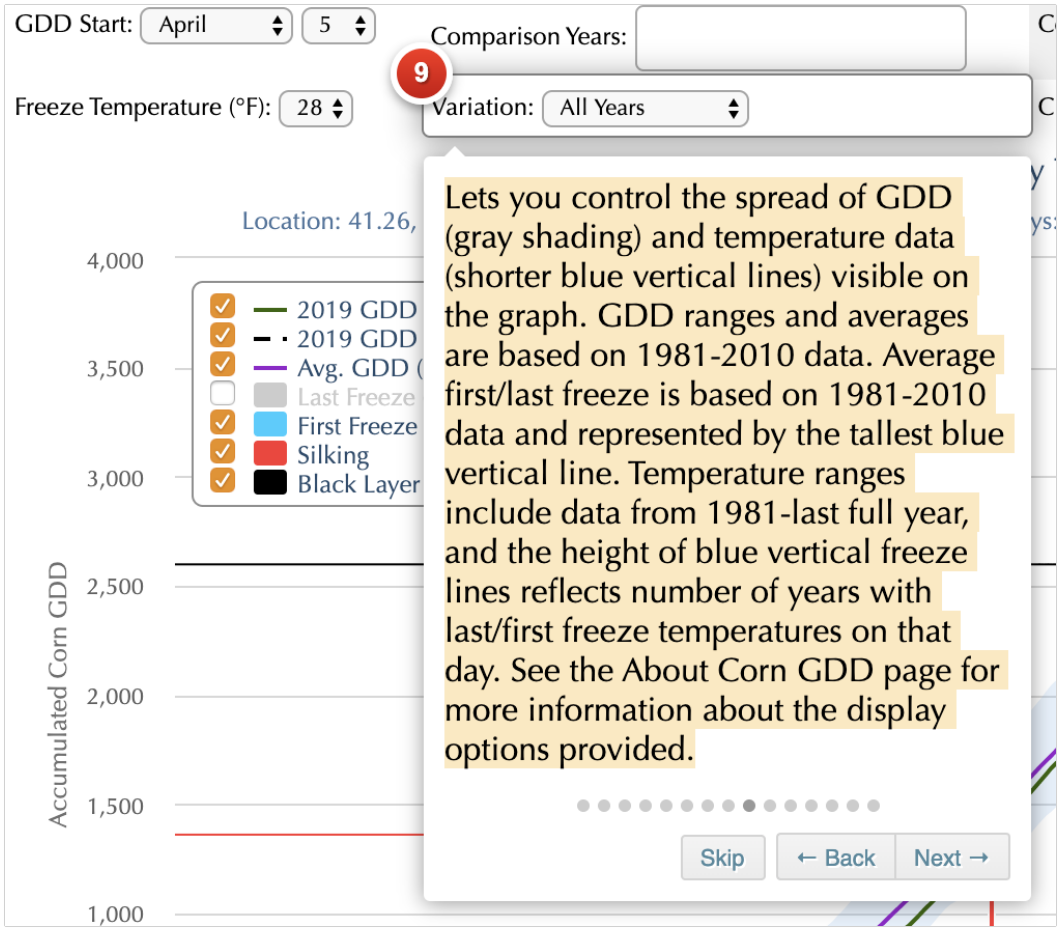
This application is very customizable for an advanced user, as illustrated by the number of fields that can be adjusted and the comparison years capabilities. For a basic user like me though, it was too much information and I found it complicated to use. At this point in my studies, I knew the formula for growing degree days using the Modified Growing Degree Days method ("Growing Degree Days - Rules", 2019):

GDD = [(maximum daily temperature + minimum daily temperature) / 2] – base temperature

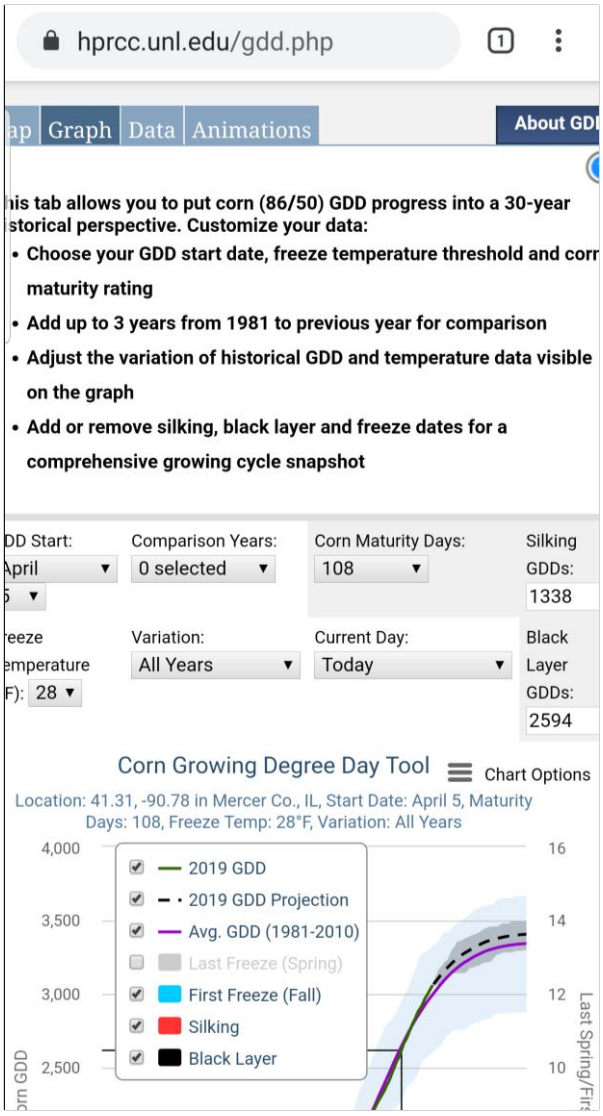
The CGDDDST application uses this as well, but it also uses additional algorithms to determine silking and black layer dates ("About Corn GDD", 2019). This went far beyond what I had learned and was a little overwhelming. There were several fields on the page that I wasn’t even sure what to enter. What does “Variation” mean? Should I change the “Freeze Temperature” or keep it at the default? Why under the “Current Day” dropdown are there only certain dates available? For example, the following screenshot from 2019 shows only dates from 2016.



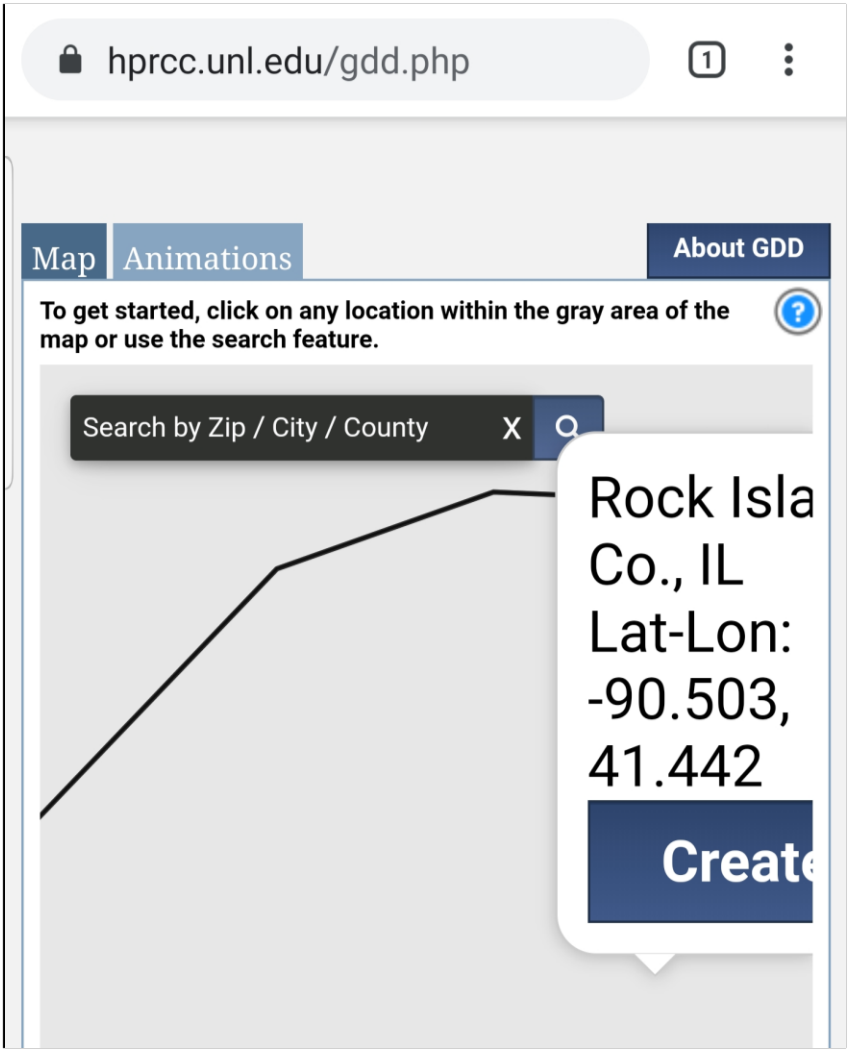
While there are some built-in help topics, the wording itself was a little advanced and resulted in me being unsure if this was a value I should change, as seen in the following screenshot.



I decided to give it a try though and see how it would serve as a learning tool. When I tested this application in the field, the first thing I noticed was that it didn't render very well on my smartphone. While I could scroll up and down and side-to-side, I couldn't pinch the screen and zoom out to see all the data at once, which resulted in page layout in the below screenshot.

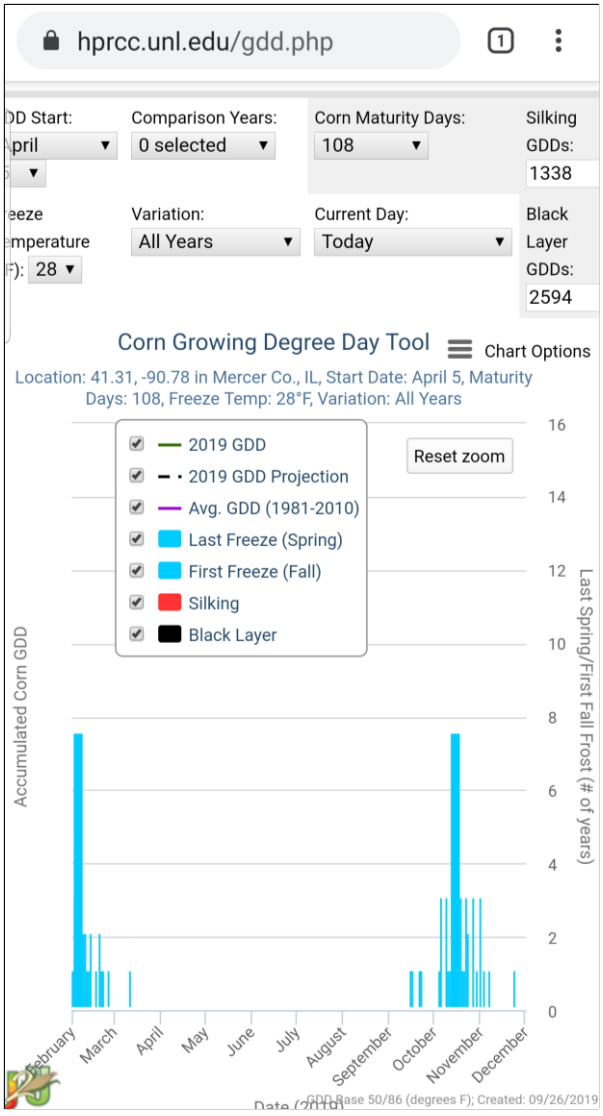


Buttons were also chopped off due to screen limitation sizes.

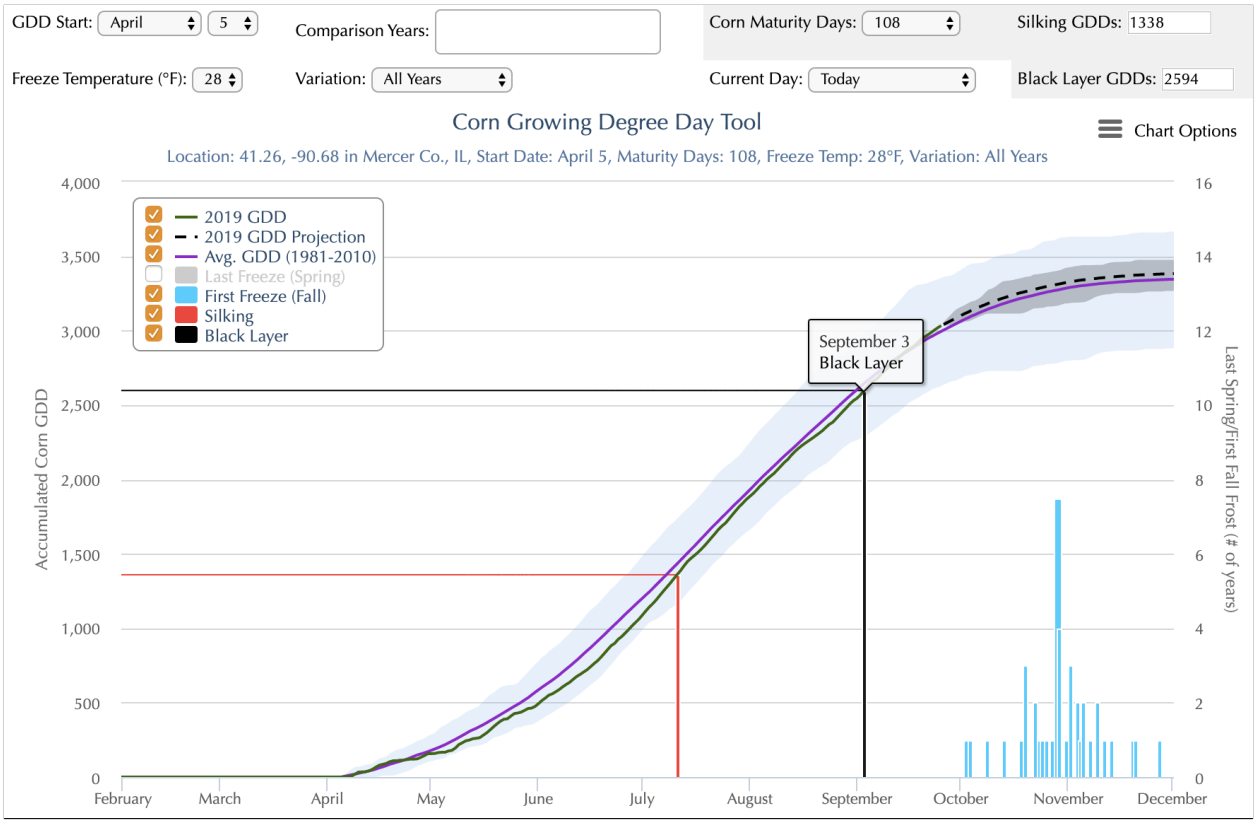


I ended up taking my laptop to the field, since I knew it worked on it. But as soon as I got out of Wi-fi range, I lost the ability to change my graph and re-render it. Unfortunately, this resulted in the tool not being very portable.

The graph that displays is very detailed, but almost overly so for a student who is learning the basics of growing degree days. Once I figured out how to view the stage by finding the vertical line on the map that lined up with today's date and hovering over it with my mouse, I was able to find out the stage. This did not work at all on my phone, as the graph did not display correctly.



This graph shown in the below screenshot is what displayed in the website when hovering over the black vertical date line.

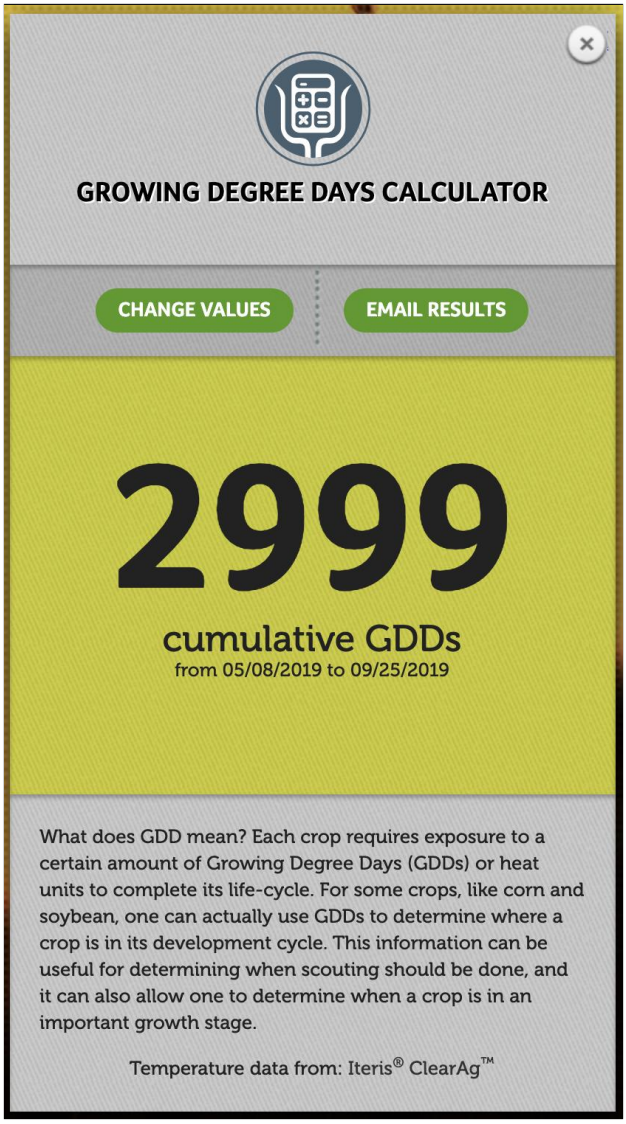


It's interesting to note that this screenshot was captured on September 26; meaning the data (and subsequent stage information) is out of date.

In the end, the only way I could verify that the stage out in the field was accurate with what the tool presented was by rendering the graph on my laptop, making note of the stage, and then going outside and verifying. Essentially, the portability was non-existent at that point.

Growing Degree Days Calculator [GDDC]

The GDDC from eKonomics is a basic, non-graphical application ("Growing Degree Days Calculator", 2019). It allows the user to enter in a location, select crop, and enter start and end date. The result is simply a number showing the list of accumulated growing degree days.



Pros and cons of the GDDC application

This tool does exactly what is says it does, calculating the total growing degree days. The downside is that there is no explanation on the results other than the blurb you see above. There's no indication of stage or any predictions available. The application does work on mobile devices however, although taking it out to the field doesn't provide the user with very beneficial results. This tool is best used in conjunction with a chart showing the expected stage so the user can look up the result.

What sets my application apart?

I wanted this application to be similar in scope to the original "Try This!" type of interactive student experience. While the other apps reviewed are both good, there is a large gap between them in terms of user knowledge expectations and output. The CGDDDST tool expects users to know quite a bit in terms of the more advanced inputs that can go into growing degree days algorithms, while the GDDC tool is very basic and can be used more as a quick homework reference to ensure that a calculation was performed correctly.

My Growing Degree Days web application strives to seek a balance between these two applications. I didn't want to make the application too complicated for those who are just learning about growing degree days, but I still wanted to provide an interactive tool that has the potential to make learning more fun and reinforce the basic concepts. There were several other features I wanted to include that would make this a good learning tool for out in the field, including the ability to be portable and localized.

GDD Web Application Instructions

Browser Requirements

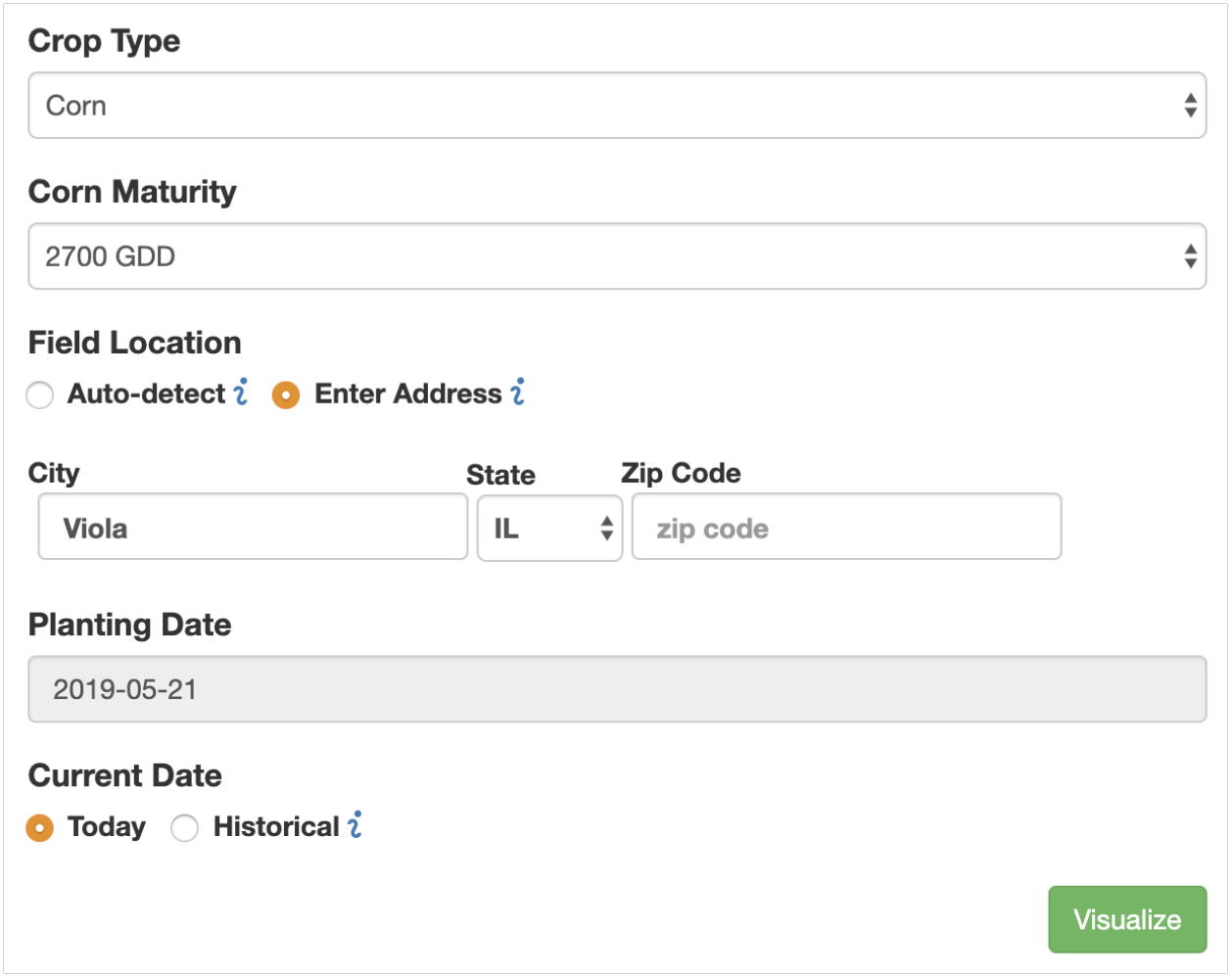
This web application should work across all browsers and versions. To date, testing has been performed on both Windows and MacOS, with various browsers such as Chrome, Firefox, Internet Explorer, Edge, and Safari. It has also been tested on various hand-held devices, including Android smartphones, Apple smartphones, and Apple iPads. Information on testing that was performed by hardware device, operation system, and browser version is included in the technical section below.

Install instructions

While you do not need to install anything, if you select the "Auto-detect" option and click the "Visualize" button, you may see a pop-up indicating that your browser wants to access your current location. You can say no if you would rather not disclose your location, which means you will manually have to enter an address to find the nearest weather station.

Entering in Data

Navigate to the following URL to access the application:
https://growing-degree-days.herokuapp.com/.



Once you load the website, you will be asked to select the following to customize your GDD chart.

1. What type of crop? Select “Corn” or “Soybean”.
    a. If “Corn” is selected, select the desired option from the “Corn Maturity” dropdown. This field will not display for the “Soybean” crop option.
2. Where is your field located? Select “Auto-detect” if you allow your browser to know your location. Or, if you do not have your location turned on or would rather enter a remote location, select the “Enter Address” option. You can then type in a specific address to look up (either “City” and “State” or “Zip Code”). Note: If there is any issue with “Auto-detect”, you will be asked to enter in the address manually.
3. When was the crop planted? Select the “Planting Date”.
4. A “Historical” end date can be entered to look up past growing season information. Note that some weather stations don’t provide their data on a daily basis, so if you specify a certain end date and the information is not available, the application will automatically adjust to include the most recent information. This is noted when the graphs are displayed with an asterisk and will show which date was actually used.

Example, I entered in August 12th and the following message displayed as seen in the below screenshot.

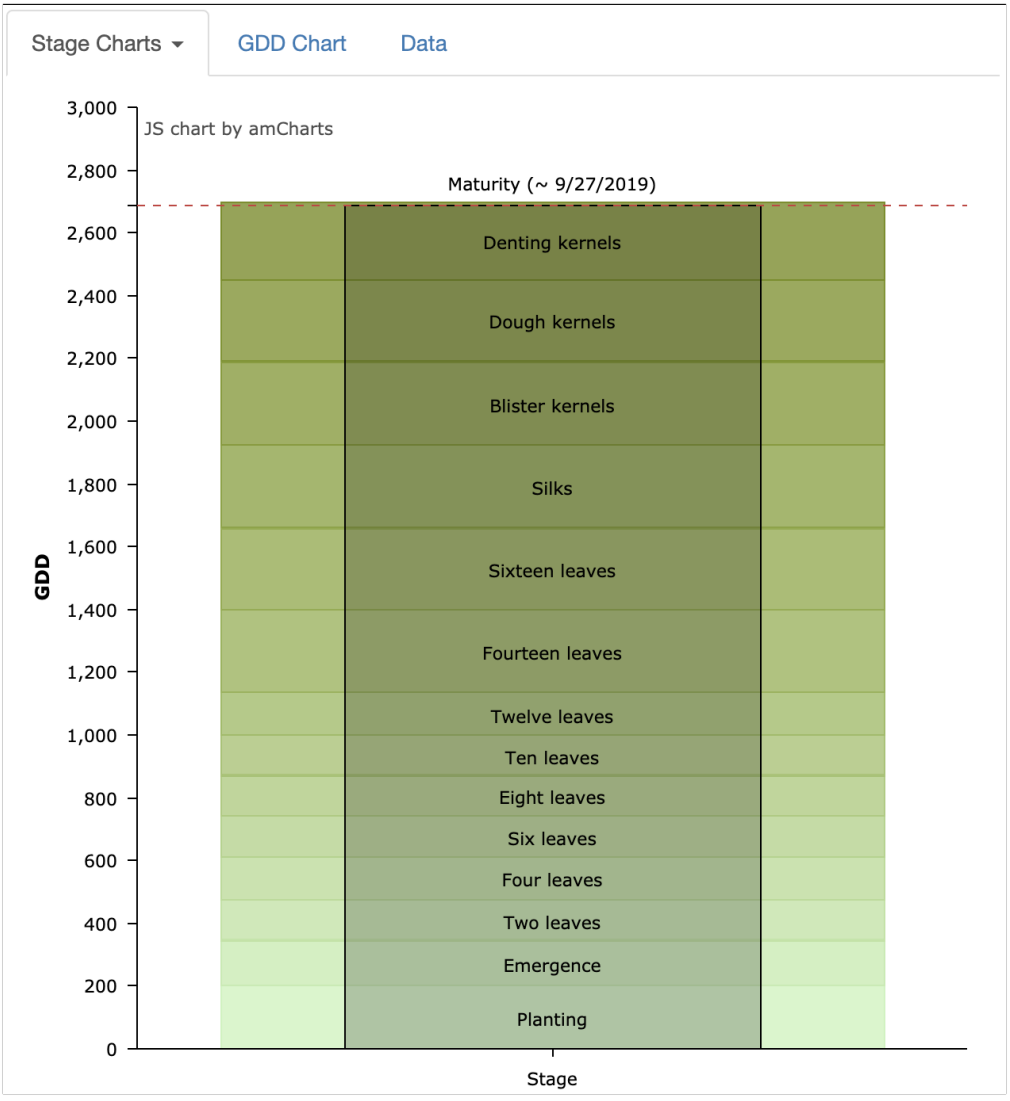
With a corn planting date of **May 4th** and a current date of **August 10th***, there are **1,891** growing degree days. The current growth stage is **Silks**. There are **34** growing degree days until the **Blister kernels** growth stage and **809** growing degree days until **Maturity**. With an average daily growing degree days of **19**, it is estimated the corn will reach Maturity on **September 22nd**, which is **43** days away from August 10th.

* Using August 10th as current date, since this is the latest weather data available

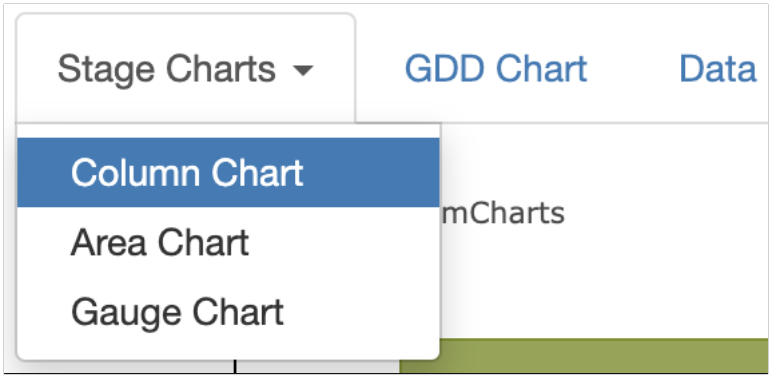
Displaying and Interacting with Graphs

To display the graphs, do the following:

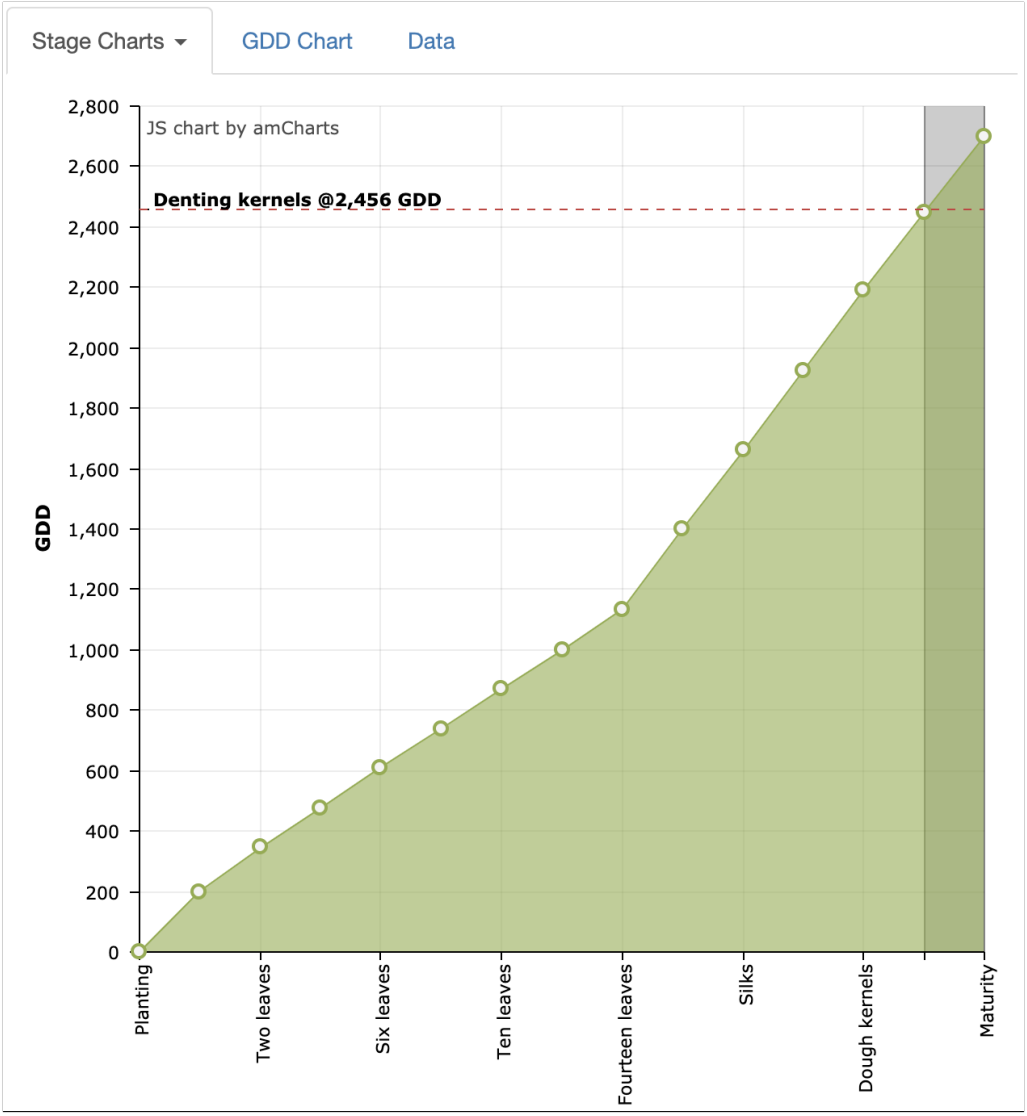
1. Click the "Visualize" button to display the "Column Chart".



2. To view other visualization types, click the down arrow next to the “Stage Charts” tab and select a different option.



You can also view an “Area Chart”.



A “Gauge Chart” can also be selected.

The information behind these charts is the same, the displays are just different in order for the user to be able to choose from whichever graphical display method they prefer. The “Column Chart” is useful for comparing the user-entered parameters with what is actually displaying in the field. This chart also has information that can be displayed by hovering over the chart with the mouse or via a finger-press on a mobile device.

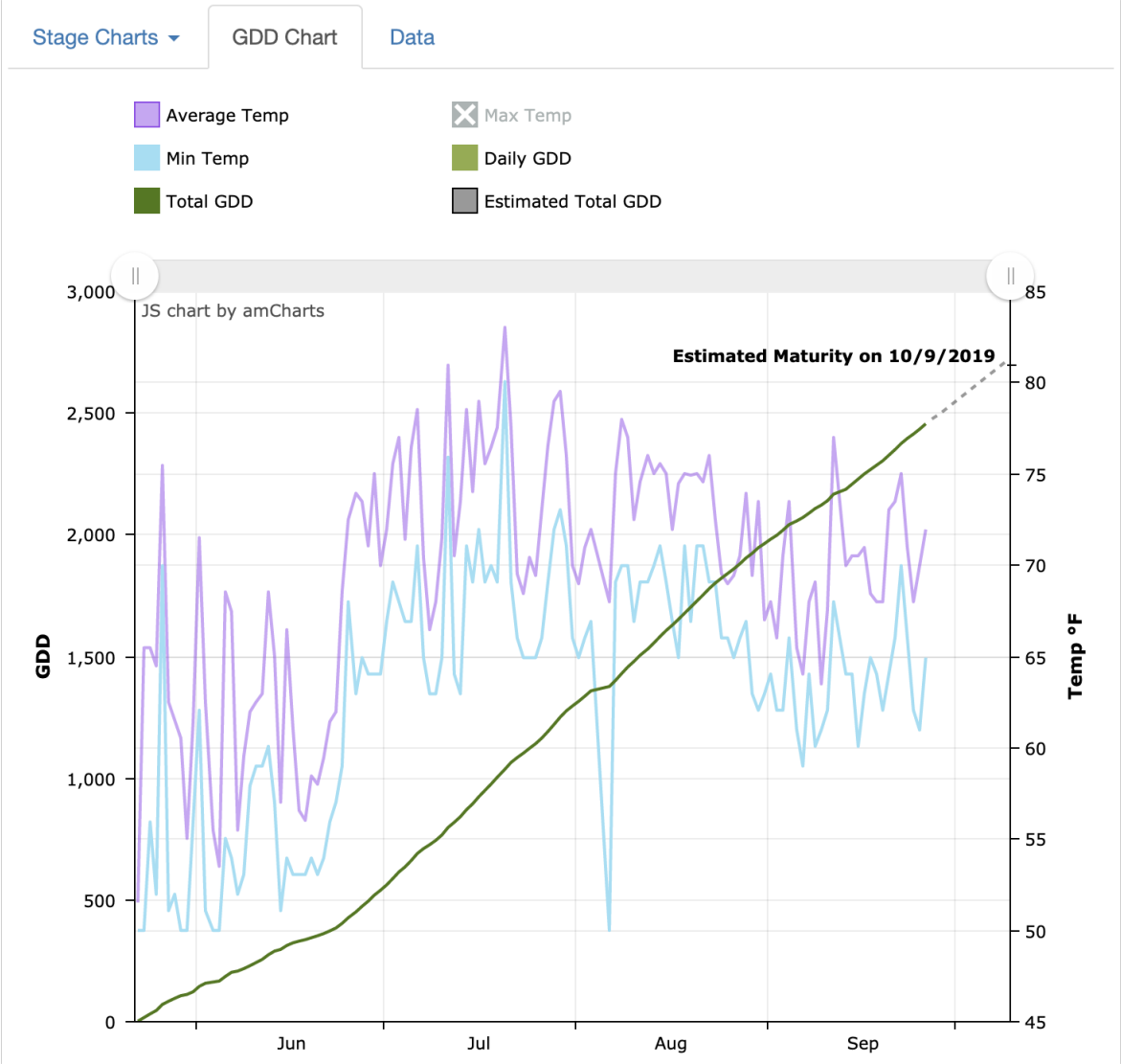
The “Area Chart” is a bit more detailed, and more closely mimics the graphical display of the previously discussed CGDDDST tool. It still shows a limited view of information for simplicity. This chart also has hover information available that displays to the user.

The “Gauge Chart” is a simpler representation that displays the accumulated growing degree units, similar to the more basic GDDC tool discussed previously. There are no hover options available on this chart type.

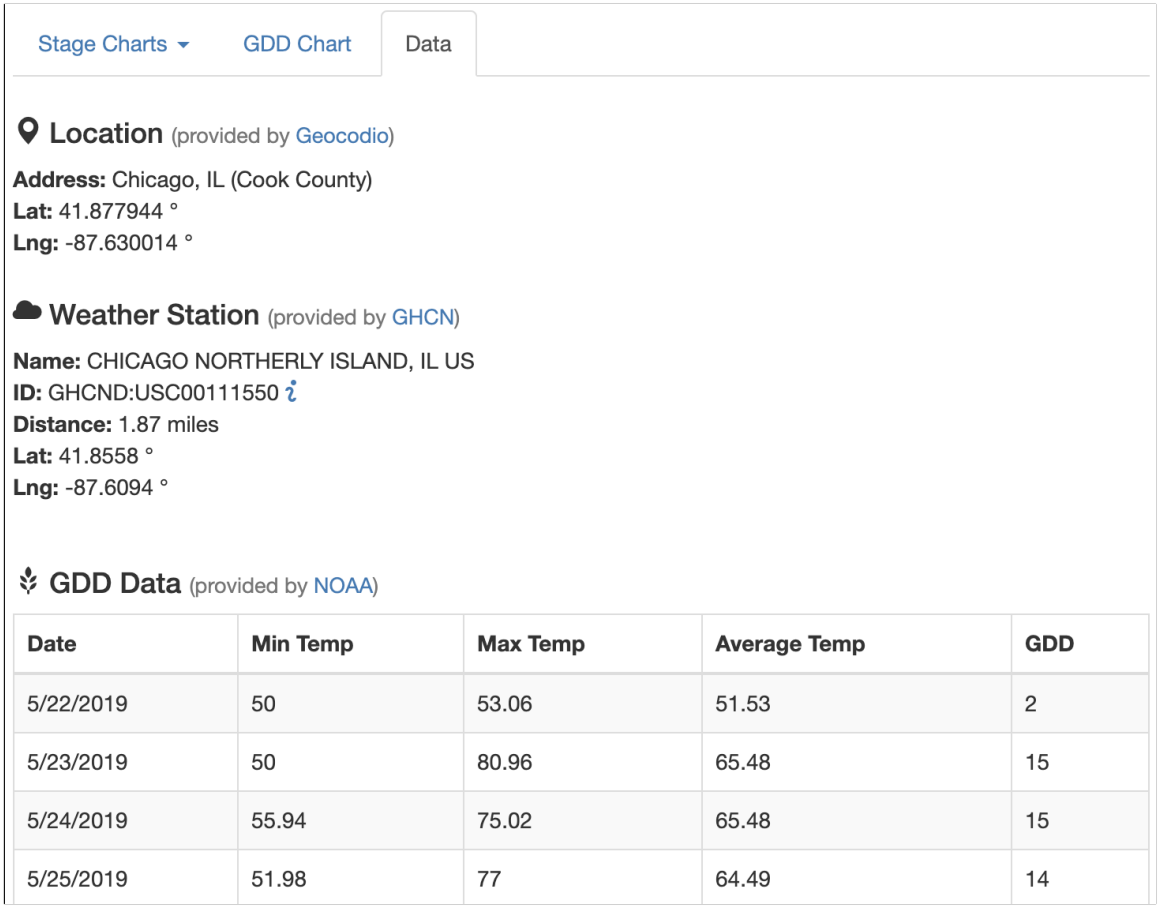
3. If you click “GDD Chart” tab to the right of the “Stage Charts” tab, you’ll see a chart that illustrates the estimated maturity date. The chart options at the top are clickable on order to only show information of interest at any given time. Like the “Stage Charts”, hovering over the visualization with either the mouse or pressing with your finger on a mobile device will show information about that particular point. You can also zoom in on this chart to see various time increments in greater detail.

   This is the most robust and customizable options of the charts, which is why it has been separated out into its own tab. Here the user can add as much or as little information to the chart as they would like, which brings it close to the complexity of the CGDDDST tool. This chart goes one step further in predicting the estimated maturity date, drawing a dotted line on the chart to complete the visualization.

   Future GDD predictions are calculated by taking the current accumulated amount and dividing it by the number of days between planting date and either the current date or the historical date specified by the user. This is then extrapolated out to determine the potential accumulation rate through maturity.



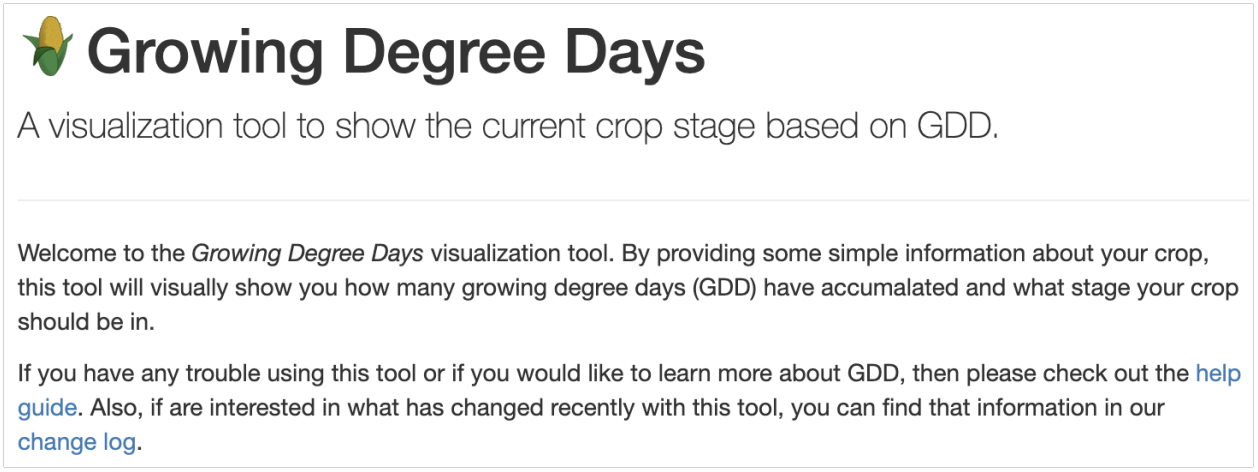
4. Clicking the Data tab displays the raw data that was used to create the visualizations. Location and weather station information is also included here.



Date	Min Temp	Max Temp	Average Temp	GDD
5/22/2019	50	53.06	51.53	2
5/23/2019	50	80.96	65.48	15
5/24/2019	55.94	75.02	65.48	15
5/25/2019	51.98	77	64.49	14

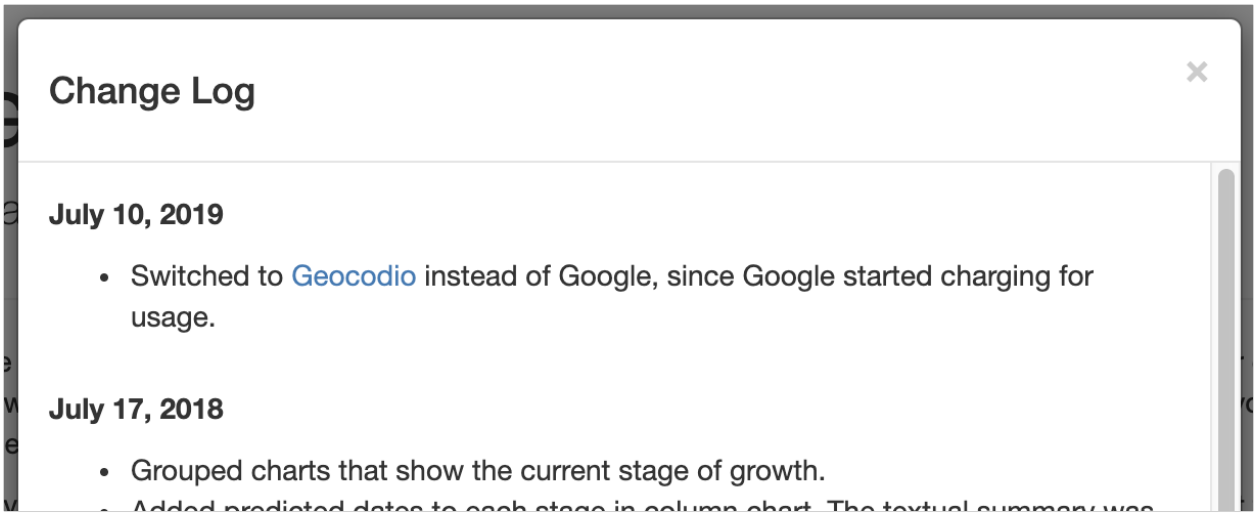
Other Application Features

On the main page links can be found to a help guide as well as the change log.



The help guide gives the user a quick explanation on how to use the tool, as well as where the data to build the graphs is pulled from.

The change log is a way to keep track of updates to the application. As new features are released and defects are addressed, return visitors can view the log to see what has changed since their last visit.



Benefits of Using this Application as a Learning Tool

Portability

As noted with my experience using the CGDDDST tool, portability was lost when I went out into the field to verify the growth stages. I could still access the web page since I had a cellular connection, but the small resolution on my phone and the fact that the application did not scale for a smaller device rendered the application unusable. For the GDDC tool, I could easily take it out into the field, but there was no real correlation between the number of growing degree day units accumulated and what I was seeing in terms of growth stages. In order to do this myself, I had to open another browser window and then switch between the two. This can be cumbersome on a small phone versus a computer monitor, where it's easier to put browser windows side-by-side.

My Growing Degree Web application overcomes this by using a responsive user interface that detects the user's device and resolution size, as well as the browser that is being used to render the page. More on this will be covered in the technical section below.

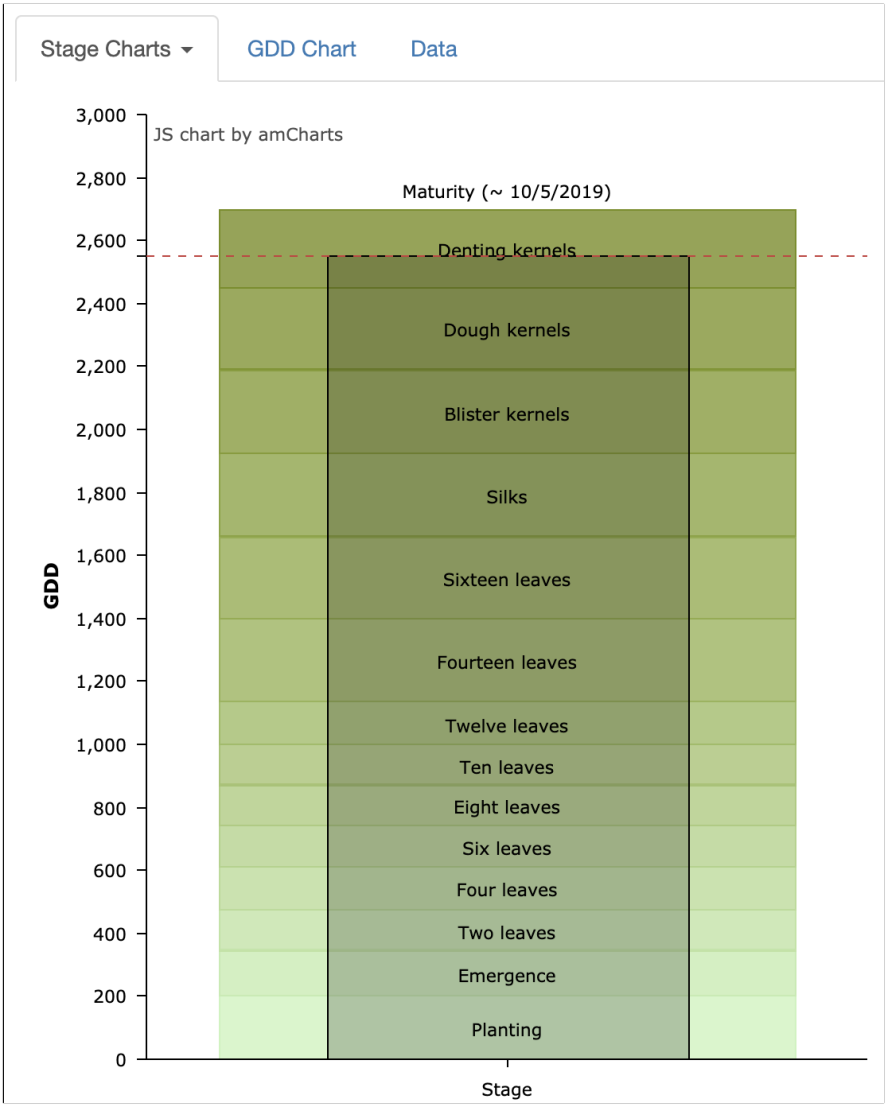
Localization

Both the CGDDDST and the GDDC applications allow the user to enter in a location before calculating the results. This is important because it allows the user to check not only their current location, but also check any other location where they may plant. From a learning tool perspective, it's also interesting to compare different locations based on their latitudinal and longitudinal differences, or to see the impact that weather might be having on a remote location (e.g., drought in Iowa, or a rainy spring in Illinois).

My Growing Degree Days web application does this as well, with the added benefit of being able to use Auto-detect to determine the user's location based on where they are connecting to the internet. More details on this feature will be covered in the technical section below.

Visual Growth Process that Corresponds with Stages in the Field

While I really liked the in-depth graphical visualizations from the CGDDDST tool, I found that it was a little hard to read due to the complexity of the information provided. When thinking of ways to display information to the user regarding the accumulation of growing degree days, I pictured something similar to how a plant would grow. I wanted a more vertical representation, along with indicators that showed each growth stage without the user having to cross-reference additional stage information. That is how I developed the Stage Charts - Column Chart graphical display, using the amCharts programming library ("JavaScript charting and mapping library - amCharts 4", 2019) in my code.



The users still have the option of looking at one of two other options: an Area Chart that is more in line with the CGDDDST way of displaying information, or a Gauge Chart, which shows a needle moving towards the end goal of Maturity.

Customizable and Interactive Graphs

Another feature I wanted to incorporate into my Growing Degree Days web application was the ability for the user to be able to control the amount of information to display, based on their knowledge level and what they are most interested in. The GDD Chart tab allows the user select what they would and would not like to see on their chart. This feature helps reduce some of the clutter that can appear when displaying all the information at one time.

Both the GDD Chart and the Area and Column Chart options under the Stage Charts tab provide the user with an interactive experience. Hovering over certain features reveals more

information via a pop-up. This feature even carries over to mobile devices, as the user can use their finger or stylus and press an area on the chart or graphical display to get more information.

Technical Discussion

Application Programming Selection

Code Repository

The code for this application is stored in a private repository in BitBucket, which is a free, web-based version-controlled code hosting service ("Bitbucket | The Git solution for professional teams", 2019).

Hosting

This site currently resides on a free host provider named Heroku ("Cloud Application Platform | Heroku", 2019). For some reason I could not get this to run on my ISU public web space when I initially started this project (public.iastate.edu). Alternative hosting sites that are currently being reviewed include https://growing-degree-days.agron.iastate.edu and https://mesonet.agron.iastate.edu/growing-degree-days/.

Languages

This application was developed using the following languages:

- CSS 2.1 ("Cascading Style Sheets Level 2 Revision 1 (CSS 2.1) Specification", 2019)
- HTML 5.2 ("HTML 5.2", 2019)
- JavaScript ("ECMAScript® 2019 Language Specification", 2019)
- PHP ("PHP: Hypertext Preprocessor", 2019)

Libraries

Charts are generated using the amCharts library that is publicly available ("JavaScript charting and mapping library - amCharts 4", 2019). Bootstrap is used for styling and basic user interface components and is what drives the responsiveness across mobile devices ("Bootstrap - The most popular HTML, CSS, and JS library in the world.", 2019). AngularJS is used to manage the user interface data in order for it to be displayed graphically ("AngularJS — Superheroic JavaScript MVW Framework", 2019).

Localization

Upon entering an address, the application will determine your latitude and longitude (unless you are using auto-detect, in which case your browser already has this information). This information is used to look up the nearest weather station. Once the nearest weather station has been located, the planting date and current date are used to find historical temperature information. Using this temperature data, the growing degree days can be accumulated.

Weather Information

Weather information is being pulled from NOAA using their web service APIs (application programming interface) ("NOAA - National Centers for Environmental Information (NCEI)", 2019). The Geocodio web service API is also being used to translate the user's latitude and longitude or inputted address into a geographic area that can be passed to the NOAA web service to determine nearby weather stations ("Hassle-free geocoding", 2019).

Note that NOAA has gaps in historical weather data (either temperature or the dates). To remedy this, I pull in data from up to the five nearest weather stations, expanding the radius until the gap(s) can be filled. However, if the missing data is not found and error will display to the user ("Unable to fetch temperature data from weather stations"). If no weather stations can be found within the specified time frame for the specified location, then an error will be displayed to the user ("No weather stations found within time frame").

Formulas and Growth Stages Used

Formulas and growth states for corn and soybeans was developed using information obtained from Dekalb Asgrow Deltapine ("Corn Growth Stages and Growing Degree Units", 2019) and the Corn Growth Stages and Growing Degree Days reference guide. (Lee, 2011).

Cross-platform Testing

Testing for this application was performed across several different combinations of devices, operating systems, and browsers. The following tests were performed.

Device	Operating System	Browser
iMac	Catalina	Chrome 76.0.38
iMac	Sierra	Safari 12.2.1
iPad	iOS 12.4	Chrome 63.0.1
iPhone 10 Plus	iOS 13.0	Safari 604.1
iPhone 6	iOS 8.0	Safari 600.1.4
MacBook	Mojave	Safari 13.0.1
MacBook	Mojave	Chrome 62.0.3
MacBook	High Sierra	Safari 13.0.1
MacBook	High Sierra	Firefox 67.0.4
MacBook Pro	Catalina	Chrome 76.0.38
MacBook Pro	Mojave	Edge (Beta Channel)
Samsung Galaxy S6 Edge	Android 7.0 (Nougat)	Chrome 64.0.3
Samsung Galaxy S9 Plus	Android 8.0 (Oreo)	Chrome 77.0.3
Windows PC desktop	Windows 8	Internet Explorer 11.0.130
Windows PC desktop	Windows 8	Firefox 68.0.1
Windows PC laptop	Windows 10	Edge 44.0.6
Windows PC laptop	Windows 10	Chrome 65.0.33

The testing process across for each was as follows:

1. Navigate to the website, verify the page loads.
2. Verify the page scales to fit the screen and that no parts are cut off.
3. Enter in data using Corn as the crop selection to verify the Corn Maturity field displays. Select Soybean to verify the Corn Maturity field is hidden.
4. Use auto-detect for location (subsequent tests used various combinations of (city, state, and/or zip code, including invalid results such as special characters).
5. Click the Visualize button.
6. Verify all charts display and that user can hover or long-press on graphs to see additional information.
7. Verify user can pinch to zoom on handheld devices to read data better.

Future of the Application

Maintenance and Enhancements Based on User Feedback

Part of the software development process entails taking user feedback and using that to fix defective code or create enhancements that improve application functionality and/or the user experience. As I am currently enrolled as a student in the Master of Business Analytics program at Iowa State University through the summer of 2021, I plan on making myself available over this time period to accept feedback and update the application as needed.

Application enhancement suggestions and defect findings can be sent to tahansen@iastate.edu. I will fix any defects found and make any enhancements or upgrades to the application as needed through the summer of 2021.

Open Sourcing the Application

Open source applications are those that are collaborated on publicly by a community interested in maintaining and enhancing the application for the greater good of the users. The community of developers that update and enhance the application can be very broad to include anyone who has an interest and the right skills to a small group of people who have been granted the access needed to make changes. Should there be a desire for development to continue beyond the summer of 2021, I can make the codebase available via a GitHub repository to either the public at large or to a select group of people, where it could be collaborated on by anyone with an interest in seeing the application carry on as a learning tool.

One of the benefits of open source applications is that the developer community has a voice in changes that are made, and due to version controlling there is little to no chance of a renegade coming along and changing the entire scope and/or appearance of the application. Open source applications are similar in this vein to Wikipedia, where the internet community at large can make changes and add new articles, but that same community can decide if the changes are justified (and undo them if needed).

Conclusion

My goal when I began my Master's in Agronomy program was to find a way to integrate my undergraduate degree in computer science and use a combination of both to further my career goals. Creating this growing degree web application and presenting it as my Creative Component has allowed me to do just that. I hope this tool is effective to others like me who enjoy visual and interactive learning tools, with the ability to take them outside and relate them to things seen in the real world.

The field of technology is ever-changing. Every day new tools come out that help us do our jobs more efficiently. I hope the integration of technology and agronomy continues, as there is great potential in these areas to help further education and engage students in the process of learning.

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