Title: Evapotranspiration and Growing Degree Day Data for Corn Growers of Minnesota
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Links

Project Github repository of all code
Final ArcOnline MapViewer

Abstract

For this project, we consulted with our clients, the MN Corn Grower's Association to find out what the specifications were for the data they wanted to be available and visualized. I chose three methods for calculating Growing Degree Days (GDD) and two methods for calculating Evapotranspiration (ET) for the past seven days worth of temperature data. I used Global Polynomial Interpolation, Cross Validation and RMSE to verify the accuracy of the models. The calculated data was subsequently pushed to a PostGIS database, up to a Flask App for downloading and onto ArcGIS Online for viewing.

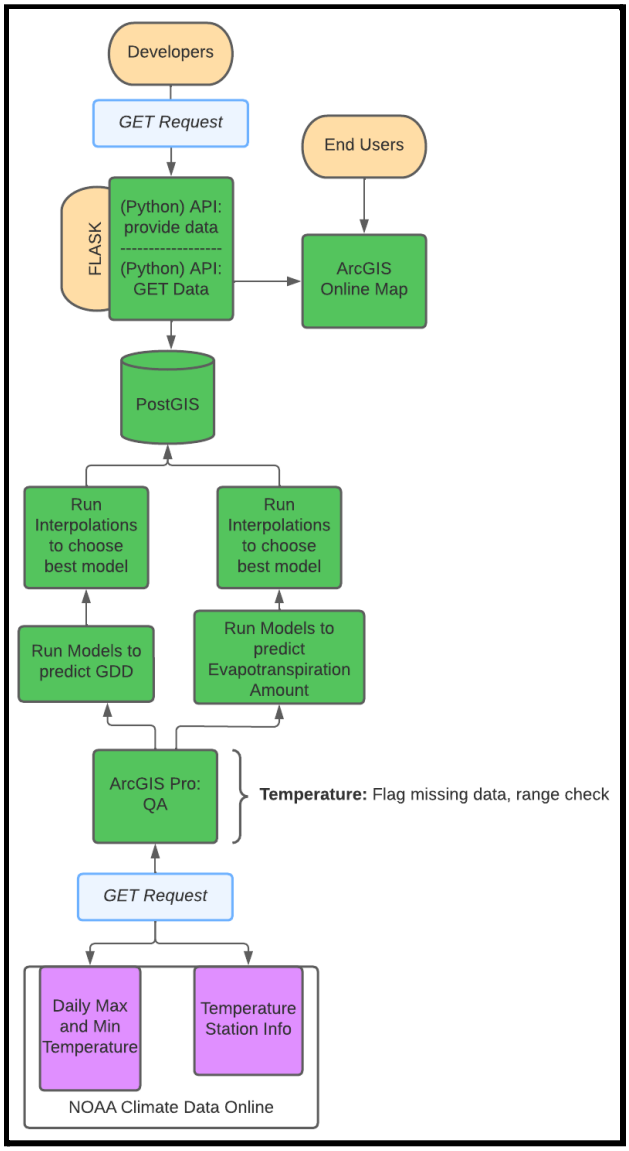
Problem Statement

The problem that we are trying to solve is to create a system that will allow Corn Growers in Minnesota to get data about three indices: current and past growing degree days, current and past soil moisture, and current and past reference evapotranspiration. The data will be provided in GeoJSON format. In addition to the raw data, we are tasked with creating an interactive map that updates daily for the entire state.

Input Data

#	Title	Purpose in Analysis	Link to Source
1	Minimum Temperature by station	Used for calculating mean daily temperature and in equations for GDD and ET	NOAA API
2	Maximum Temperature by station	Used for calculating mean daily temperature and in equations for GDD and ET	NOAA API
3	Station data	Station data to create a point feature class	NOAA API

Data Flow Diagram for System



Model Comparison

#	Model Name	Evaluation Metric 1: RMSE via Global Polynomial Interpolation on each day at every station	Rank Score of Model
1	GDD: Average Method	{Day1: '0.2727542028493769', Day2:'1.4024861317327315', Day3:'2.4471635711131228', Day4:'3.7586281798269994', Day5:'4.23678900228468', Day6:'4.670311807926968'}	2
2	GDD: Modified Average Method	{Day1:'2.454474466364828', Day2:'3.08435083695795', Day3:'3.2420933935500633', Day4:'3.618280860844914', Day5:'4.4458123558877745', Day6:'4.6750963656350635'}	1

3	GDD: Baskerville-Emin Method	{Day1:'5.329312498998381', Day2:'5.653327338287235', Day3:'5.573762400048193', Day4:'5.209931927932244', Day5:'5.2742148334798316', Day6:'4.812903060692723'}	3
1	ET: Kharrufa Method	{Day1:'0.6524917106517513', Day2:'0.8774503247903924', Day3:'0.8909178177633358', Day4:'1.1995049885114883',Day5: '1.529571767424264',Day6:'1.7674210004015922'}	2
2	ET: Blaney-Criddle Method	{Day1:'0.35285523032883814', Day2:'0.44741062496811623', Day3:'0.4257967449468412', Day4:'0.5568246157814677', Day5:'0.7224569952365121', Day6:'0.844490656206078'}	1

Growing Degree Days Model: Average Method
Simply take the mean temperature of each day and subtract the degree-day accumulation base. For corn, the base temperature is 50 degrees Fahrenheit. If the resulting number is negative, the GDD value is 0.
Average Method GDD = (Max + Min) / 2

Growing Degree Days Model: Modified Average Method
The modified average method first requires modification of temperatures. If the minimum temperature is below the base temperature, the base value temperature replaces the minimum temperature. If the maximum temperature is above 86 degrees Fahrenheit, this value replaces the maximum temperature. If the mean temperature is at or below the base temperature, then the GDD is set to 0. If the mean temperature is above the base temperature, then the GDD is the mean temperature minus the base temperature.

if Min < 50 then (new min) = 50
if Max > 86 then (new max) = 86

Mean = (Max + Min)/2
if Mean <= 50 then GDD = 0
if Mean > 50 then GDD = Mean - 50

Growing Degree Days Model: Baskerville-Emin Method
The Baskerville-Emin Method requires looking at the maximum and minimum temperatures for each day and going through the following conditional statements:

1. if max temperature < 50 then GDD = 0 (Else, keep going)
2. if min temp >= 50 then GDD = average - base temp
3. Else:
    a. With TAVE = ((max+min)/2)
    b. With BASE = 50
    c. W = (Max - Min)/2
    d. A = Arcsin((BASE-TAVE)/W)

e. GDD = ((W*Cos(A))-((BASE-TAVE)*(3.14/2)-A)))/3.14

Evapotranspiration Model: Kharrufa Method

$ET = 0.34pTa^{(1.3)}$

where ET is the Kharrufa potential evapotranspiration (in mm/month) Ta is mean temperature in °C, p is percentage of total daytime hours for the period used (daily or monthly) out of total daytime hours of the year.

Evapotranspiration Model: Blaney-Criddle Method

$ET = kp(0.46)Ta + 8.13$

$ET = (0.8)p(0.46)Ta+8.13$

where ET is evapotranspiration from the reference crop (in mm) for the period in which p is expressed, Ta is mean temperature in °C, p is percentage of total daytime hours for the period used (daily or monthly) out of total daytime hours of the year, and k is a monthly consumptive use coefficient, depending on vegetation type, location and season (using 0.8).

Recommendation for Decision-making

Based on the results comparing these models, for Growing Degree Day calculations, Irecommend that the Minnesota Corn Growers Association should use GDD data based on the Modified Average Method for decision-making. From my evaluation metric of interpolation, I saw that it had the lowest RMSE meaning that it had the least amount of error and would give a more accurate measure of hours of sunlight so that the corn can thrive and you can plan for modifications in your farming methods accordingly.

Based on the results, for Evapotranspiration, I recommend that the Minnesota Corn Growers Association should use the Blaney-Criddle method. From my evaluation metric, I saw that it had the lowest RMSE meaning that it had the least amount of error and would give a more accurate measure of Evapotranspiration to find which locations have an adequate amount of Evapotranspiration to yield the most corn.

Reflection

I learned how to configure a flask app, how to send shapefiles to a PostGIS database using code within ArcGIS Pro, and I practiced my skills manipulating data using pandas. I feel like my code with pandas is still clunky but it's always good to keep practicing. I also learned to use open source tools like Google Cloud.

In a perfect world I would have been able to collaborate more with my partner but because he was so busy I ended up doing a lot on my own and then what he wanted to present was different from what I had in mind and what I had already coded. In a perfect world I would have figured out if you wanted us to compare methods of calculating the indices or whether you wanted us to compare interpolation methods. I would have also been able to visualize a year’s worth of data but arcpro wouldn’t allow me to automate the interpolation of that many layers to automate that process.

References

- "CHAPTER 3: CROP WATER NEEDS." Accessed May 12, 2022. https://www.fao.org/3/s2022e/s2022e07.htm#3.1.3%20blaney%20criddle%20method.
- "Cross Validation (Geostatistical Analyst)—ArcGIS Pro | Documentation." Accessed May 12, 2022. https://pro.arcgis.com/en/pro-app/2.8/tool-reference/geostatistical-analyst/cross-validation.htm.
- "Explanation of Growing Degree Days." Accessed May 12, 2022. https://mrcc.purdue.edu/gismaps/info/gddinfo.htm.
- Penn State Extension. "Understanding Growing Degree Days." Accessed May 12, 2022. https://extension.psu.edu/understanding-growing-degree-days.
- Xu, C.-y, and V. P. Singh. "Evaluation and Generalization of Temperature-Based Methods for Calculating Evaporation." *Hydrol. Process*, 2001, 305–19.

Appendix (include your original spec)

- SRS Document