The Potential Impact of Climate Change on Chill Hours in North Carolina

Dr. Timothy Glotfelty and Corey Davis, North Carolina State Climate Office

Dr. Sheila Saia, Tetra Tech

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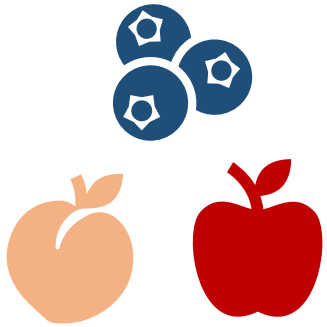
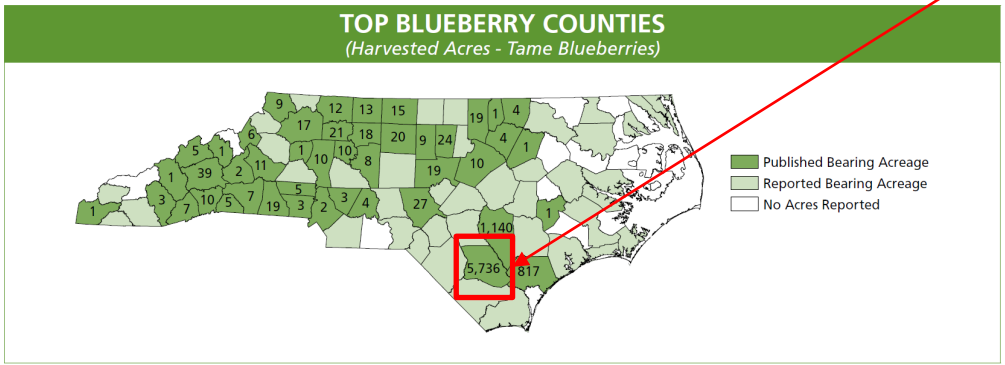
Climate and Chilling Hours

- Fruit and nut producing plants enter a dormancy period to tolerate freezing temperatures
- During this dormancy period temperatures must remain in a certain range (i.e., 0-7°C or 32-45°F) for a certain period before they are able to bloom again
- Accurately predicting chill hours is important for frost protection
- Changes to chilling from climate change will impact what plant varieties producers can grow



Application: Blueberry Farming



- **Stakeholder Application**
  - Blue River Legacy Farms
    - Bladen County, NC
  - What types of blueberry varieties will they need to plant for the next 20 years?
- **North Carolina Application**
  - Considerable acreage is devoted to blueberries in NC
  - In 2021 NC contributed ~5% of the U.S. blueberry production
  - Generating $54,710,000 to the NC Economy

Chill Models used in North Carolina

Simple 0 to 7 Model (Generic)

Mainland Model (Blueberries)

Richardson Model (Peaches)

Shaltout and Unrath Model (Apples)

Modified 0 to 7 Model (Blackberries)

Yazetti and Clark (Blackberries)

Modified Richardson Model (Blackberries)

Warmund and Krumme Model (Blackberries)

https://products.climate.ncsu.edu/ag/chill-models/

Method 0-7 Model

Criteria

- Hourly and Daily Estimate
- Chill Inception: Nov. 1st*
- Accumulation
  - 0°C to 7.2°C = 1 unit

Simple Diurnal Profile

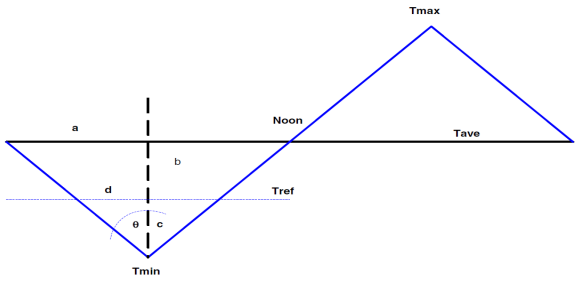


Fig. 1 Schematic of the idealized mean diurnal temperature course. *Line a* is 6 h in length, *line b* is the distance between average and minimum temperatures, *line c* is the distance between the reference and minimum temperature and *line d* is one-half the duration that temperature is below the reference temperature

Baldocchi and Wong, 2008

- **Why?**
  - Climate model datasets typically only contain daily maximum and minimum temperatures

*Modified from day in the fall when chill units stop negative accumulation

Objectives

1. Determine how reliable the daily estimation method for the 0-7 chill hour model is compared to the hourly method in NC

2. Determine how well a gridded observation-based climate dataset can reproduce chill hours compared to station observations in NC

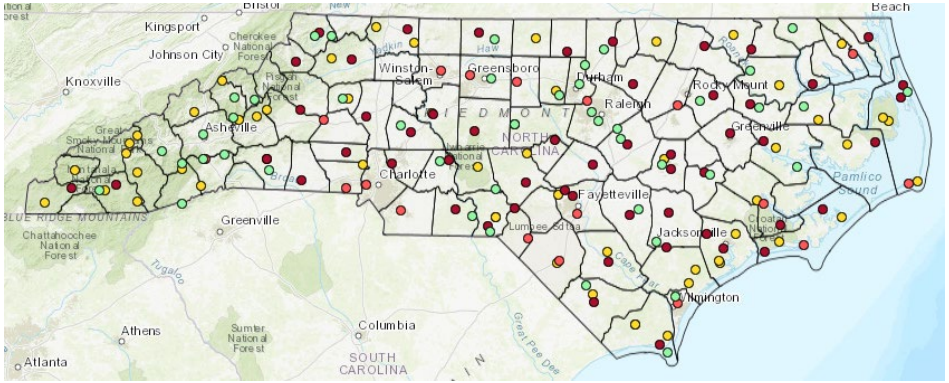
3. Determine how well downscaled climate model datasets represent chill hours in NC

4. Determine how NC chill hours will evolve in response to climate change

Current Climate Data Sources (2008-2023)

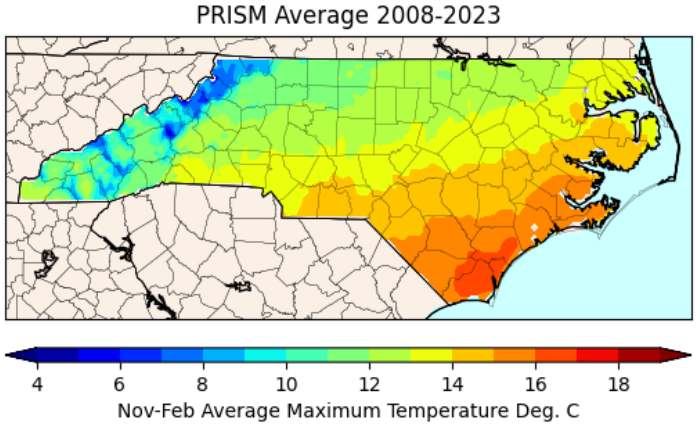
Observations

- Station Data (148)
  - Mesonet: Environment & Climate Observing Network (ECONet)
  - National Weather Service: ASOS/AWOS
  - U.S. Forest Service: Remote Automatic Weather Stations (RAWS)



Gridded Product

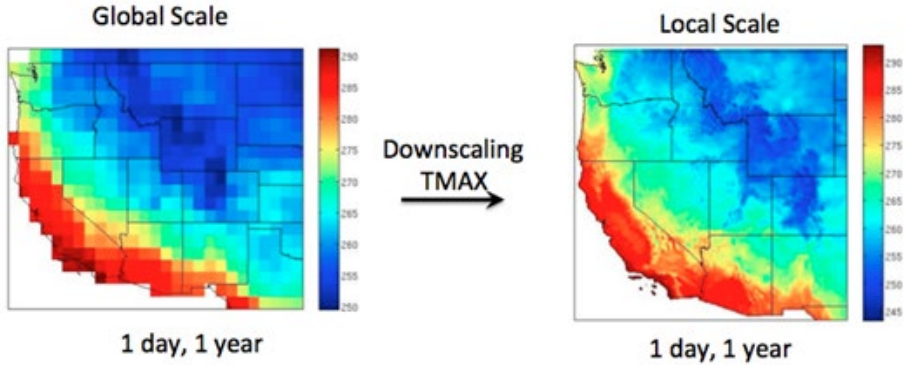
- PRISM
  - Observations blended with advanced numerical and statistical techniques
  - Maps of 2-m Daily Max. and Min. Temperatures
  - ~4 km Resolution



Current and Future Climate Projections

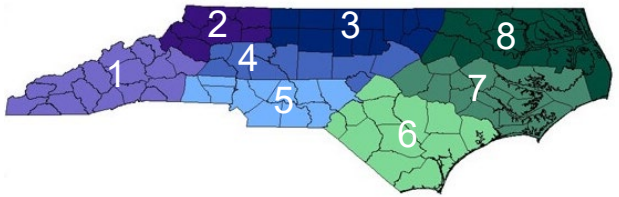
Multivariate Adaptive Constructed Analogs (MACA)

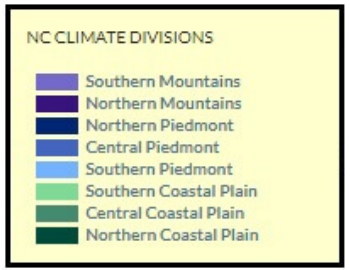
- Gridded Dataset
  - ~6 km
- Daily Max. and Min. Temperatures
  - 1950-2099
- Generated from Climate Models
  - 20 Models
- Two Climate Scenarios
  - RCP8.5 (High Emissions)
  - RCP4.5 (Lower Emissions)



Daily Method and PRISM Evaluation

CD.	1	2	3	4	5	6	7	8
Hourly	1050	1081	1091	1037	967	846	902	953
N. Stn.	29	7	13	14	19	26	22	18
Daily	915	1041	978	906	832	746	814	875
Bias	-132	-40	-113	-131	-135	-103	-88	-78
Corr.	0.90	0.73	0.90	0.92	0.93	0.94	0.95	0.90
PRISM	819	930	927	863	826	768	829	878
Bias	-96	-111	-51	-42	-6	21	15	3
Corr.	0.79	0.82	0.90	0.86	0.87	0.90	0.91	0.93





Daily method underestimates by 100 ± 30 per season

PRISM does well but is not as good in the mountains

Comparison PRISM vs. MACA

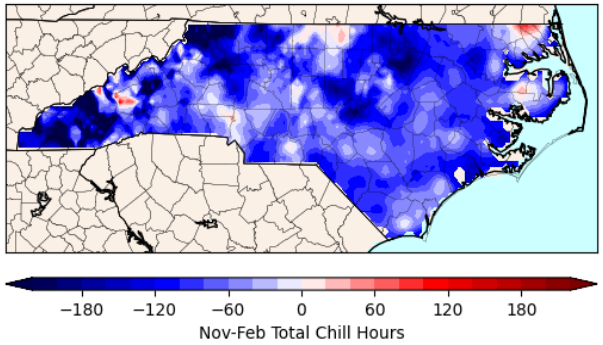
Climate Models Underestimate

Challenge: Climate Model Years Aren't Real

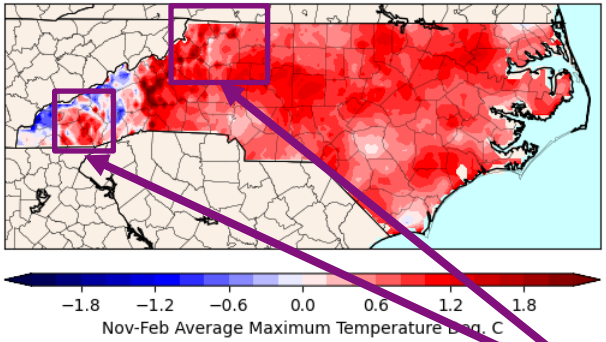
- Simulation (MACA) for 2006-2025
- Gridded Observations (PRISM) for 2008-2023
- Chill Season: November - February

Climate Models Overestimate

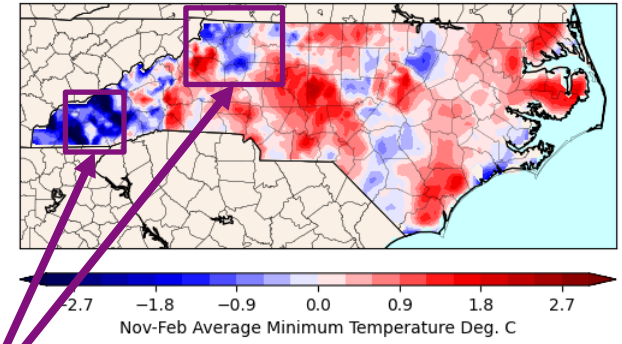
Total Chill Hours



Maximum Temperature

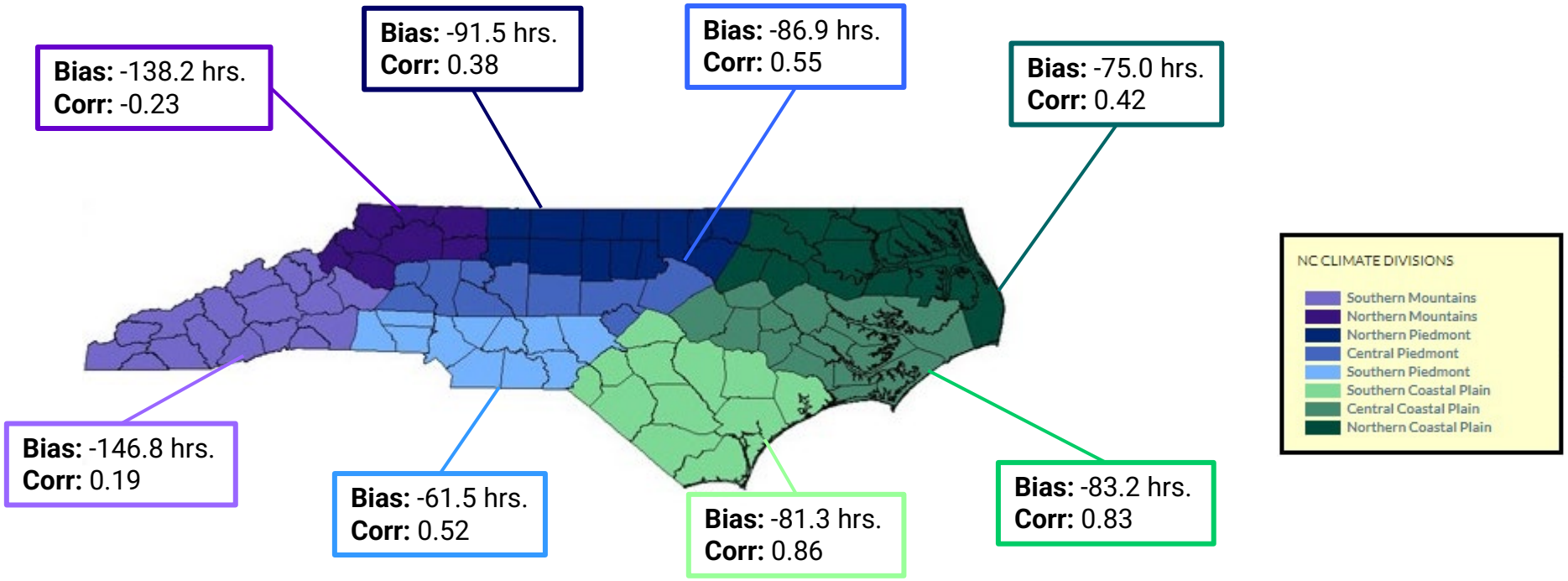


Minimum Temperature



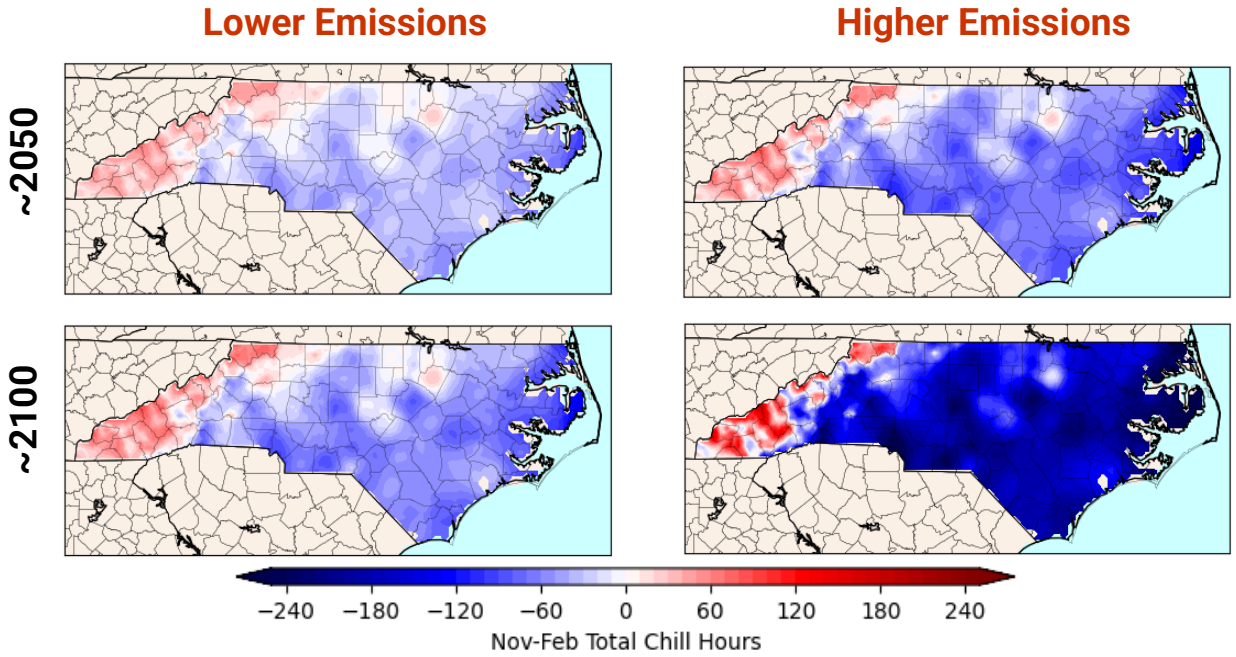
In the mountains the diurnal profile is exaggerated compared to PRISM

Statistical Evaluation PRISM vs. MACA



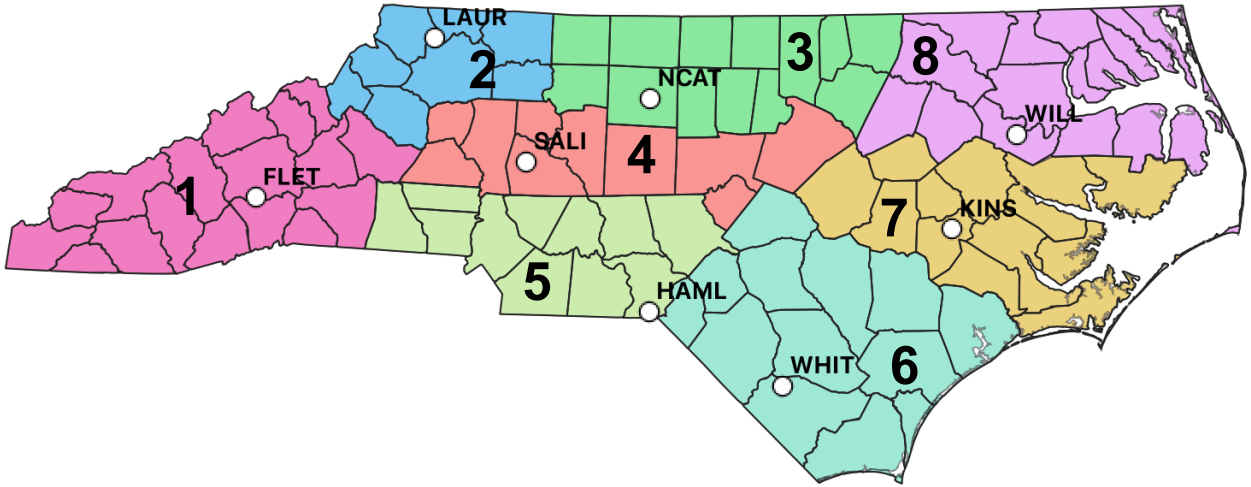
The absolute values from the climate models are not consistently accurate so instead we will focus on the change over time.

Future Trends in Chill Hours from MACA



- **Climate Model Insights**
  - No information on very good or bad chill years
  - By 2100 there will be ~10-60 less chill hours per season with lower emissions
  - By 2100 there will be over ~100-200 less chill hours per season with higher emissions
  - There will be more chill hours in the mountains due to less freezing conditions

Representative Stations (Explore Variability)

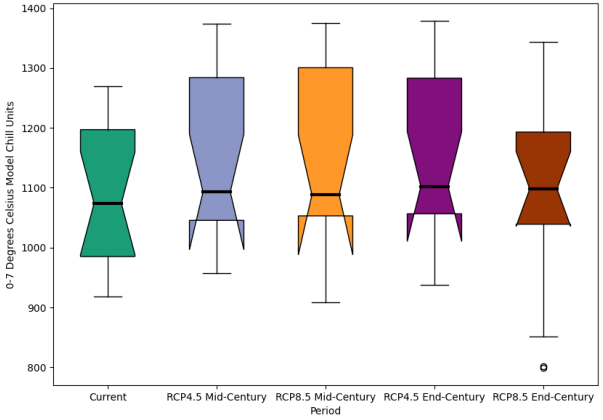


Stations

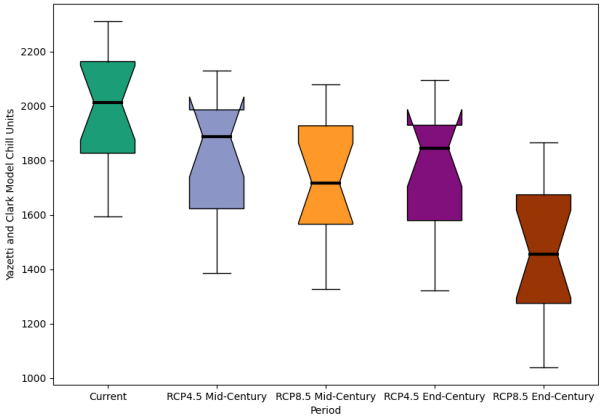
- We scaled the observed temperatures by the average temperature change from MACA
- Assumes we will see the same variability in a warmer climate
- Used these values to calculate some of the more complex chill models

Future Climate Variability Northern Mountains

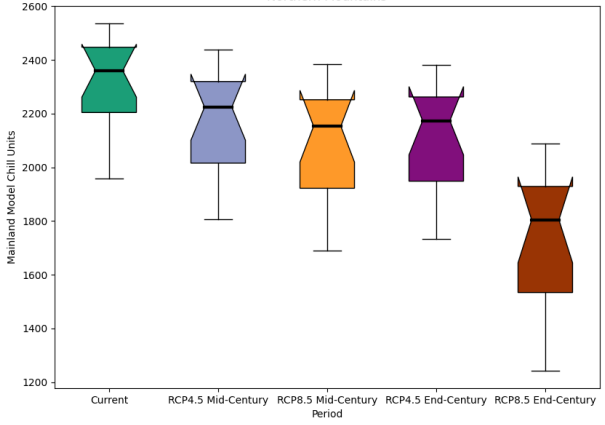
0-7 Model (Generic)



Yazetti and Clark (Blackberries)



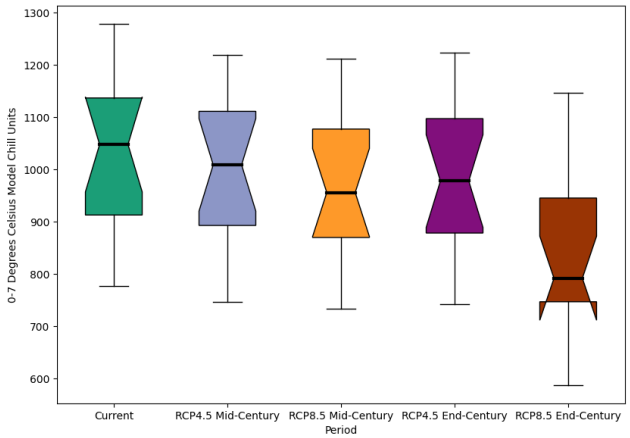
Mainland (Blueberries)



Current **Lower Mid-Century** **Higher Mid-Century** **Lower End-Century** **Higher End-Century**

Future Climate Variability Central Piedmont

0-7 Model (Generic)



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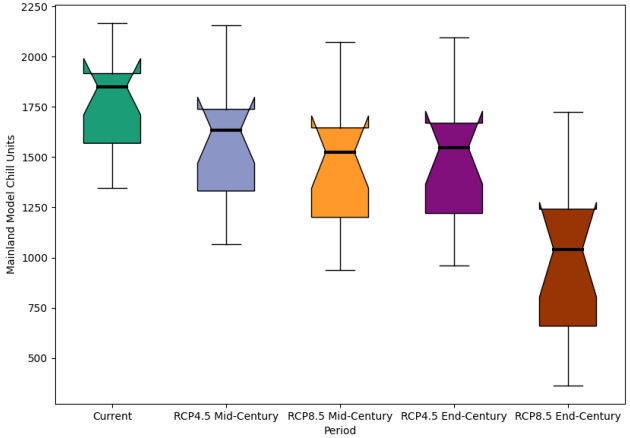
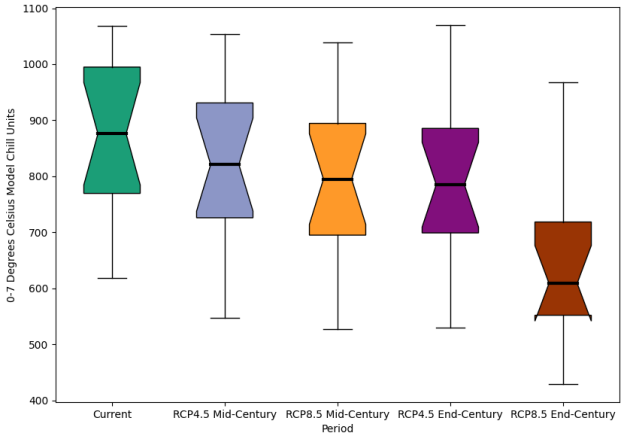


Current **Lower Mid-Century** **Higher Mid-Century** **Lower End-Century** **Higher End-Century**

Future Climate Variability Southern Coastal Plain

0-7 Model (Generic)



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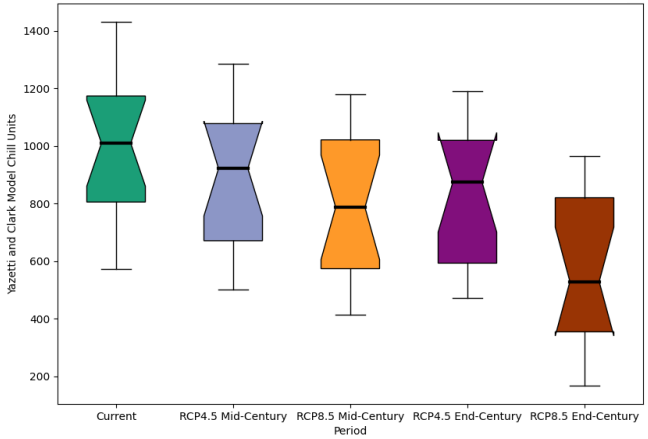

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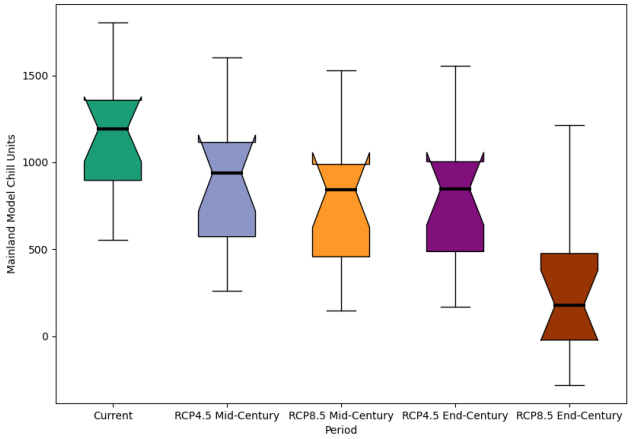


Current **Lower Mid-Century** **Higher Mid-Century** **Lower End-Century** **Higher End-Century**

Summary and Conclusions

1. The daily method underestimates chill hours by ~100 ± 30 hrs. per season
2. PRISM reasonably represents chill hours across the state with better performance in the Coastal Plain than the Mountains
3. MACA performs best in the Coastal Plain where most blueberry production takes place but is less accurate in the Mountains.
4. MACA predicts reductions on the order of 10s of hrs. per season under the lower emissions scenario and 100s of hrs. per season under the higher emissions scenario.
5. The climate models suggest berry producers will need to begin transitioning to lower chill varieties of berries in the coastal plain to mitigate the impacts of climate change over the next 80 years.

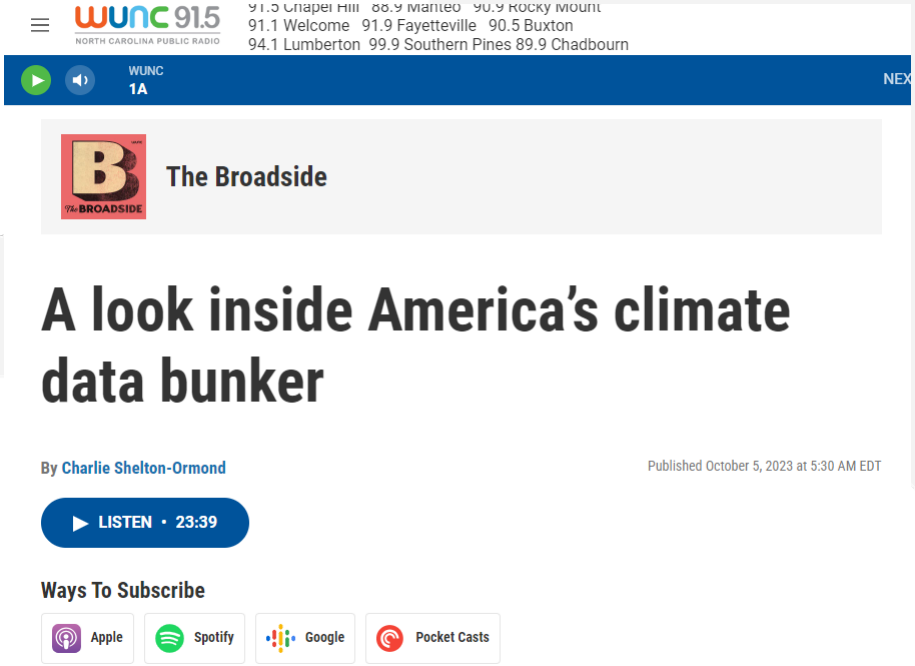
Future Work

1. Conduct the future climate analysis using CMIP6 recently available statistically downscaled data
2. Build connections between the chill hour change and biologically relevant cultivar processes.

Acknowledgements

- Joe Williams, Blue River Legacy Farms
- Dr. Gina Fernandes, Department of Horticulture
- Dr. William Cline, Department of Entomology and Plant Pathology
- Dr. Rebecca Ward, College of Natural Resources

Thank you!



Timothy Glotfelty

twglotfe@ncsu.edu

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