“Plugin”-based architecture of software to predict corn phenotypes

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2020 G2F Collaborator’s Meeting, Phenome Meeting

Acknowledgements

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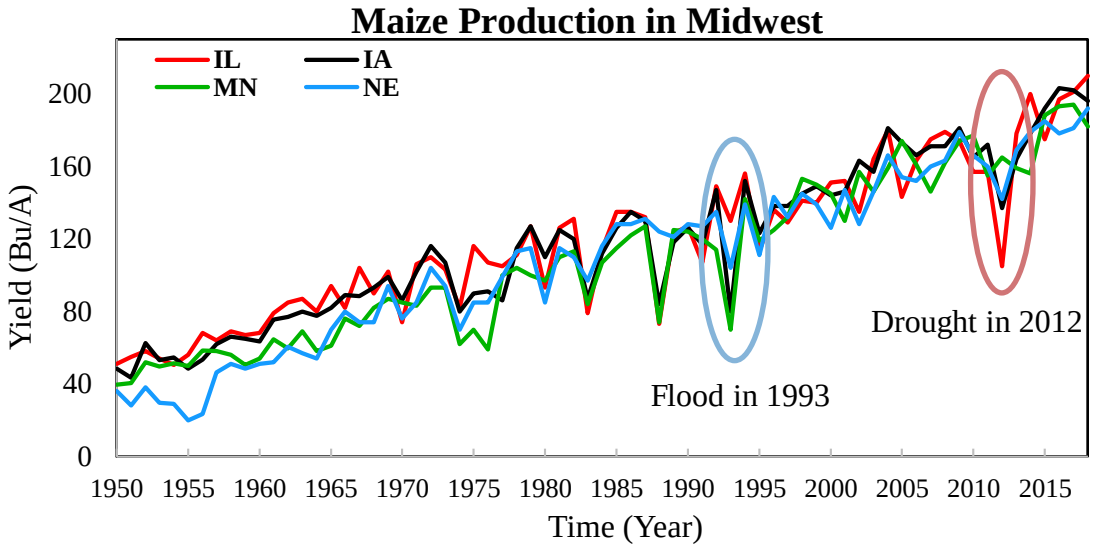
Genomes to Fields initiative

UNL's Department of Computer Sciences and Engineering Senior Design

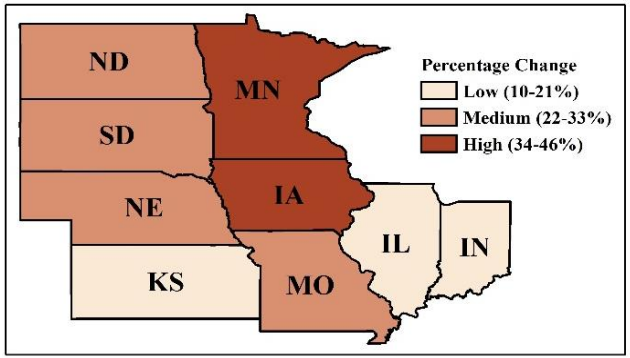
Motivation

- Consistent increase of water use efficiency, farmers revenues and yields

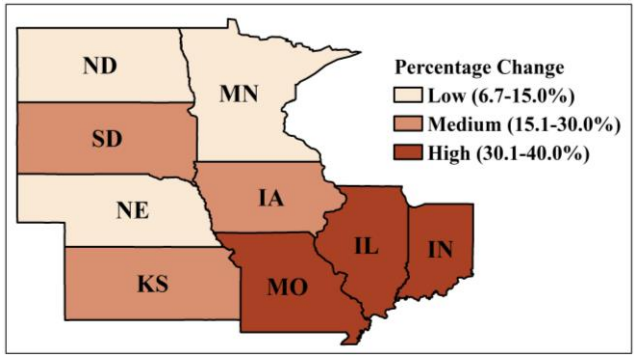
- Drops in water use efficiency, farmers revenues and yields after the occurrence of floods and droughts



Maize Yield Reduction (1992 -1993)



Maize Yield Reduction (2010 -2012)

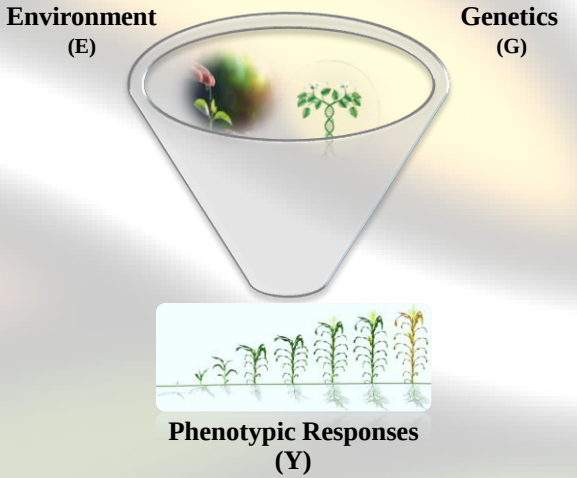


Ref: USDA NASS

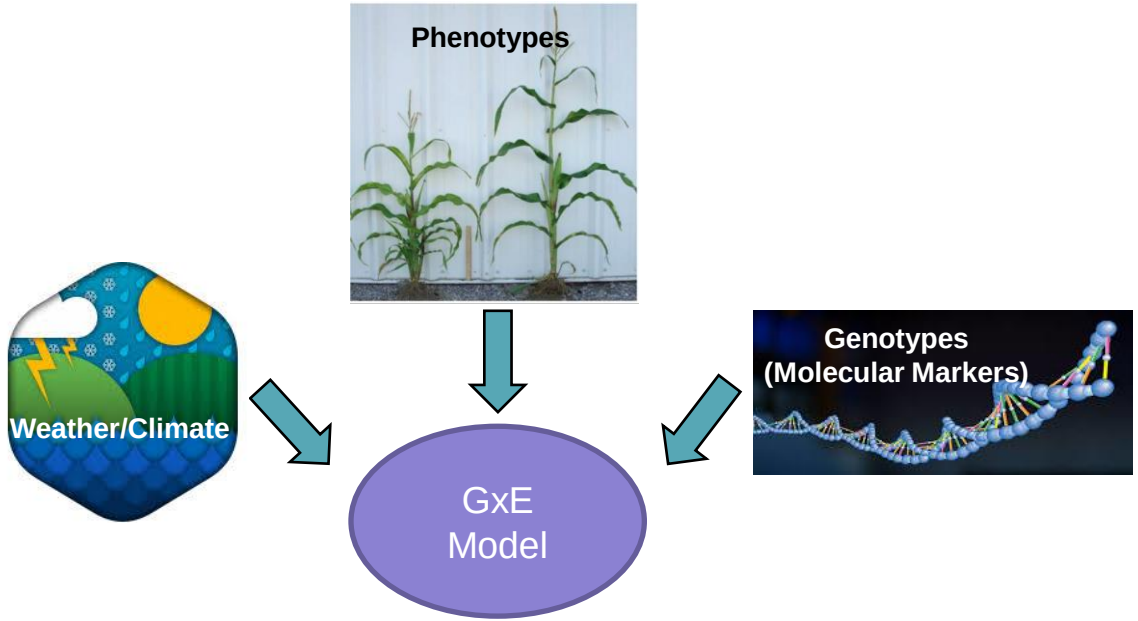
Outline

- Framework
- G2F
- Software Architecture
  - Preprocessing
  - Option Selection
  - Processing
  - Postprocessing
- Software Demo
- Complexities
- Conclusion
- Future Work

Framework



Develop a framework to collect, store, manage, and use weather/climate data to predict plant phenotypes using GxE model

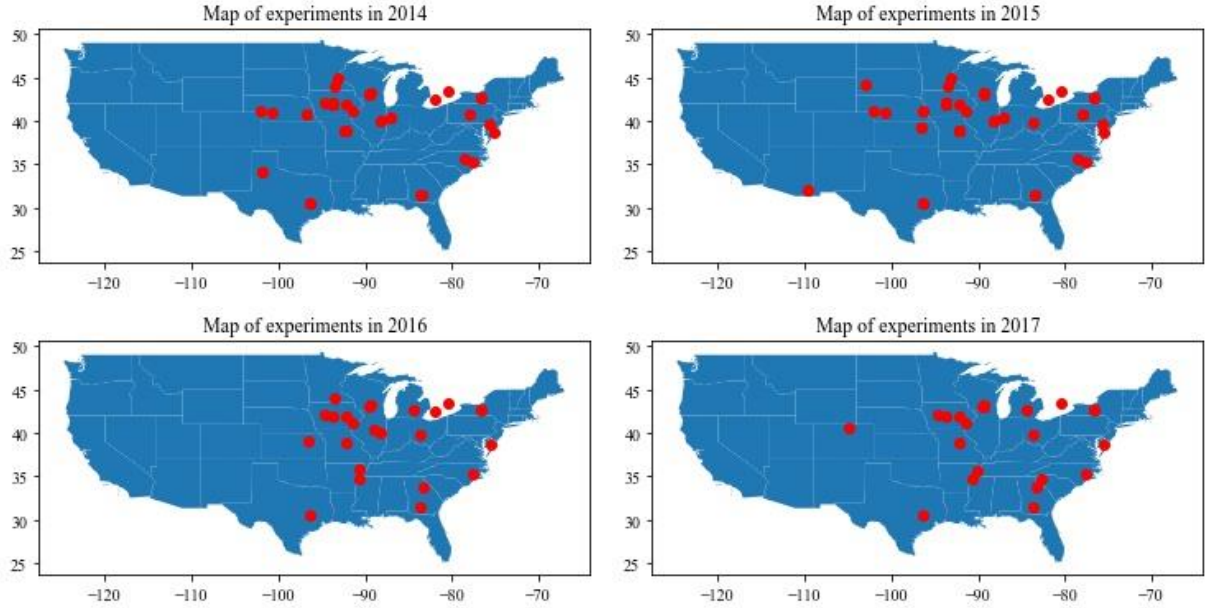


G2F

- Genetics
- Environments
- Phenotypes (traits)

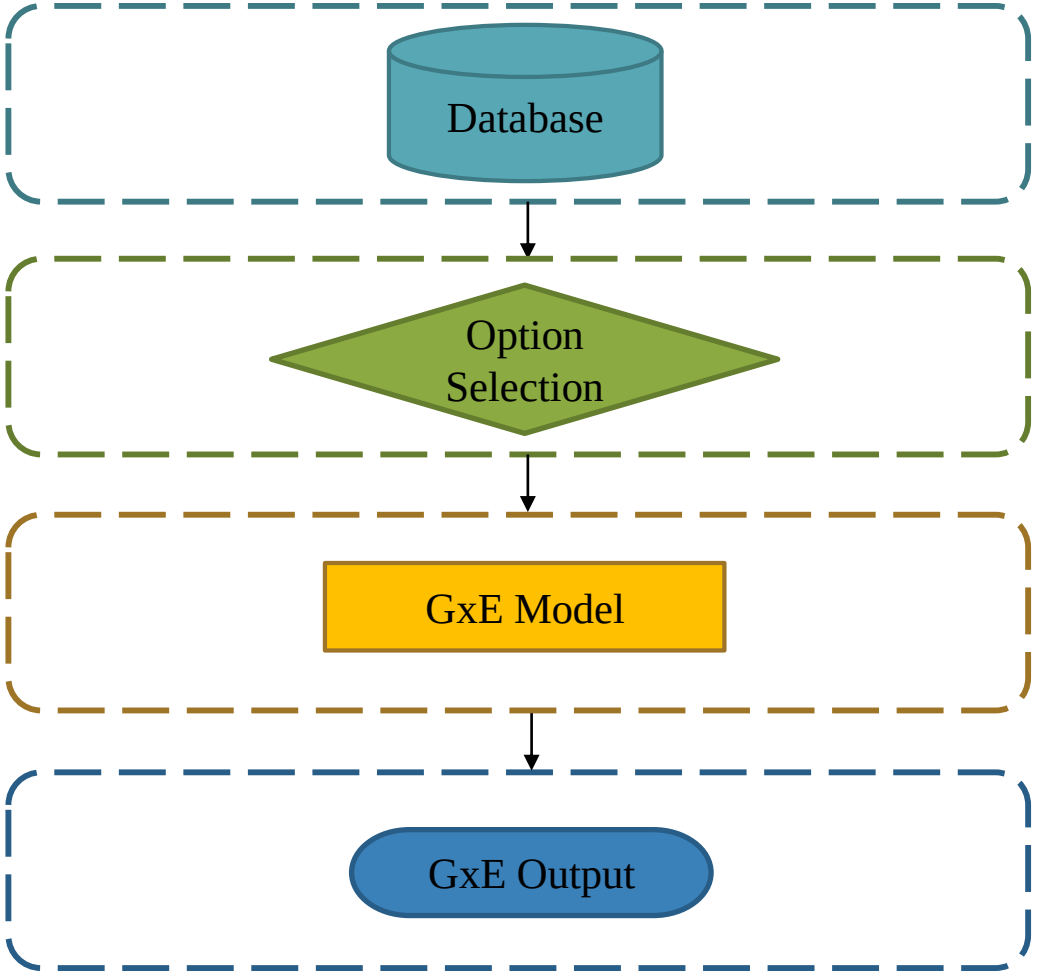
Incorporation of Environmental Information to Improve Phenotypic Predictability in Maize G2F-GxE Hybrid Project

G2F Experiments Distribution



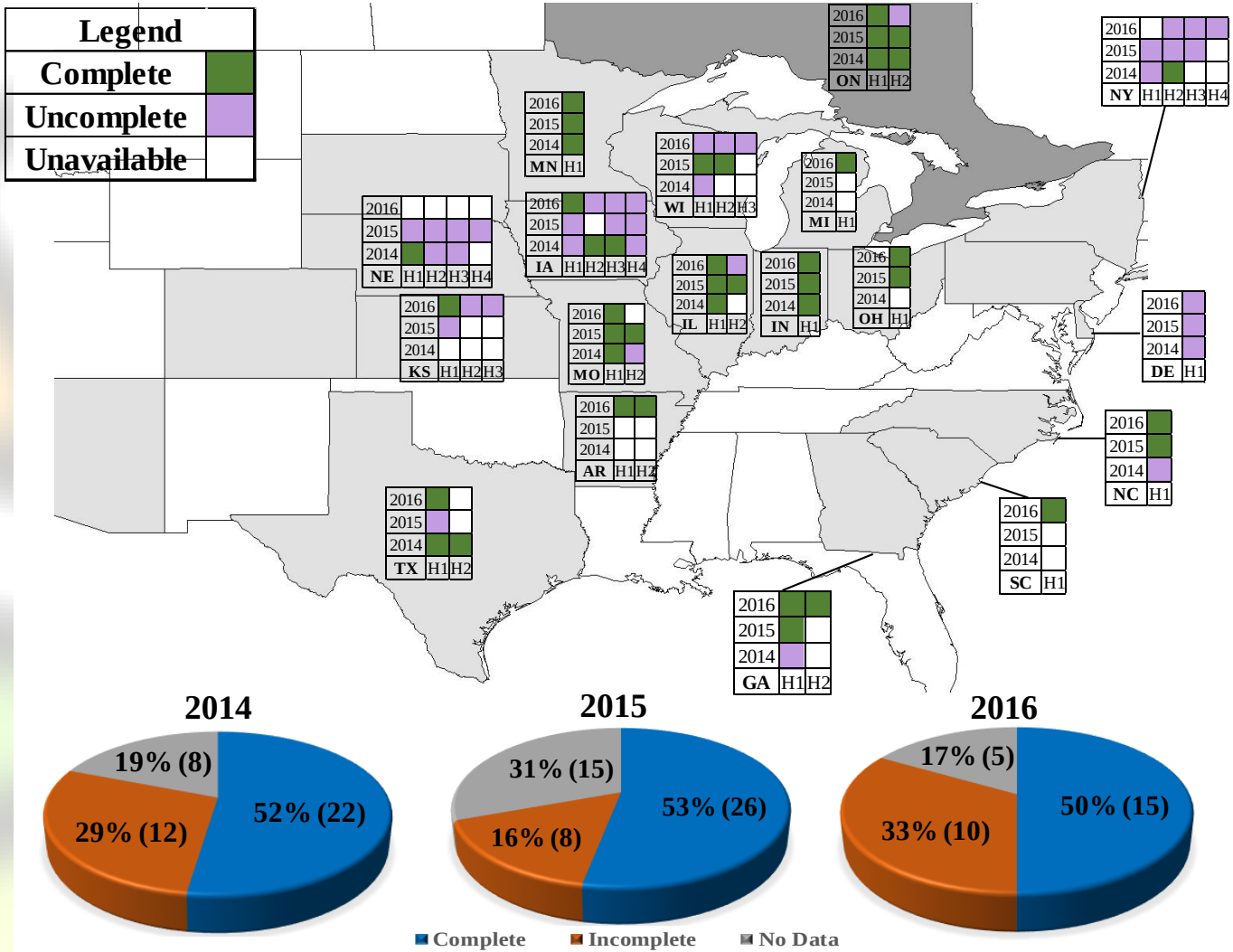
Software Architecture

- Preprocessing
- Selection
- Processing
- Postprocessing



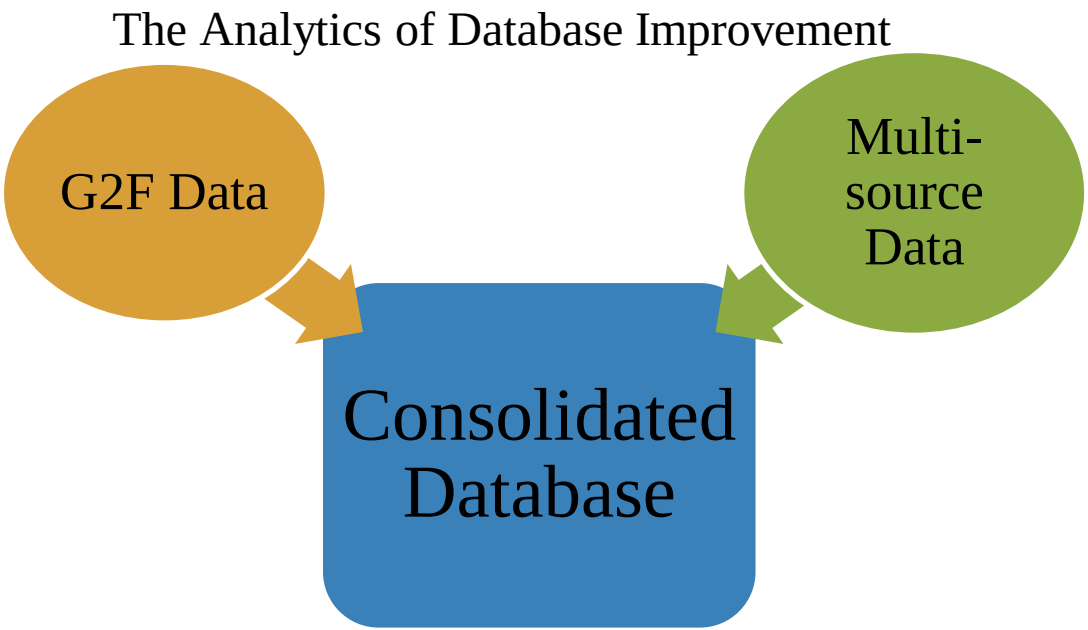
Database

- Temperature
- Dew Point
- Relative Humidity
- Solar Radiation
- Rainfall
- Wind Speed
- Wind Direction
- Wind Gust



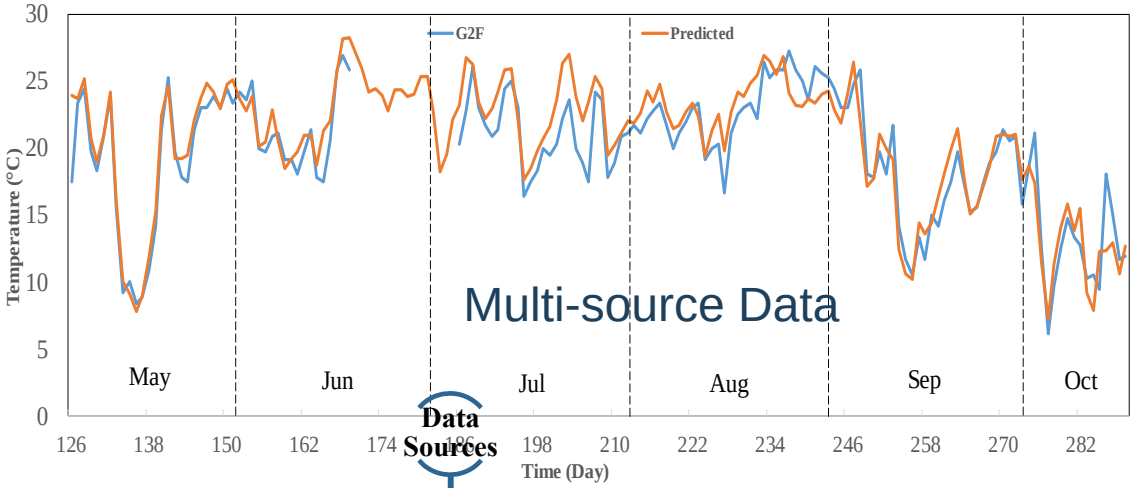
Pre-processing

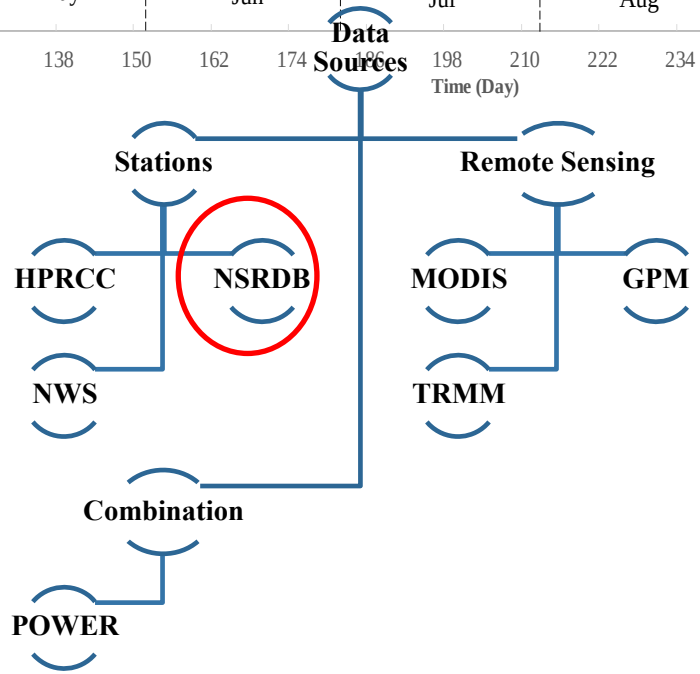
1. **Integration of various data sources**
2. **Correction the data**
3. **Synthesis the data**



Data consolidation

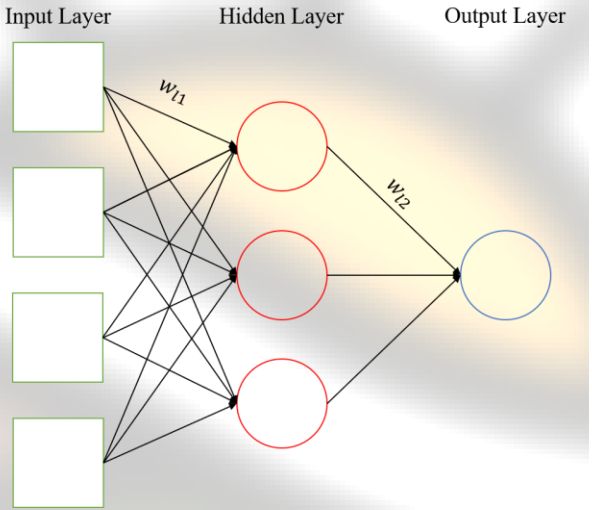
- Temperature
- Dew Point
- Relative Humidity
- Solar Radiation
- Rainfall
- Wind Speed
- Wind Direction

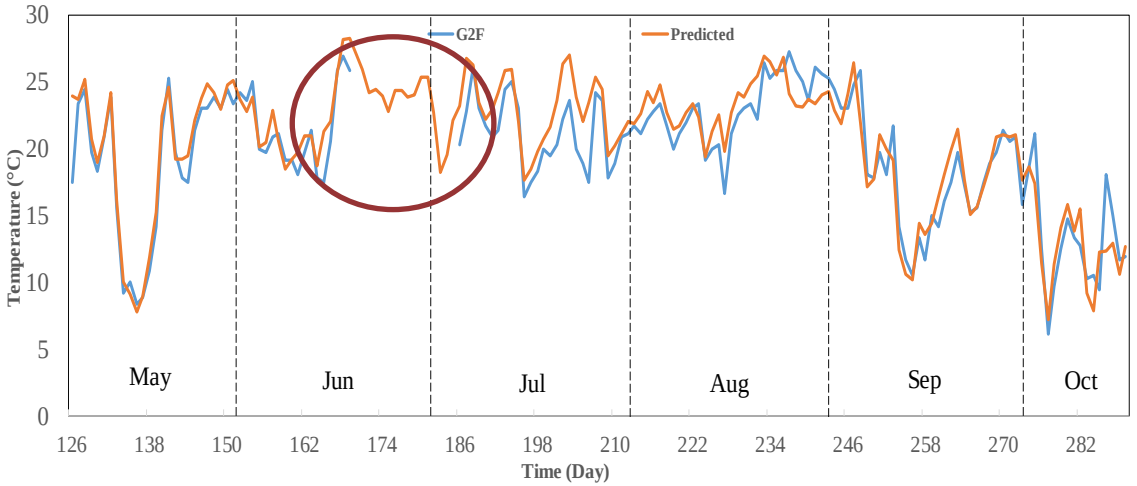




Ref: NSRDB-NREL

Data-driven analytics





Performance Metrics

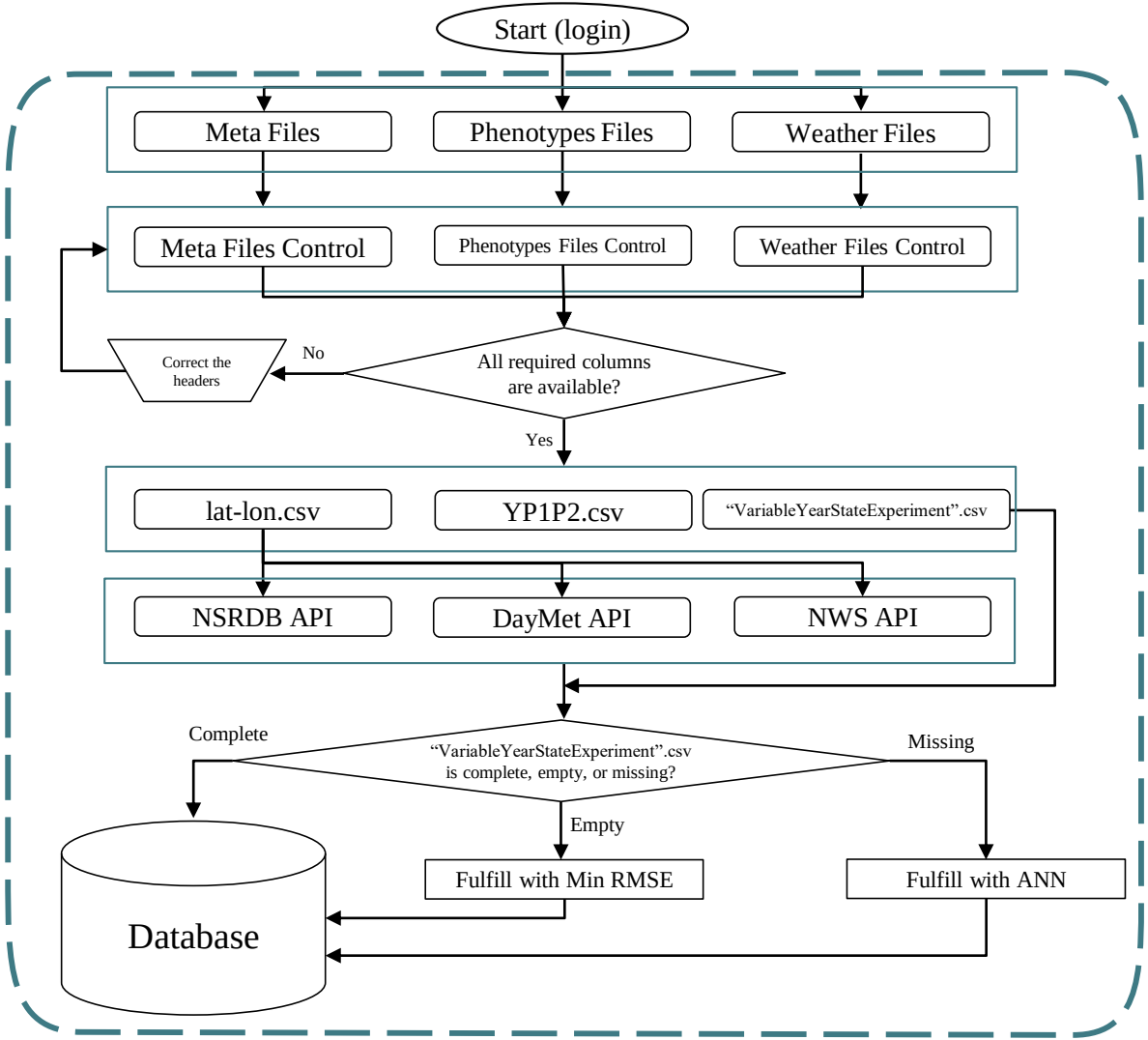
- R^2
- Bias
- RMSE
- NSE

Performance Metric	Mean	Min	Max	SD
R^2	0.88	0.61	0.96	0.10
Bias	-0.52	-1.15	0.13	0.37
RMSE	1.67	1.13	3.00	0.55
NSE	0.87	0.80	0.98	0.05

Pre-Processing

Preprocessing

- Input Files
- Files Control
- Data Processing
- APIs
- Database
- Option Selection
- GxE Model
- GxE Output



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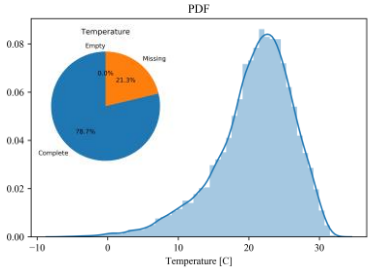
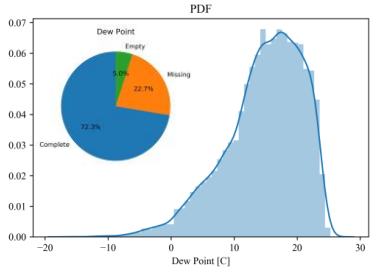
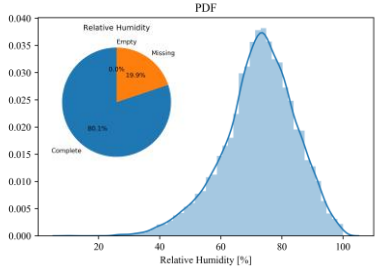
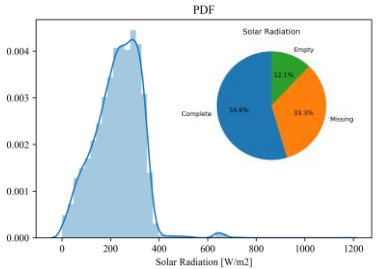
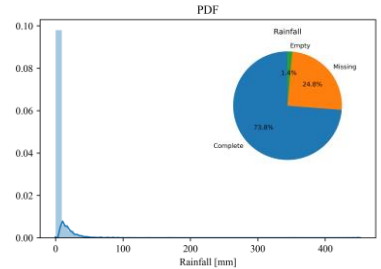
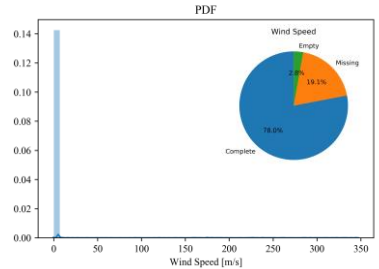


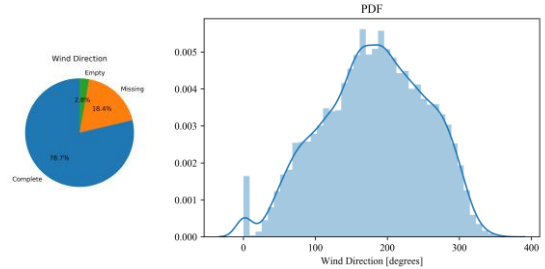


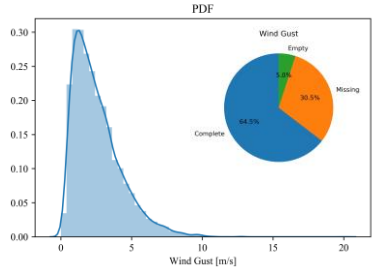












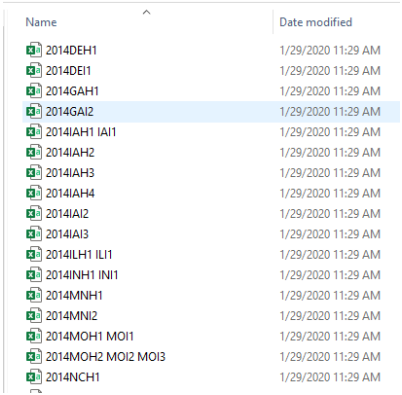
Complete

Empty

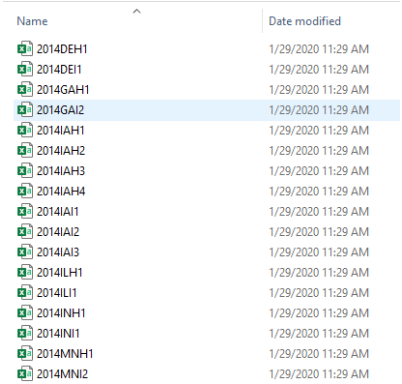
Missing

Pre-processing

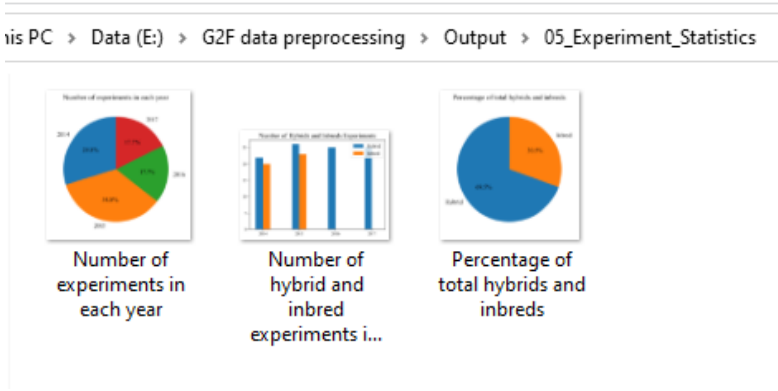
Data separation for each experiment



Correction of the Experiment names and Check the sequence of days



Charts for experiments analysis

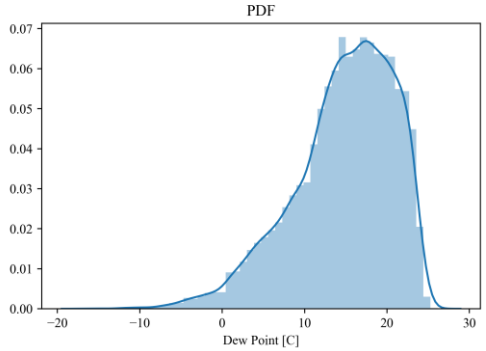


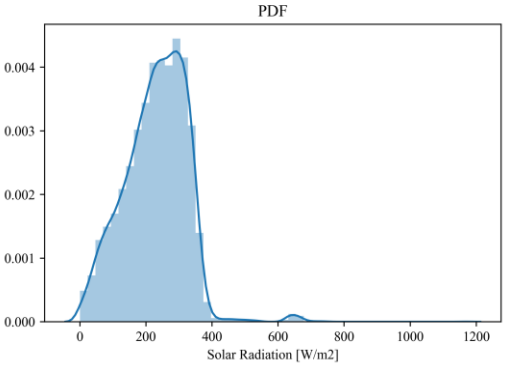
Pre-processing

Separating data for each variable

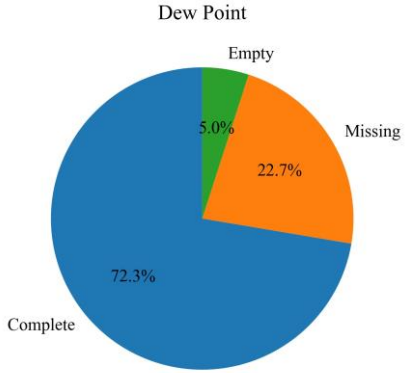
Name	Date modified
D2014DEH1	1/29/2020 11:31 AM
D2014DEI1	1/29/2020 11:31 AM
D2014GAH1	1/29/2020 11:31 AM
D2014GAI2	1/29/2020 11:31 AM
D2014IAH1	1/29/2020 11:31 AM
D2014IAH2	1/29/2020 11:31 AM
D2014IAH3	1/29/2020 11:31 AM
D2014IAH4	1/29/2020 11:31 AM
D2014IAI1	1/29/2020 11:31 AM
D2014IAI2	1/29/2020 11:31 AM
D2014IAI3	1/29/2020 11:31 AM
D2014ILH1	1/29/2020 11:31 AM
D2014ILI1	1/29/2020 11:31 AM
D2014INH1	1/29/2020 11:31 AM
D2014INI1	1/29/2020 11:31 AM
D2014MNH1	1/29/2020 11:31 AM
D2014MNI2	1/29/2020 11:31 AM
D2014MOH1	1/29/2020 11:31 AM
D2014MOH2	1/29/2020 11:31 AM
D2014MOI1	1/29/2020 11:31 AM
D2014MOI2	1/29/2020 11:31 AM
D2014MOI3	1/29/2020 11:31 AM
D2014NCH1	1/29/2020 11:31 AM

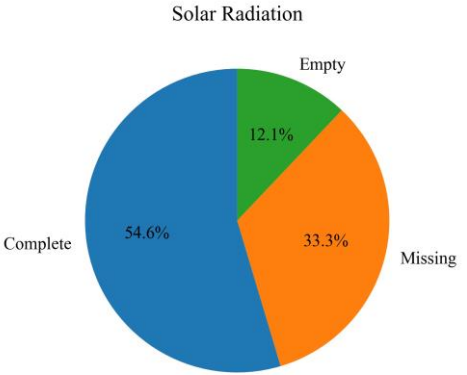
Providing PDFs for each variable





Providing charts to analyze data availability for each variable



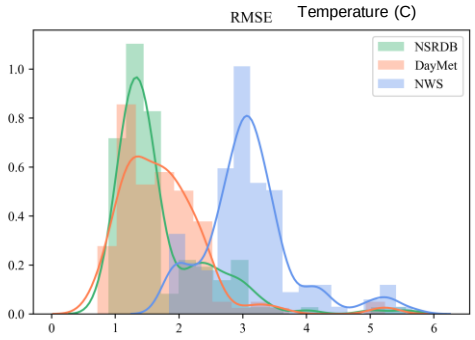


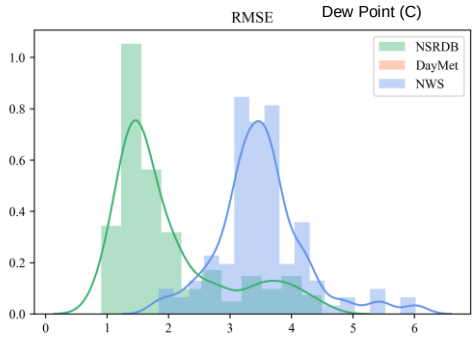
Pre-Processing

Preprocessing

- Input Files
- Files Control
- Data Processing
- APIs
- Database

- Option Selection
- GxE Model
- GxE Output





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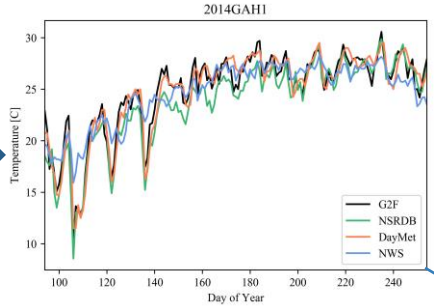

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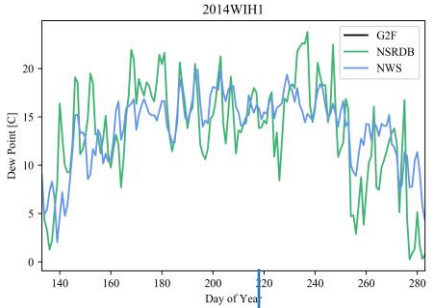

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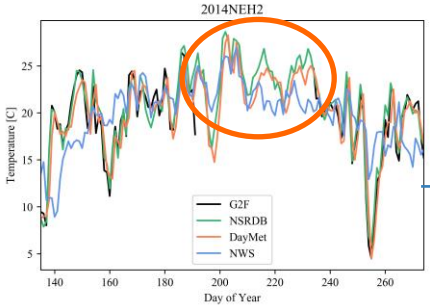

Filling

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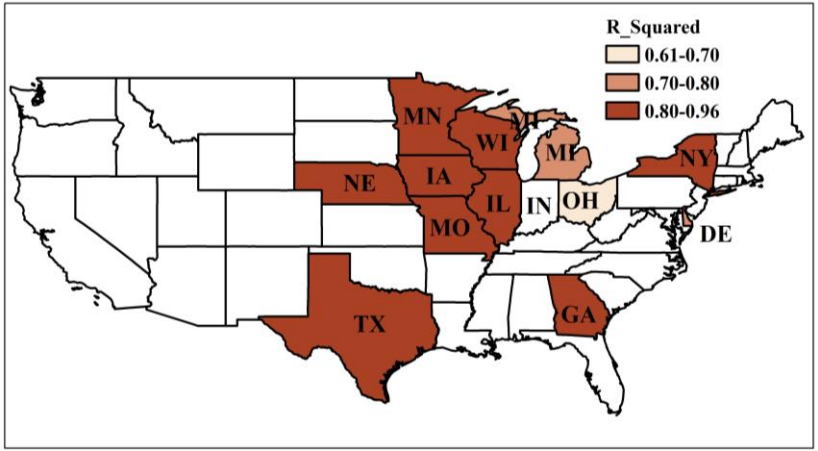
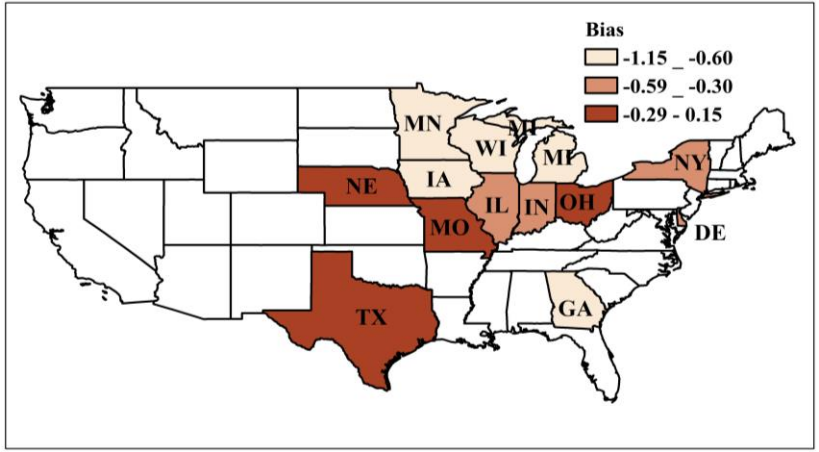
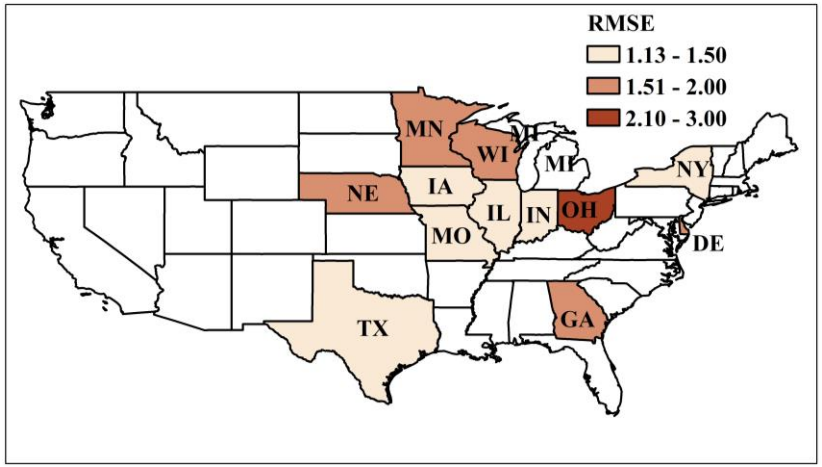
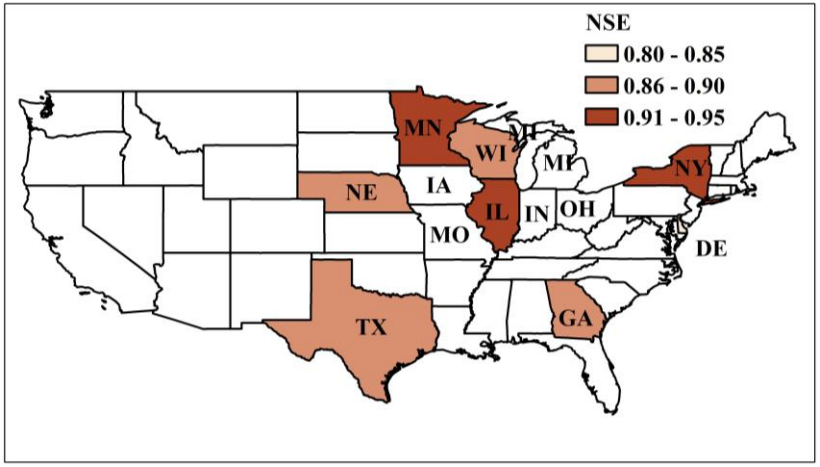
Database

Performance Metrics









Selection

Preprocessing

Option Selection

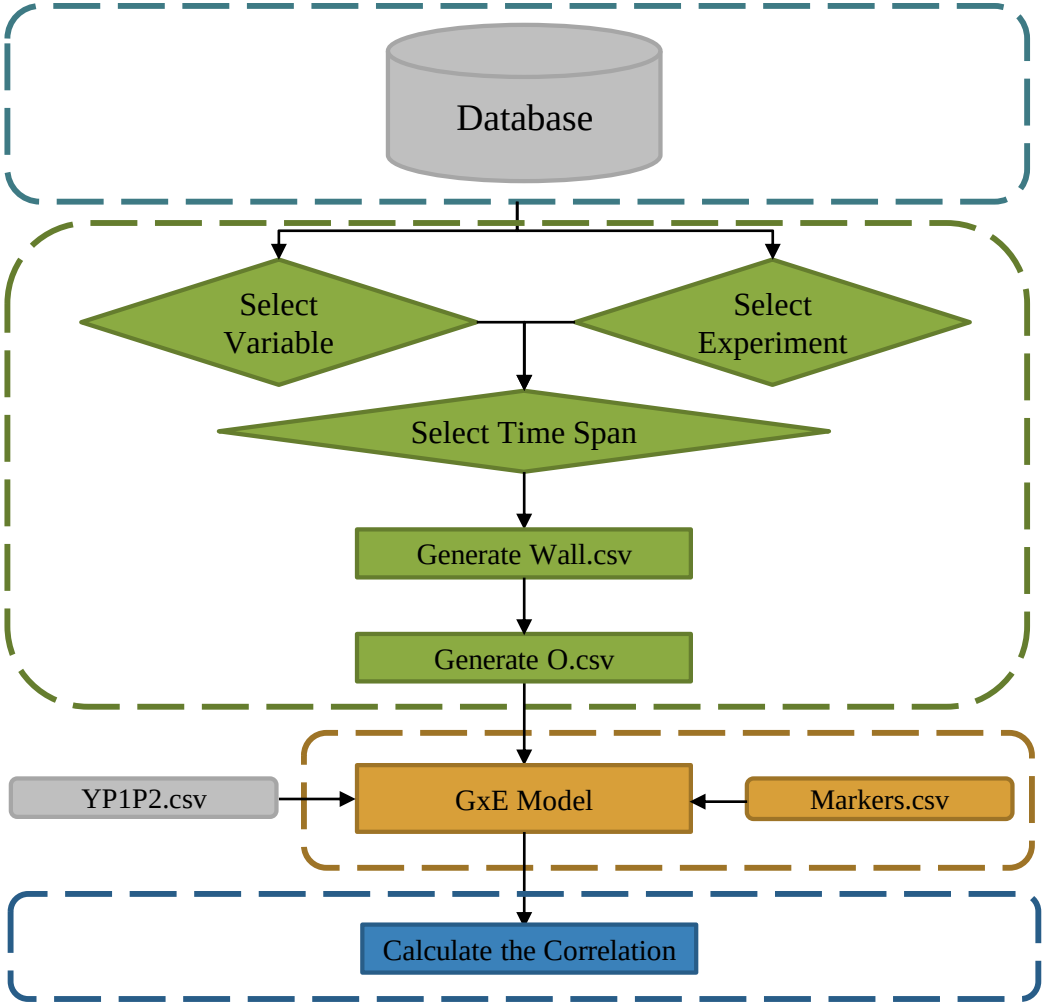
Select Variables

Select Experiment

Select Time Span

GxE Model

GxE Output



Selection

Option Selection

- Preprocessing
- Select Variables
- Select Experiment
- Select Time Span

GxE Execution

- GxE Model
- GxE Output

Select Variable(s)

- [ ] Temperature (C)
- [ ] Dew Point (C)
- [ ] Relative Humidity (%)
- [ ] Solar Radiation (W/m2)
- [ ] Rainfall (mm)
- [ ] Wind Speed (m/s)
- [ ] Wind Direction (degrees)
- [ ] Pressure (mb)
- [ ] Precipitable water (mm)

Select Experiment(s)

- [ ] 2014IAH3
- [ ] 2015NEH3
- [ ] 2017MOH1

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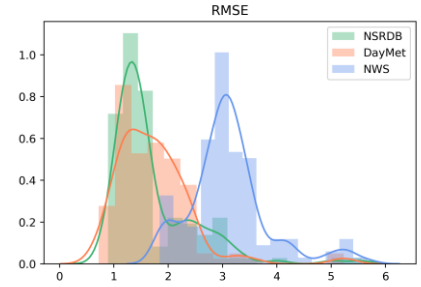
Start day =

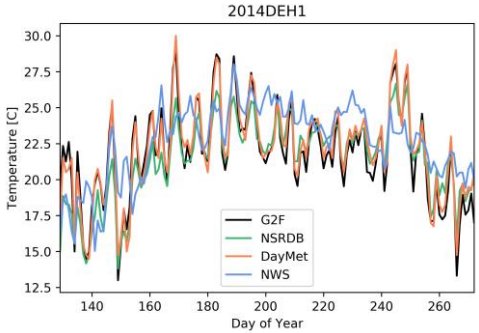
End day =

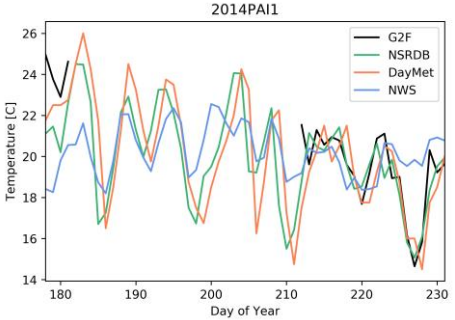
		Tested Genotypes: YES	Tested Genotypes: NO
Tested Environments	YES	CV2	CV1
Tested Environments	NO	CV0	CV00

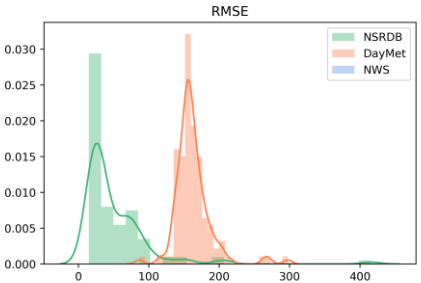
CV00: Predicting performance of unobserved lines in unobserved environments;
CV0: Predicting performance of unobserved environments;
CV1: Predicting performance of new developed lines through relationships with others;
CV2: Predicting Performance of Lines Captured in Other Environments

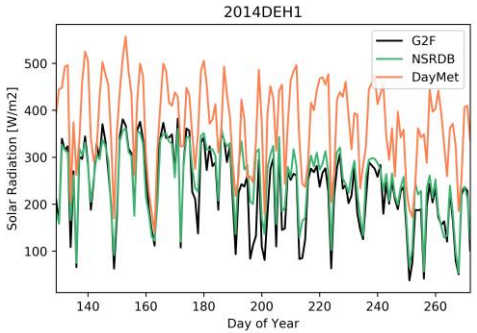
Selection

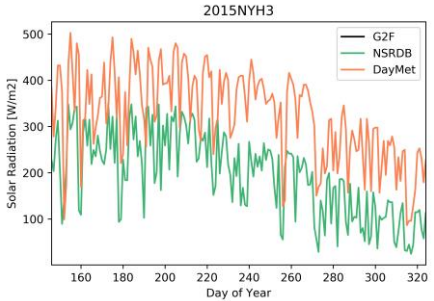

RMSE
NSRDB
DayMet
NWS


2014DEH1
Temperature [C]
Day of Year
G2F
NSRDB
DayMet
NWS


2014PAI1
Temperature [C]
Day of Year
G2F
NSRDB
DayMet
NWS


RMSE
NSRDB
DayMet
NWS

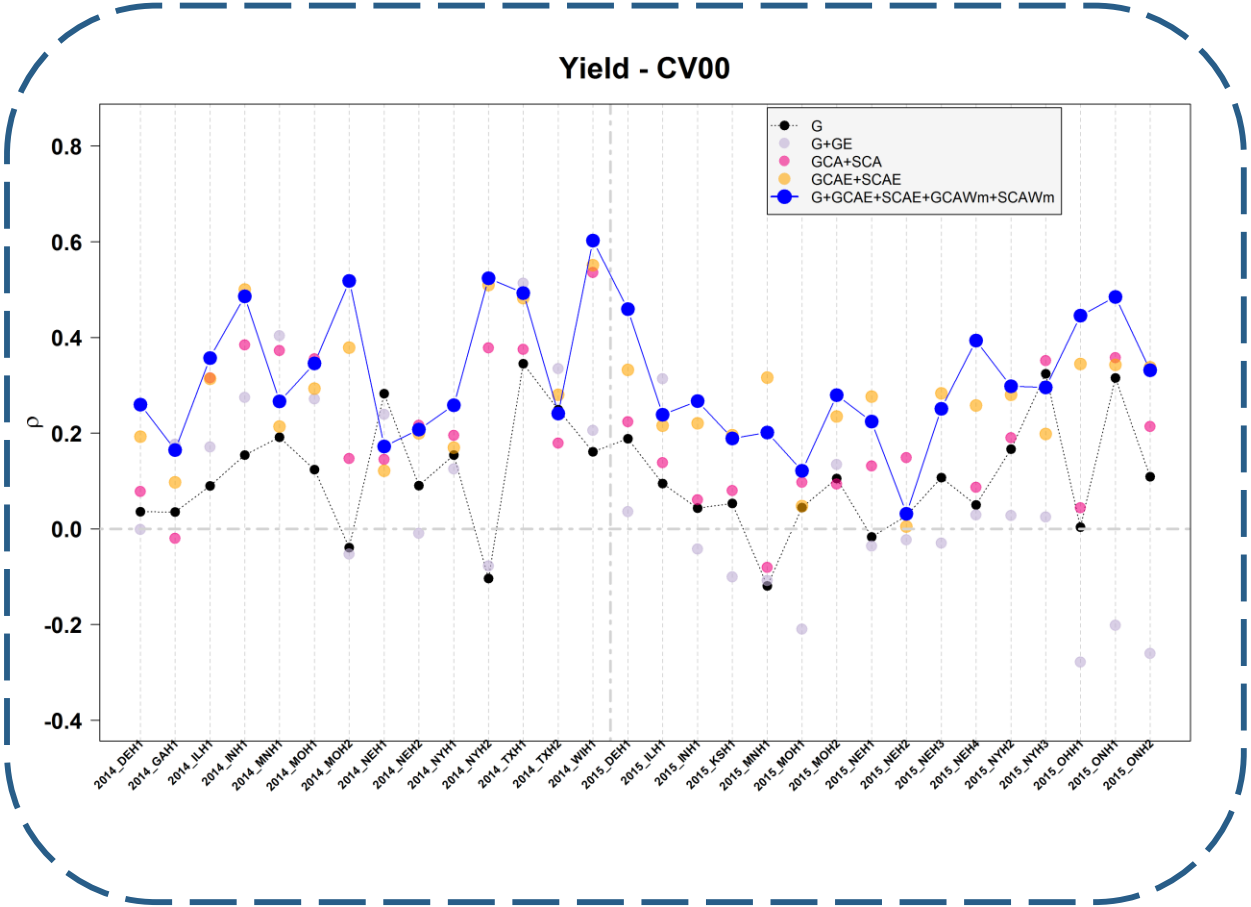

2014DEH1
Solar Radiation [W/m2]
Day of Year
G2F
NSRDB
DayMet


2015NYH3
Solar Radiation [W/m2]
Day of Year
G2F
NSRDB
DayMet

Post-Processing

- Preprocessing
- Select Variables
- Select Experiment
- Select Time Span
- GxE Model
- GxE Output

GxE Predictability



Post-Processing

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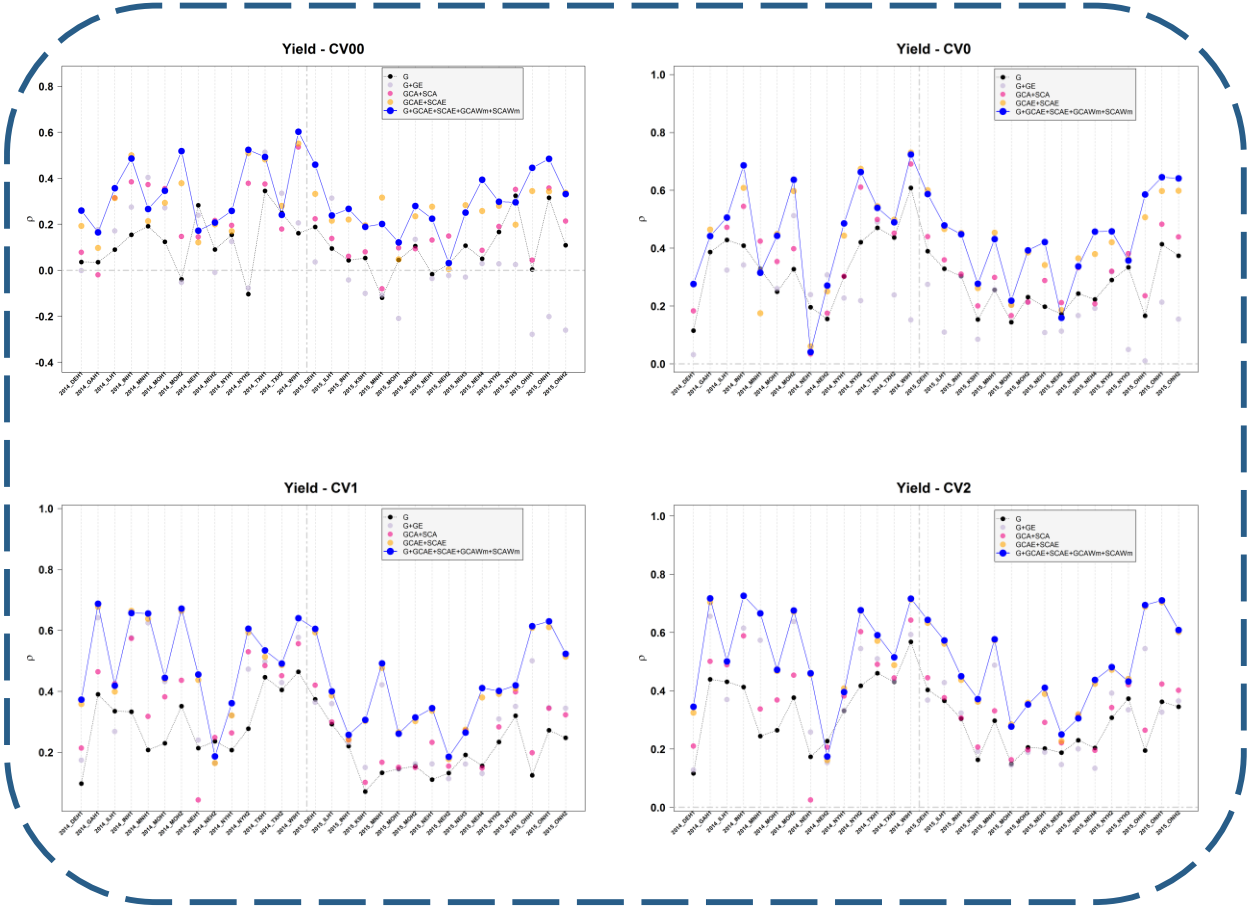
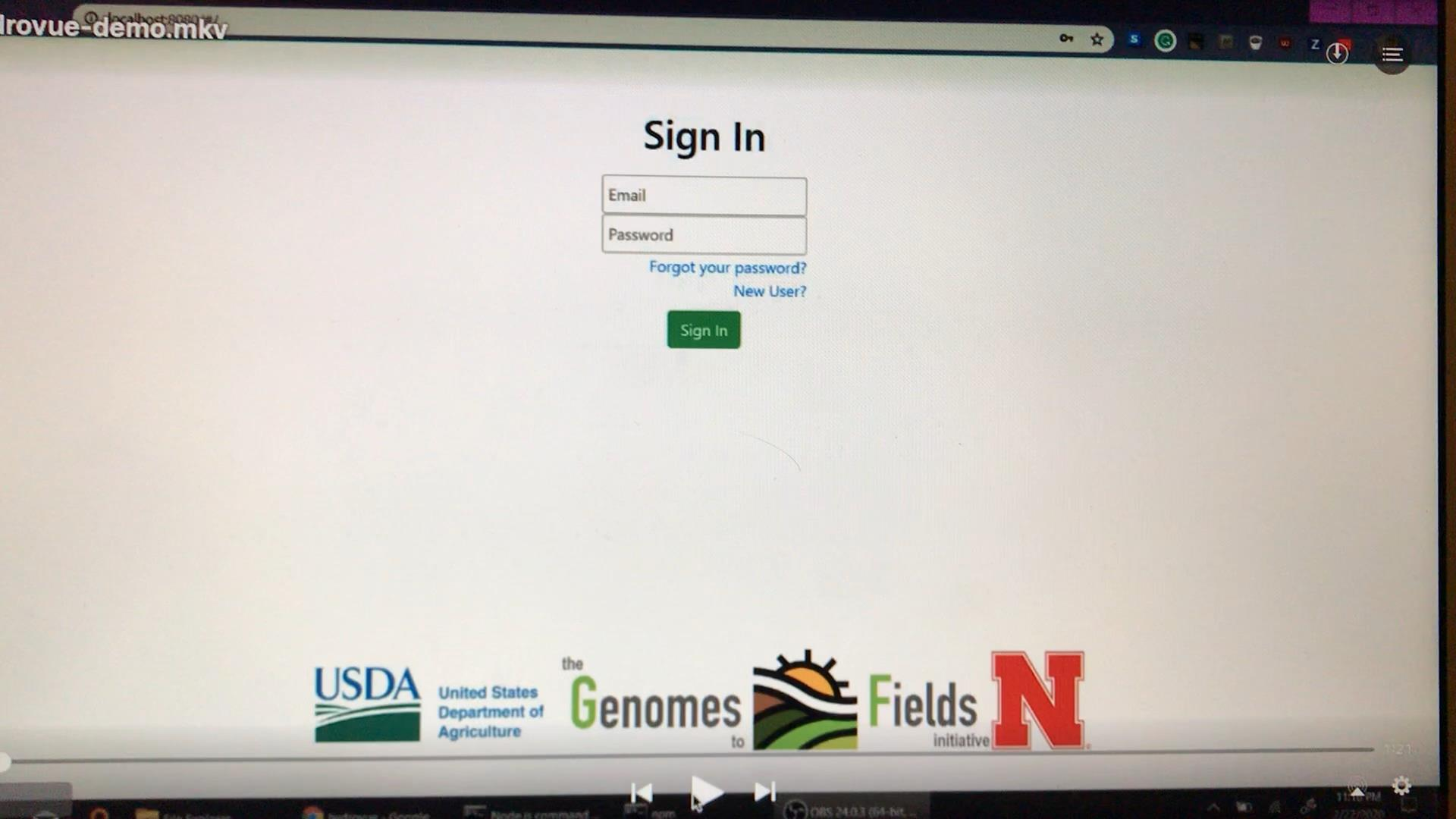
- GxE Output

GxE Predictability

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Complexities

Providing AWS (Amazon Web Service) as platform for the phenotypic predictability application;

Authentication for different users;

Transferring all the data (G2F, NSRDB, DayMet, and NWS) and scripts (R and Python) to the platform;

Coupling R and Python scripts to develop an integrated software for phenotype-prediction in the G2F experiment.

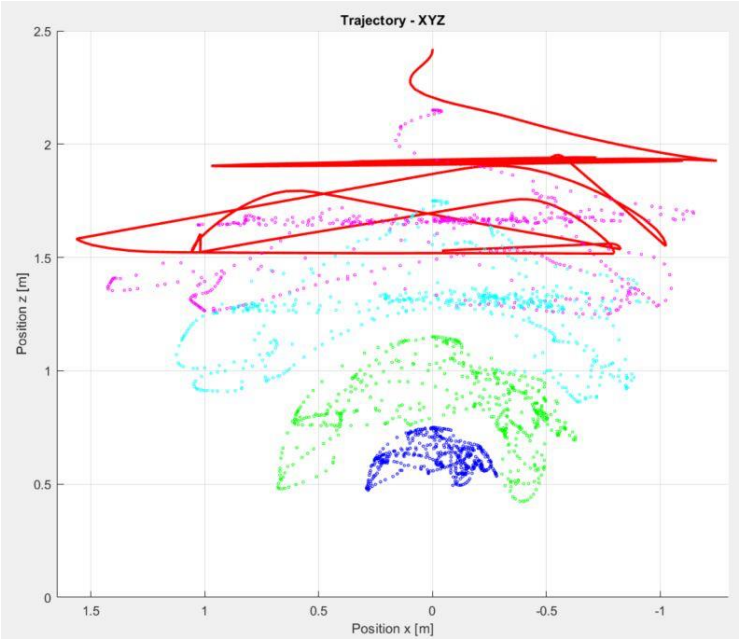
Conclusions

- The integration of other data sources to improve G2F database unclearly improved the predictability of phenotypes;
- Transferring and coupling the hydroclimate data analytics and GxE modeling scripts to the web service platform is feasible;
- Increasing the number of experiments may lead to a better accuracy of phenotype predictability.

Future work

- Add climatic spatial and temporal analytics of GxE predictability module;
- Add a global sensitivity of GxE accuracy module to estimate sources and propagation of uncertainty in response to various climatic (environmental) factors;
- Add the remote sensing data plugin module to increase the number of climatic variables and phenotypes in the database.

Some more future work



Team members and tasks:

- **Francisco Munoz-Arriola**; Team leader
- **Diego Jarquin: GxE model developer**; Develops R scripts for phenotypes predictions using GxE
- **Hallie Hohbein: Project Manager**; Takes care of project management tasks, documentation, and testing
- **Parisa Sarzaeim: Hydroclimate data scientist**; Develops Python scripts to manage hydroclimate database
- **Joseph Carter: Frontend/Backend Developer**; Works on user authentication, frontend development, and testing.
- **David Recic: Backed Developer**; Creates the database and works on user authentication.
- **Zoe Trautman: Frontend Developer**; Develops the frontend and writes documentation.
- **Anna Zhang: Development Manager**; In charge of AWS and helps with backend development.
- **Byrav Ramamurthy and Francisco Munoz-Arriola;** Computer science advisers

Thank You

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