

MICHIGAN STATE

UNIVERSITY

Project Plan Presentation

Wildfire Risks Forecasting Tool

The Capstone Experience

Team Anthropocene Institute

Jingxian Chen

Andrew Haas

Andrew McDonald

Ben Miller

Jamie Schmidt

Nathan Woods

Department of Computer Science and Engineering

Michigan State University

Spring 2022



*From Students...
...to Professionals*

Functional Specifications

The Problem

- Wildfires in the San Francisco Bay Area pose significant threats to life, property, and the environment
- Climate change is increasing temperatures and drought, leading to more frequent and intense wildfires
- Public understanding of wildfire risk lags science
- Existing wildfire simulations have a high barrier to entry

Our Solution

- Create an intuitive web app which simulates wildfires and predicts their impacts
- Target Bay Area residents of marginalized communities, communicating critical information to prevent wildfires and engage with policymakers

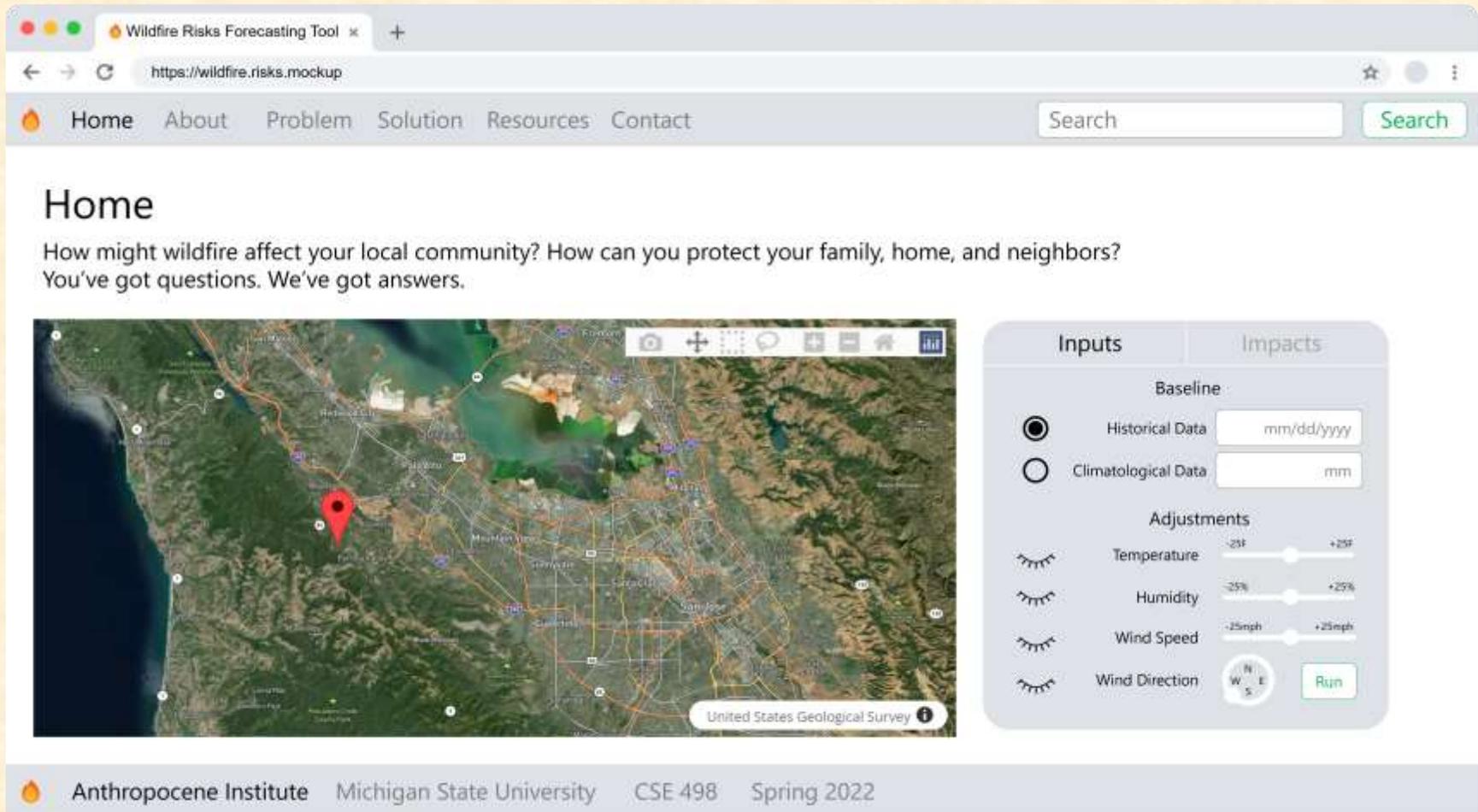


Design Specifications

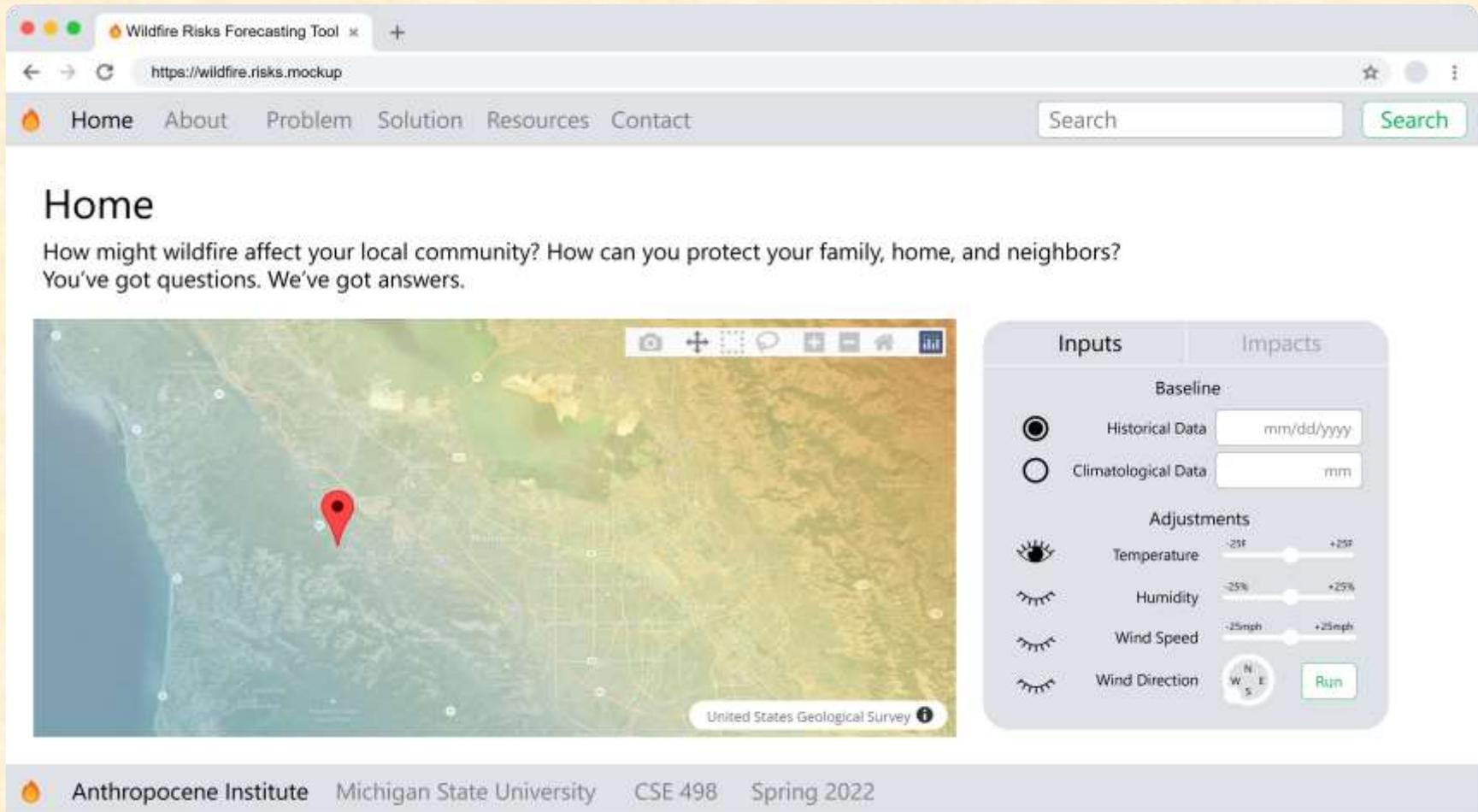
- Accessible from any internet-connected computer, smartphone, or tablet
- Modern, minimalist, intuitive
- Homepage
 - Map-based interface for wildfire simulation & impact exploration
 - Fully interactive with satellite base
 - Toggleable translucent data layers
 - User-specified baseline simulation parameters
 - Live weather conditions
 - Historical weather conditions from a particular day
 - Climatological average conditions in a particular month
 - User-specified adjustments to baseline simulation parameters
 - Temperature, Humidity, Wind Speed, Wind Direction
 - Allows exploration of effects of climate change
 - Impact exploration by category
 - Economic: structures damaged or destroyed, firefighters needed, closures, evacuations, etc.
 - Health: injuries, deaths, hospital beds needed, hospital staff needed, etc.
 - Demographic: municipalities affected, breakdown by income level, education level, age, race, ethnicity, equity analysis, etc.
 - Environment: acres burned, smoke footprint, watershed footprint, CO₂e emissions, PM 2.5 emissions, etc.
- Supplementary Pages
 - About, Problem, Solution, Resources, Contact



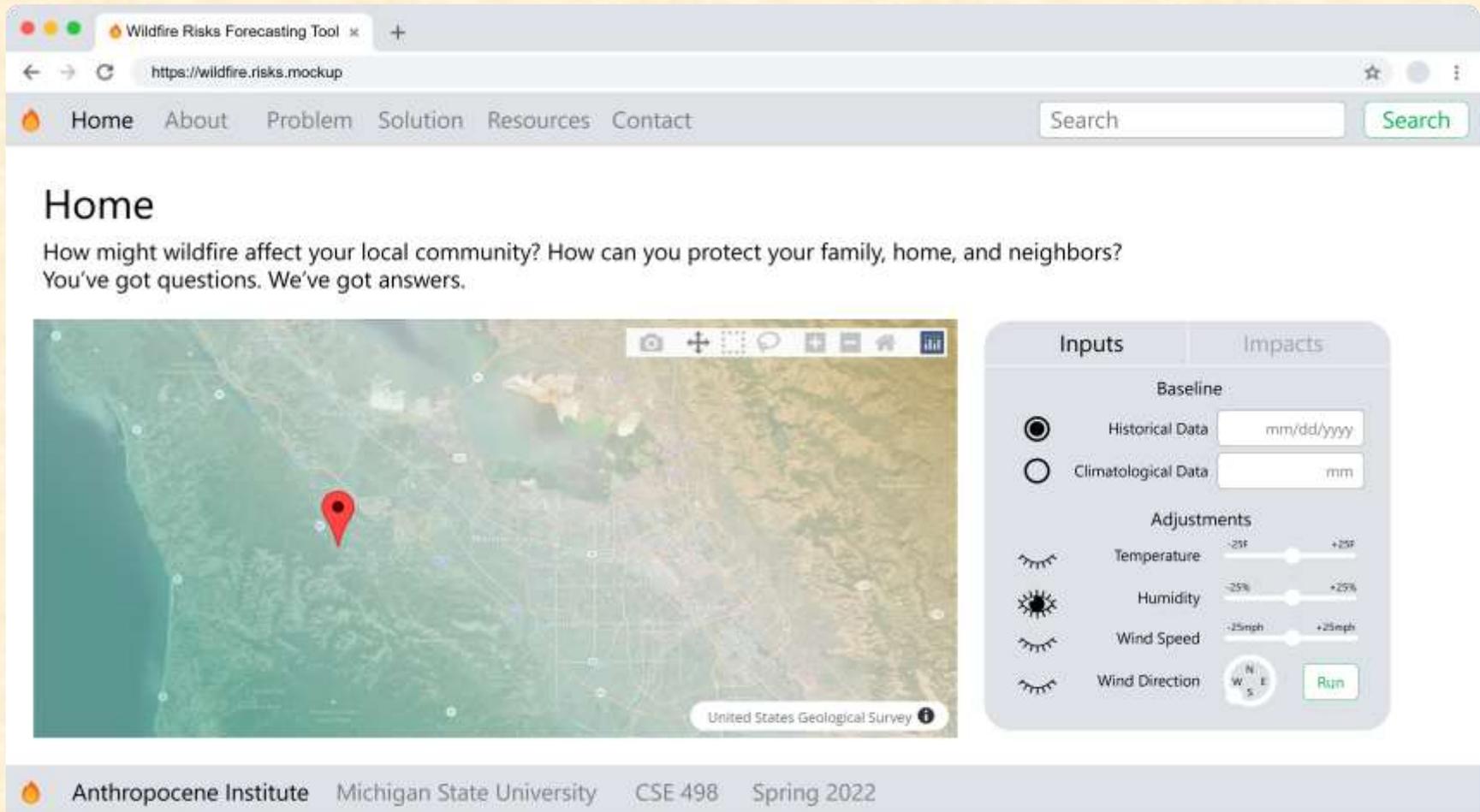
Screen Mockup: Simulator > Inputs > Base



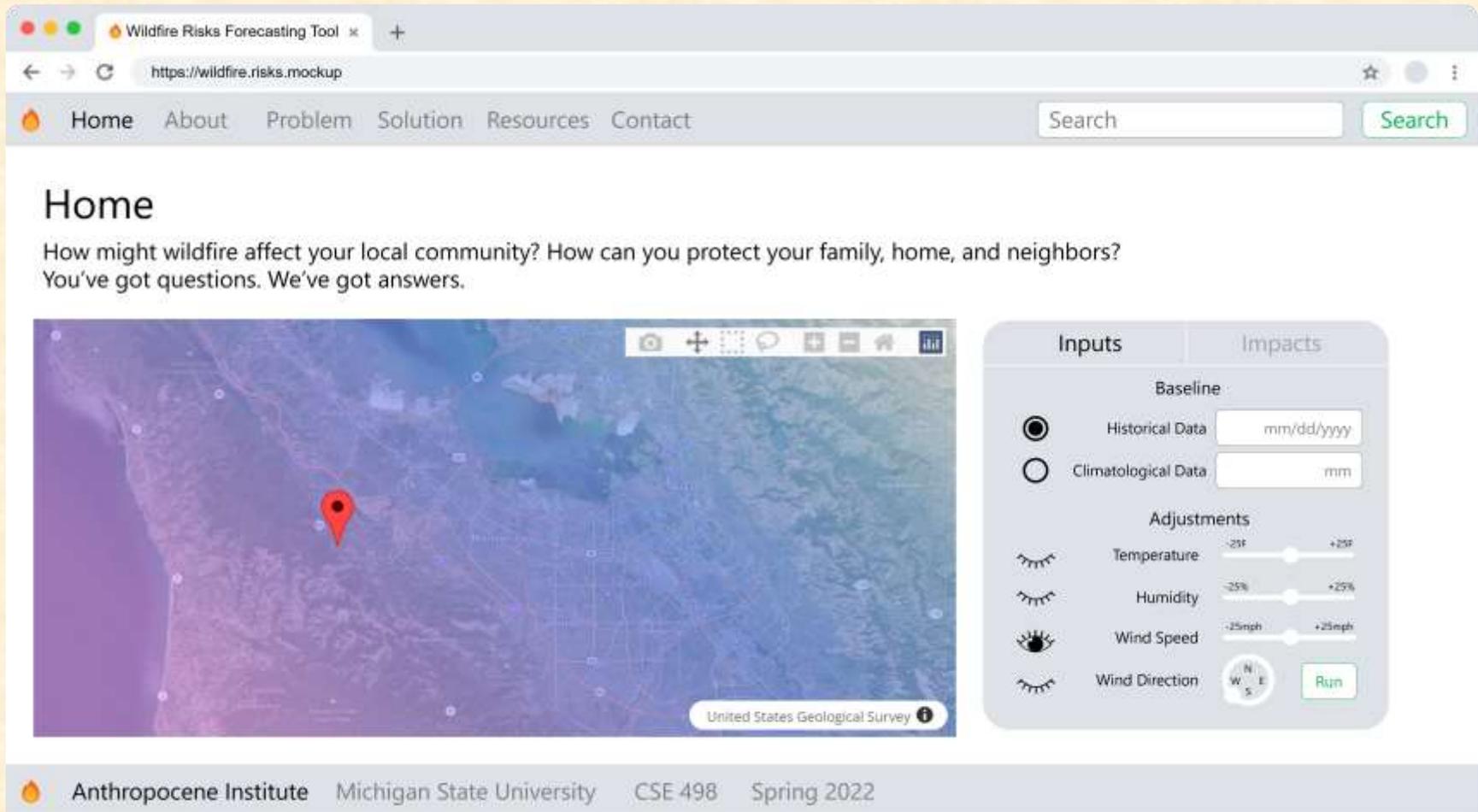
Screen Mockup: Simulator > Inputs > Temperature



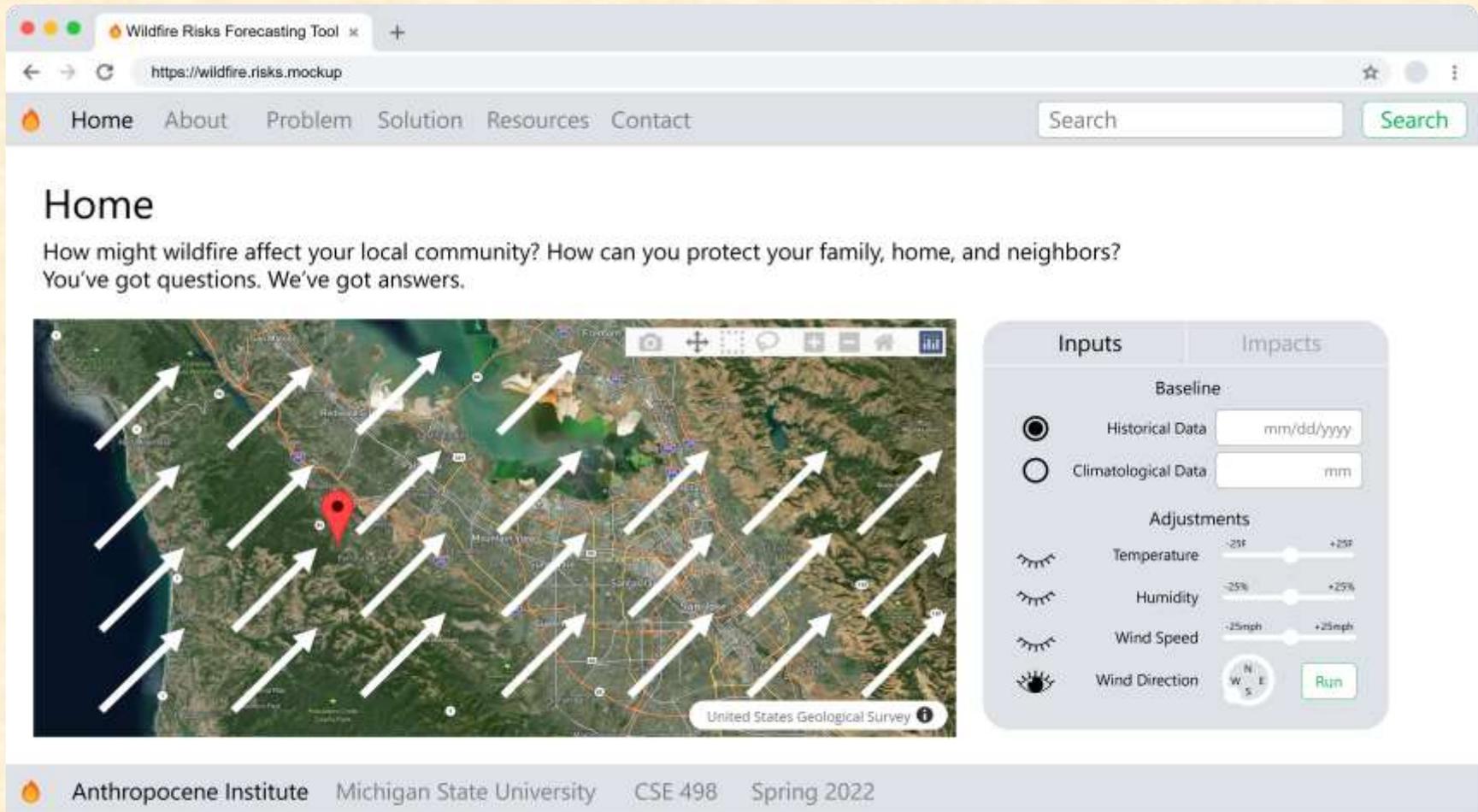
Screen Mockup: Simulator > Inputs > Humidity



Screen Mockup: Simulator > Inputs > Wind Speed



Screen Mockup: Simulator > Inputs > Wind Direction



Screen Mockup: Simulator > Impacts > Economic

Wildfire Risks Forecasting Tool x +

https://wildfire.risks.mockup

Home About Problem Solution Resources Contact

Search Search

Home

How might wildfire affect your local community? How can you protect your family, home, and neighbors? You've got questions. We've got answers.

United States Geological Survey

Inputs		Impacts	
Economic	Health	Demographic	Environment
Direct Loss			
	Structures Destroyed	124	\$50m
	Structures Damaged	37	\$10m
	Firefighters Needed	94	\$1m
Indirect Loss			
	Business Closures	432	\$10m
	Evacuations	10k	\$50m
Total Loss		Cost	
			\$121m

Anthropocene Institute Michigan State University CSE 498 Spring 2022



Screen Mockup: Simulator > Impacts > Health

Wildfire Risks Forecasting Tool x +

https://wildfire.risks.mockup

Home About Problem Solution Resources Contact

Search Search

Home

How might wildfire affect your local community? How can you protect your family, home, and neighbors?
You've got questions. We've got answers.

United States Geological Survey

Inputs		Impacts	
Economic	Health	Demographic	Environment
Losses			
		Injuries	34
		Deaths	1
Resources Needed			
		Hospital Beds Needed	27
		ICU Beds Needed	12
		Nurses Needed	10
		Doctors Needed	5

Anthropocene Institute Michigan State University CSE 498 Spring 2022



Screen Mockup: Simulator > Impacts > Demographic

Wildfire Risks Forecasting Tool x +

https://wildfire.risks.mockup

Home About Problem Solution Resources Contact

Search Search

Home

How might wildfire affect your local community? How can you protect your family, home, and neighbors?
You've got questions. We've got answers.

United States Geological Survey

Inputs		Impacts	
Economic	Health	Demographic	Environment
Communities Affected			
	Cities	Palo Alto, ...	
	Counties	San Mateo, ...	
	Congressional Districts	CA-14	
Equity Factors			
	Household Income	\$50k	
	Education Level	Some college	
	Median Age	41	
	Percent Nonwhite	23%	

Anthropocene Institute Michigan State University CSE 498 Spring 2022



Screen Mockup: Simulator > Impacts > Environment

Wildfire Risks Forecasting Tool × +

← → ↻ https://wildfire.risks.mockup ☆ ● ⋮

🔥 Home About Problem Solution Resources Contact Search Search

Home

How might wildfire affect your local community? How can you protect your family, home, and neighbors? You've got questions. We've got answers.

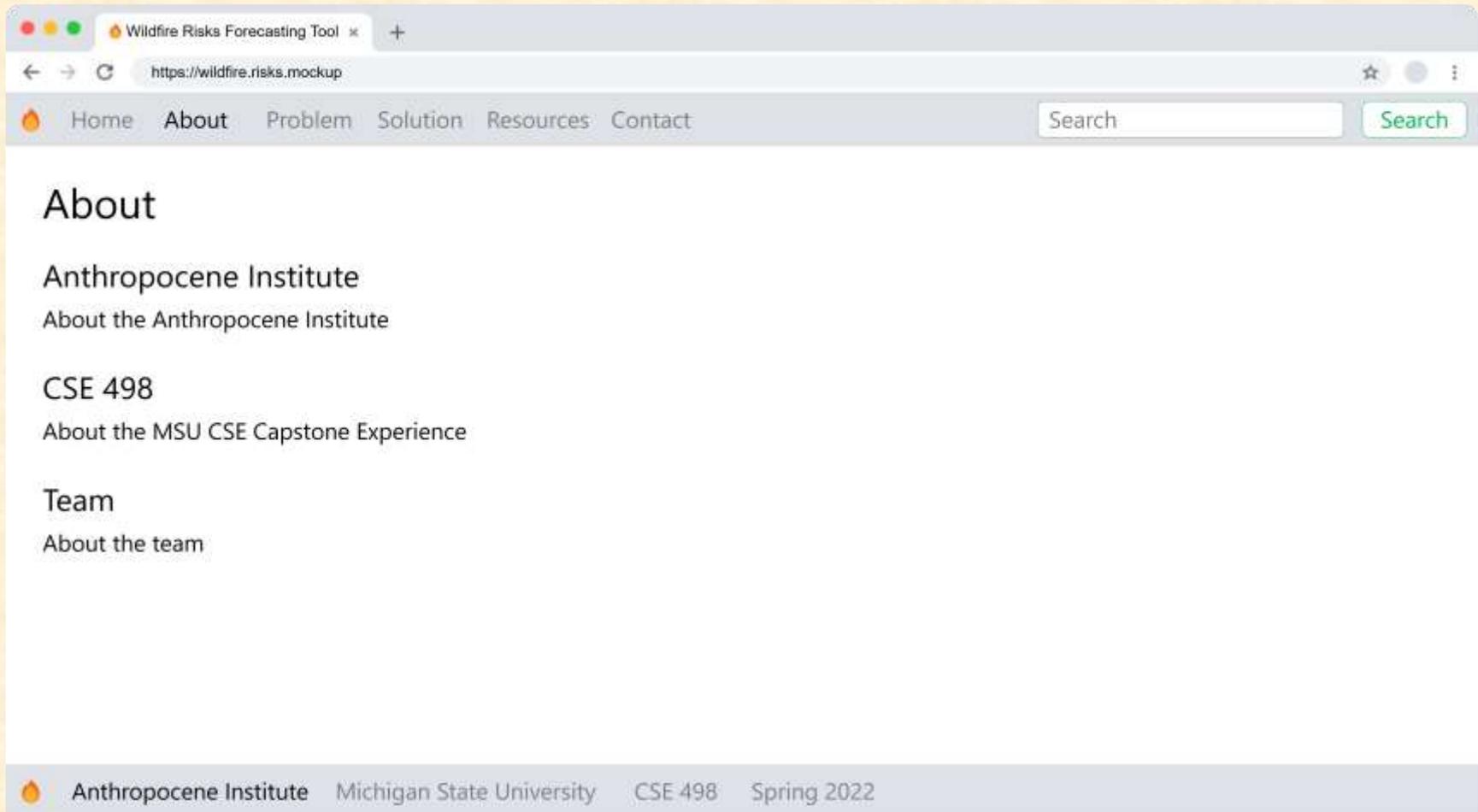
United States Geological Survey ⓘ

Inputs		Impacts	
Economic	Health	Demographic	Environment
Consequences			
	Acres Burned	342ac	
	Smoke Footprint	100mi²	
	Watershed Footprint	20mi	
	CO ₂ e Emissions	2mmt	
	PM 2.5 Emissions	31µg/m³	

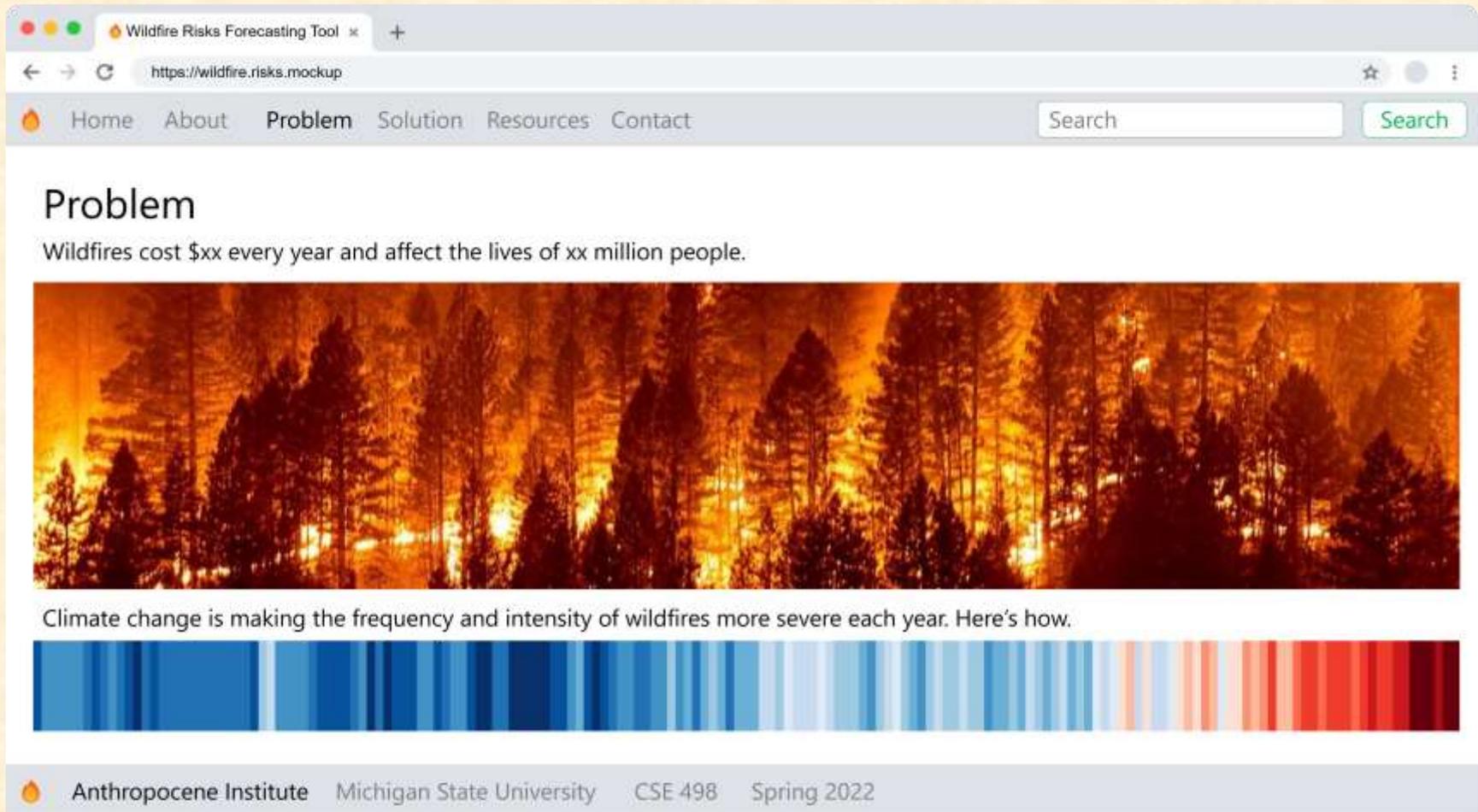
🔥 Anthropocene Institute Michigan State University CSE 498 Spring 2022



Screen Mockup: About



Screen Mockup: Problem



Screen Mockup: Solution

Wildfire Risks Forecasting Tool × +
https://wildfire.risks.mockup

Home About Problem Solution Resources Contact Search Search

Solution

Our Wildfire Risks Forecasting Tool is designed as follows.

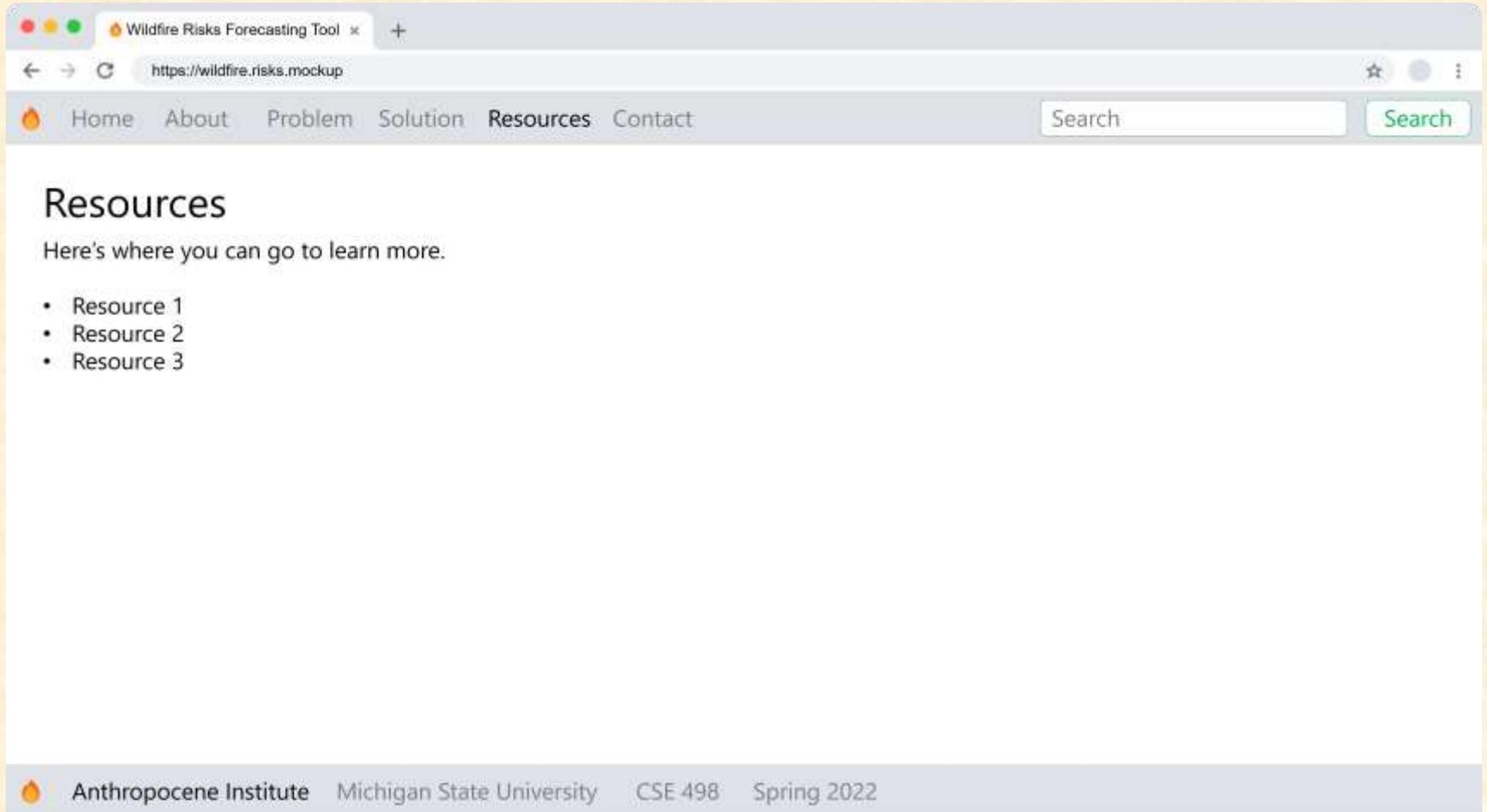
Data Aggregators | **Wildfire Modeling** | **Frontend UI**

The diagram illustrates the system architecture. On the left, a box labeled 'Data Aggregators' contains logos for LANDFIRE, UAS, NASA, NOAA, USDA, and USGS. An arrow points from this box to a 'Database' box containing the MySQL logo. The 'Database' box is connected to an 'aws' Hosting box. Above the 'aws' box is a 'Wildfire Modeling' box containing logos for NumPy, SciPy, python, Numba, xarray, and pandas. A double-headed arrow connects the 'Wildfire Modeling' box to the 'aws' box. To the right of the 'aws' box is a 'Frontend UI' box containing logos for python, Bootstrap, Flask, plotly, and Jinja. A double-headed arrow connects the 'Frontend UI' box to the 'aws' box. Below the diagram, the text 'Here's how it works.' is visible.

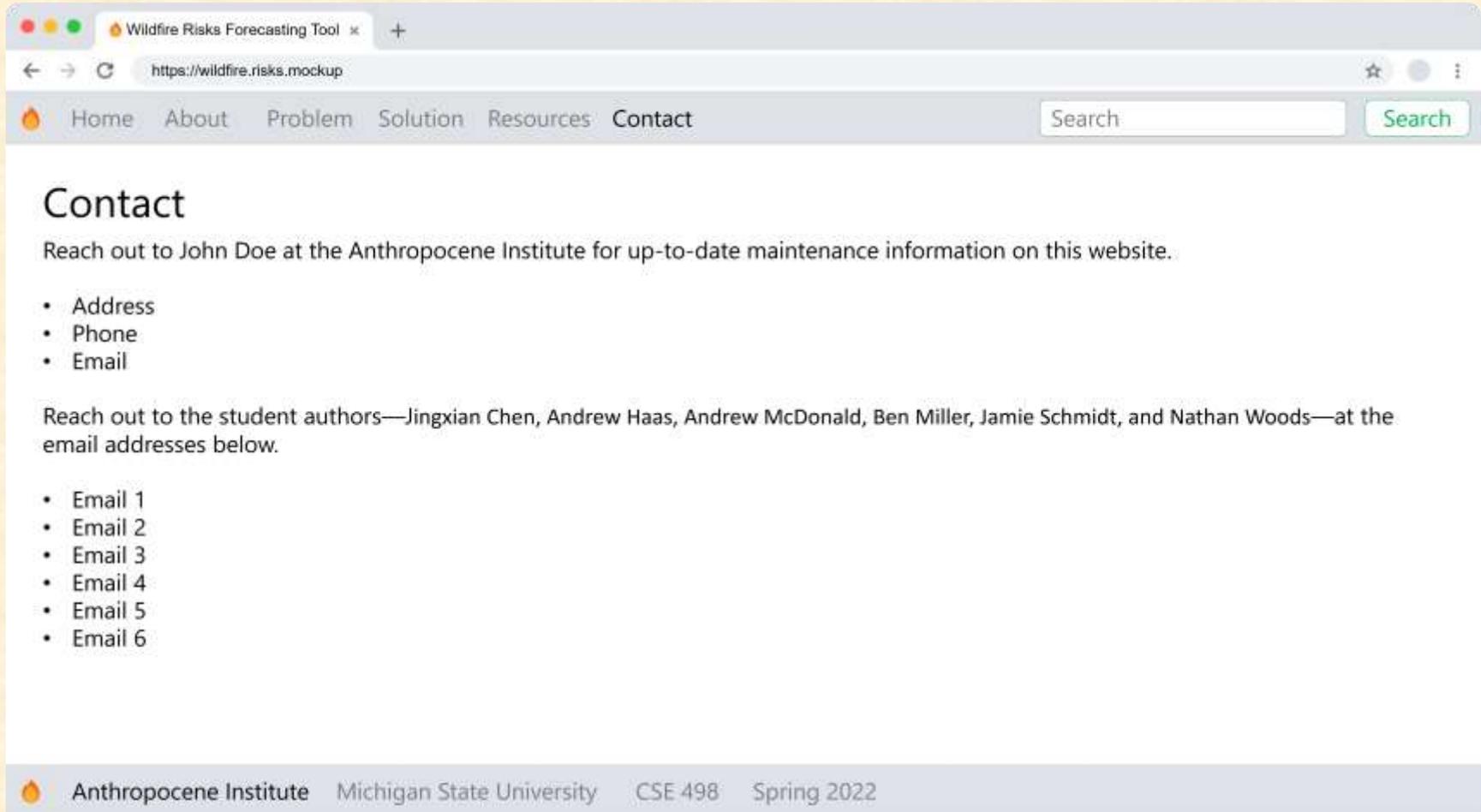
Anthropocene Institute Michigan State University CSE 498 Spring 2022



Screen Mockup: Resources



Screen Mockup: Contact



Technical Specifications

- Open-source on GitHub with conda package management for reproducibility
- Four major technical components with unit and integration tests throughout

1. Wildfire Modeling & Simulation

- Gold-standard physics-based FARSITE model ([Finney, USFS, 1998](#))
- Standard Fire Behavior Fuel Models ([Scott & Burgan, USFS, 2005](#))
- Builds upon earlier Rothermel Surface Fire Model ([Rothermel, USFS, 1972](#))
- Implemented in Python, Numpy, and Scipy
- Parallelization and acceleration with Numba

2. Data Pipeline

- NOAA NCEI API for dynamic weather and climate data
- LandFire database for static fuel and topography data

3. Infrastructure & Hosting Solutions

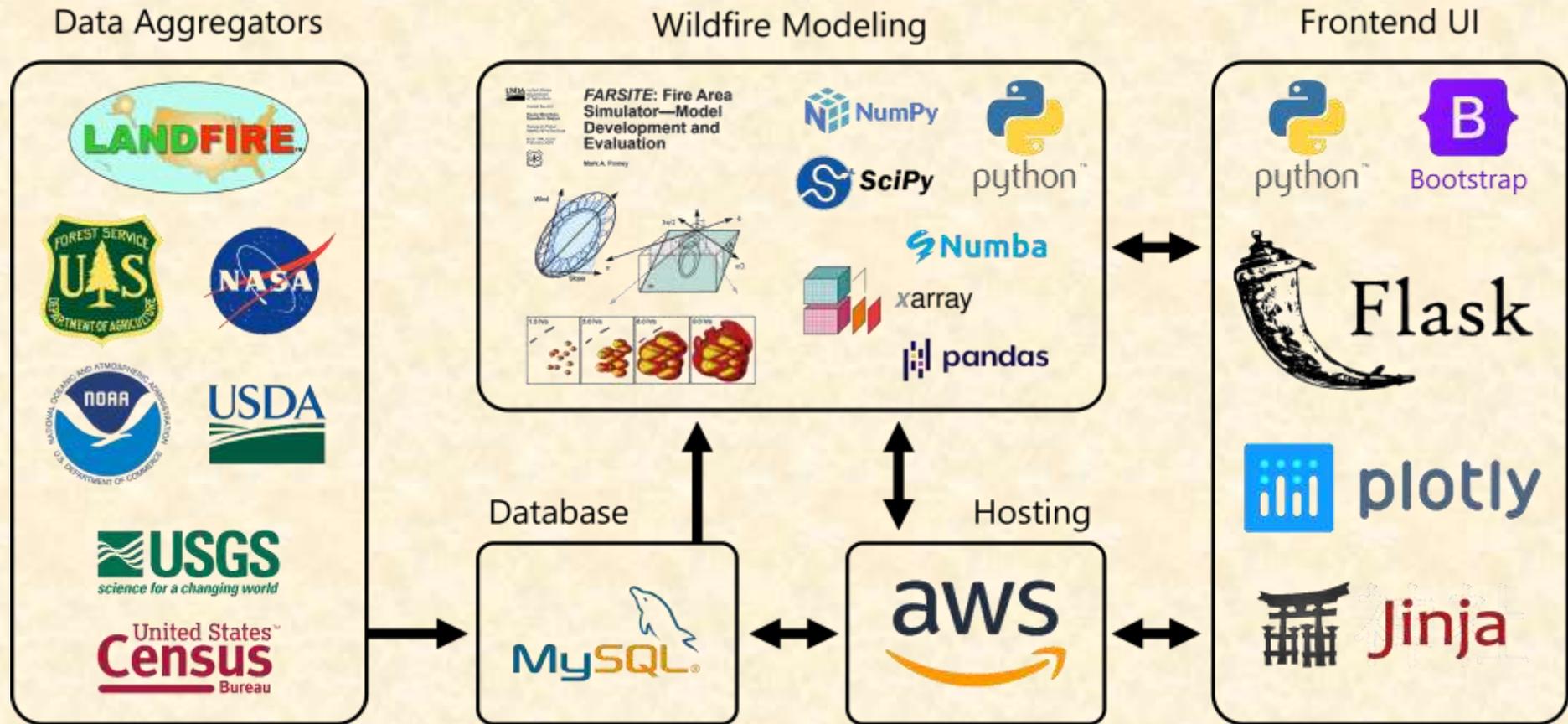
- AWS hosting for web application and scalable computing resources

4. Frontend

- Python Flask application with modern Bootstrap CSS
- Data transfer to/from backend via Xarray, Pandas, and Numpy
- Interactive map with toggleable data layers rendered by Plotly



System Architecture



System Components

- **Hardware Platforms**
 - **End-User:** Internet-connected computer, smartphone, or tablet
 - Accessible by any Bay Area resident, particularly in at-risk, marginalized communities
 - **Server:** Cloud
 - Simplifies handoff from student developers to long-term maintainer
 - Simplifies scaling with demand for computational resources
 - Stability and security
 - **Maintainer:** Internet-connected computer
 - Expect a non-wildfire-domain-expert software engineer at the Anthropocene Institute
- **Software Platforms / Technologies**
 - **Development:** GitHub, VS Code, PyCharm, Jupyter, Anaconda
 - **Wildfire Modeling & Simulation:** Python, Numpy, Scipy, Numba, Pandas
 - **Infrastructure & Hosting Solutions:** AWS / Azure / GCP with MySQL
 - **Frontend:** Python, Flask, Bootstrap, Xarray, Pandas, Numpy, Plotly
 - **Quality Assurance:** Python unittest, Postman, Google Lighthouse



Risks

1. Uncertainty of End-User

- Client has left end-user up to our discretion
 - Need to balance specificity with breadth and marketability
 - Too narrow: (high impact)(small userbase) = low impact
 - Too wide: (low impact)(large userbase) = low impact
- Mitigation: Consult with Bay Area fire agencies, governments, and residents

2. Data Sourcing & Maintenance

- Fuel and climate data tend to be updated on an impractically slow timeline
 - May cause errors in our simulation
- Mitigation: Download latest data and document data update procedures

3. Computational Complexity

- Wildfire simulation across (h, w, t) is computationally expensive
 - Simulations may require several seconds to run and render
- Mitigation: Implement parallelization and low-level acceleration using Numba

4. Storage Complexity

- Budgetary constraints limit server storage space for climate and fuel data
- Mitigation: focus on small geographic regions and downscale data resolution



Questions?

?

?

?

?

?

?

?

?

?

