

Remote Sensing: Public Information Group

BWSI 2024: Final Project

Presentation made by:

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SEVERE WEATHER ALERT

LOCAL

4



Reports from experts say that a hurricane is
headed our way!!!

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We have been tasked with the job of protecting the civilians



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Preparation for Hurricane Sam & Atef (Samtef)



Sam and Atef have both had it with us.

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The BWSI Remote Sensing and Disaster Response 2024 Community agrees to the following...

We are guided by the **seven principles** of:

- Timeliness and Efficiency
- Empathy
- Equity
- Safety
- Neutrality
- Primum non nocere (first, do no harm)
- Transparency

Ultimately, our purpose is to protect life and health; to ensure respect for the human being.

AGENDA

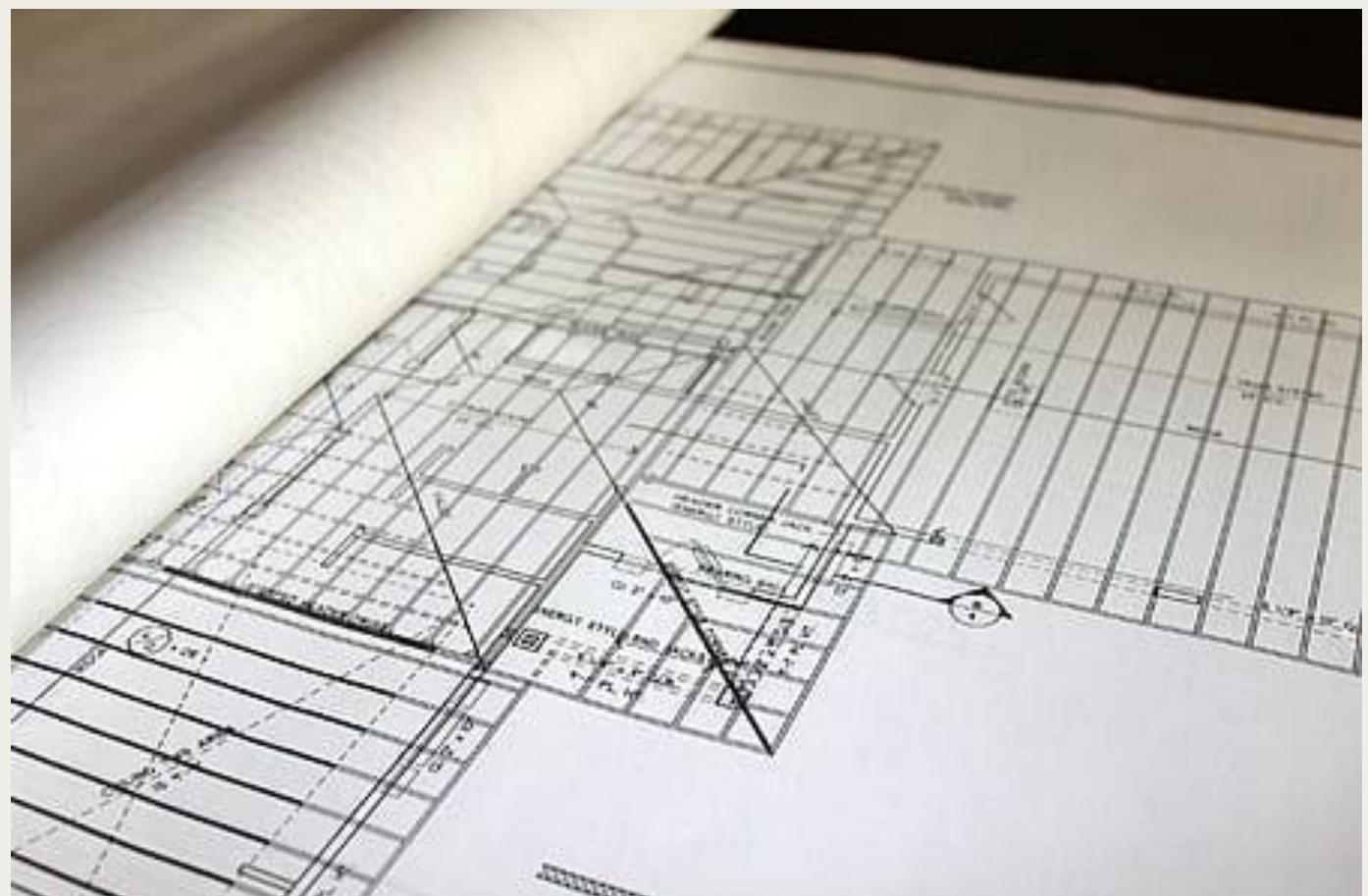
- Introduction
- Planning Team
- Logistics Team
- Operations Team
- Questions



How do we respond to a disaster?

After knowing that a disaster (natural or manmade) is coming our way, there are various steps taken to ensure safety. For a hurricane, we need to:

- Create a predicted path for the hurricane
- Create maps to predict tropical storm and flood damages
- Determine the affected areas





How do we respond to a disaster?

At the same time, our logistics team are creating their plan of action. Which includes:

- Moving resources to where they're needed
- Creating efficient routes for travel

However, there are many challenges to this.

- Limited amount of vehicles that can be used
- A limited amount of resources each vehicle can carry
- A time limit

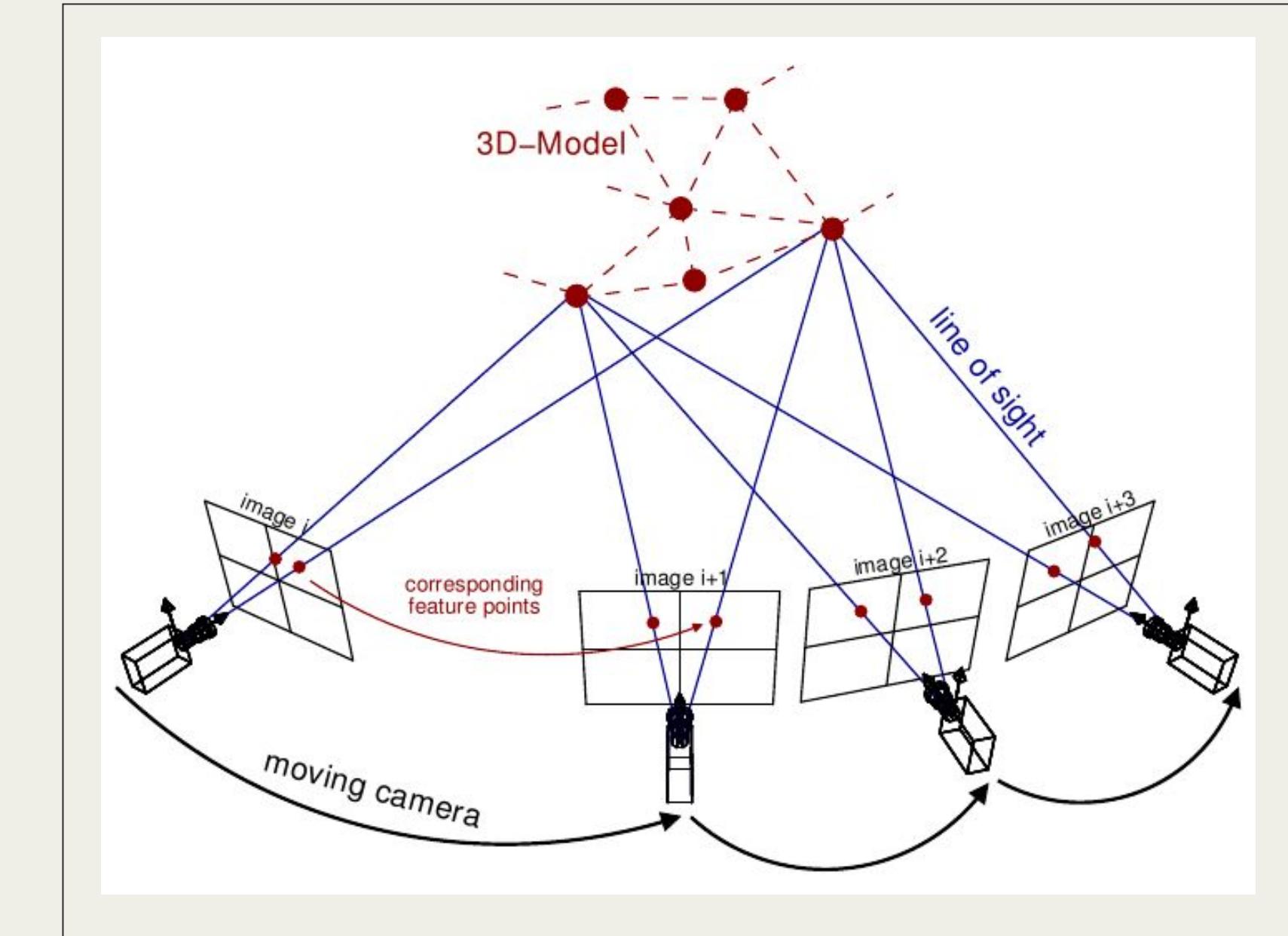




How do we respond to a disaster?

In order to deal with the aftermath, the operations team is tasked with:

- Assessing the damage of the surrounding area by analyzing infrastructure (roads, buildings, etc.)
- Creating a 3D representation of the scene for further analysis.
- Using this data, send out search and rescue teams



*How SfM 3D Models are created from multiple images

How do we respond to a disaster?

At the same time, the public information team will serve to provide the people with developments from the other teams. This includes:

- evacuation plans
- affected regions
- hurricane path
- where the supplies are sent
- potential power outages
- what to do to stay safe



MEET THE TEAMS



Planning Team

- Forecasting and prediction of the path of the hurricane.
- Creating a map of the tropical storm winds & cone of uncertainty.
- Creating a flood depth map for damage assessment.
- Creating evacuation plans and designating zones for evacuees.



Logistics Team

- Pre-allocate supplies to distribution centers
- Work on a transport network to efficiently supply resources to hospitals and shelters
- Visualizing truck routes



Operations Team

- Completing computer vision tasks using Structure from Motion (SfM: creates 3D representations of hurricane scenes)
- Use deep learning to classify damage and/or infrastructure with segmentation masks



Public Information Team

- Maintain communication between all 3 other teams.
- Act as liaisons between the public and the entire group.
- Inform the press, public, and instructors on daily updates.

Planning Team Members

Raahat Amin



Avika Teotia



Sivani Ryali



Alina Zhu



Sophia Tang



Nikhil Lalwani



Haley Clark



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Logistics Team Members

Vinay Karthik



Eric Shaobo Wang



Krish Arora



Rudransh Singh



Rajat Rawat



Aneesh Chatrathi



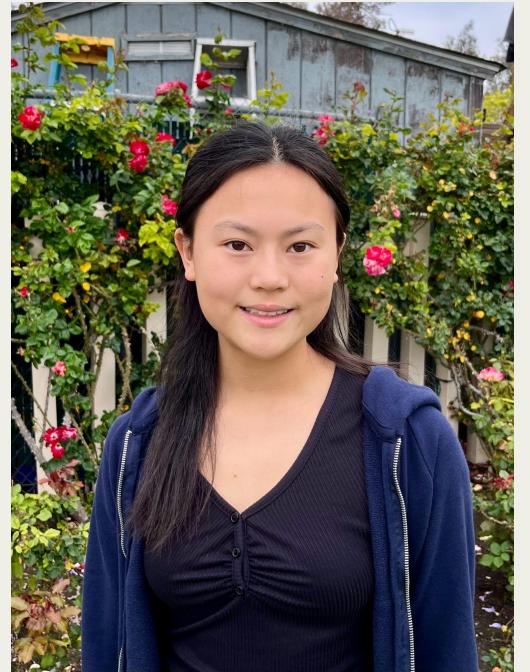
Aanya Singh

MIT
BWSI



Operations Team Members

Serena Liu



Jimmy Zhong



Saahiti Bondalapati



Ashrita Pinnamaneni



Amy Li



Tishya Banka



Benjamin Gao



MIT
BWSI



Public Information Team Members

Arjun Nair



Liaison to Operations Team

Jonathan Barnett



Liaison to Logistics
Team

Yul Kim



Liaison to Planning Team

Caitlyn Chen



Chief Information Officer

Planning Team

Preparations

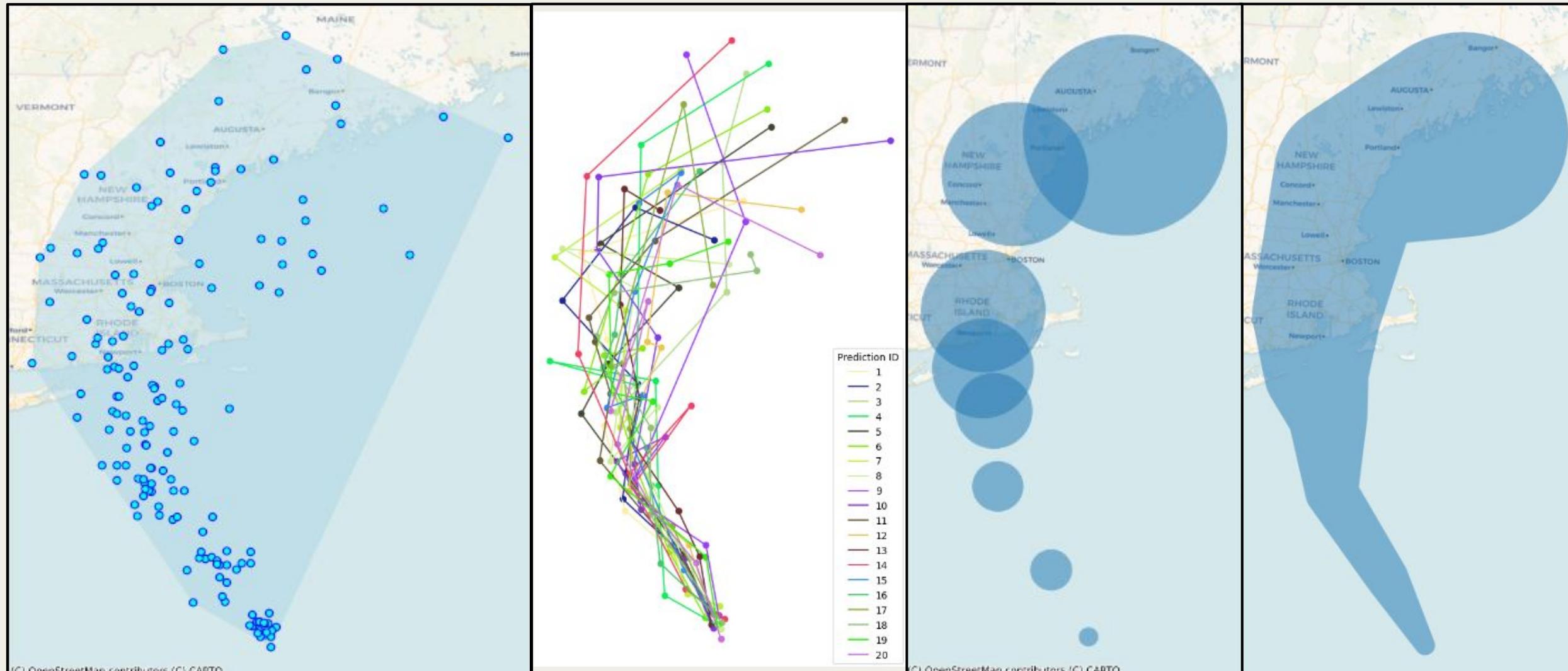
Day 1 Inputs

Day1_forecasts_024
It provides potential
wind forces at a
specific point and time.

day1_track_past.geojson
The track of the
hurricane.

Planning Team

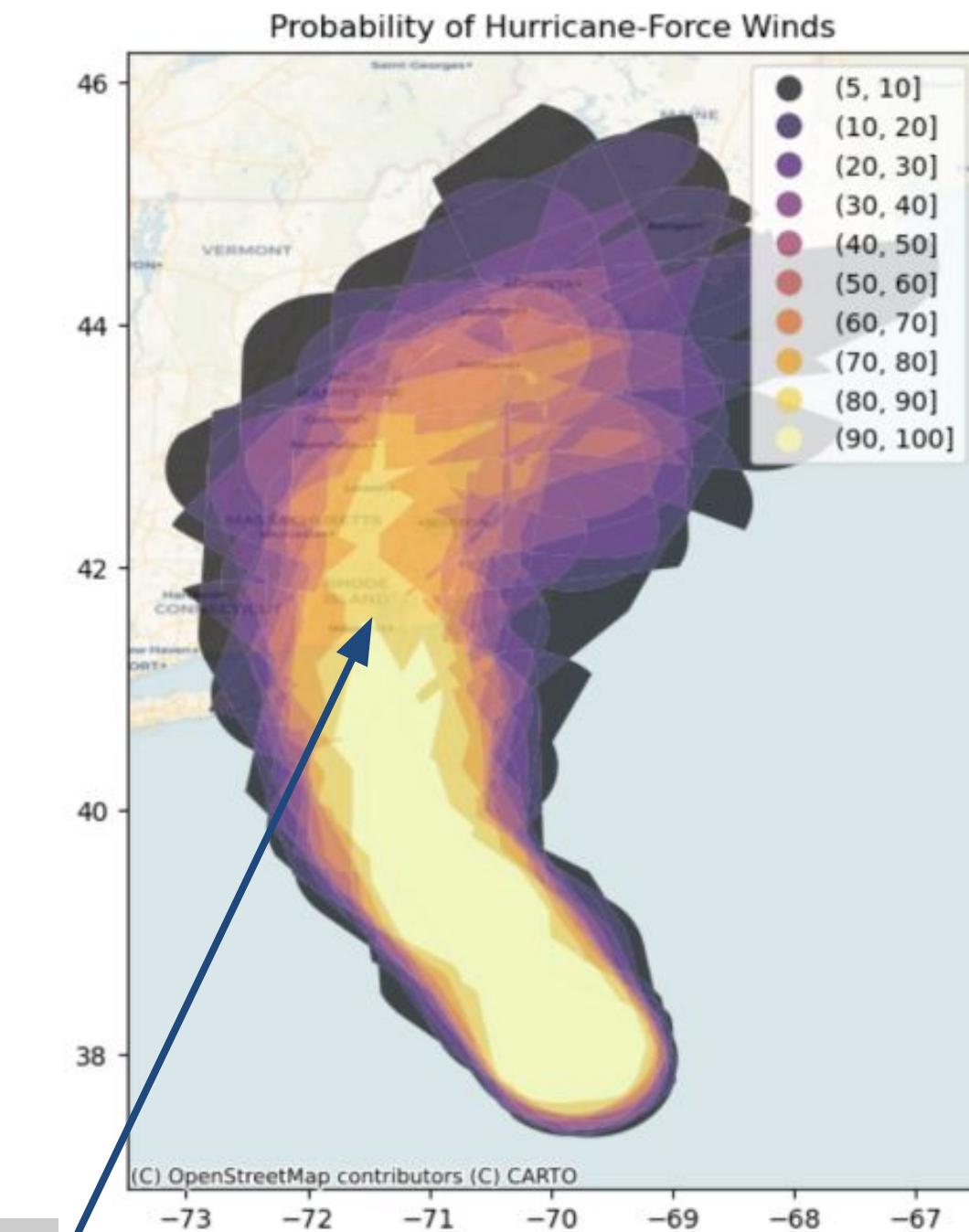
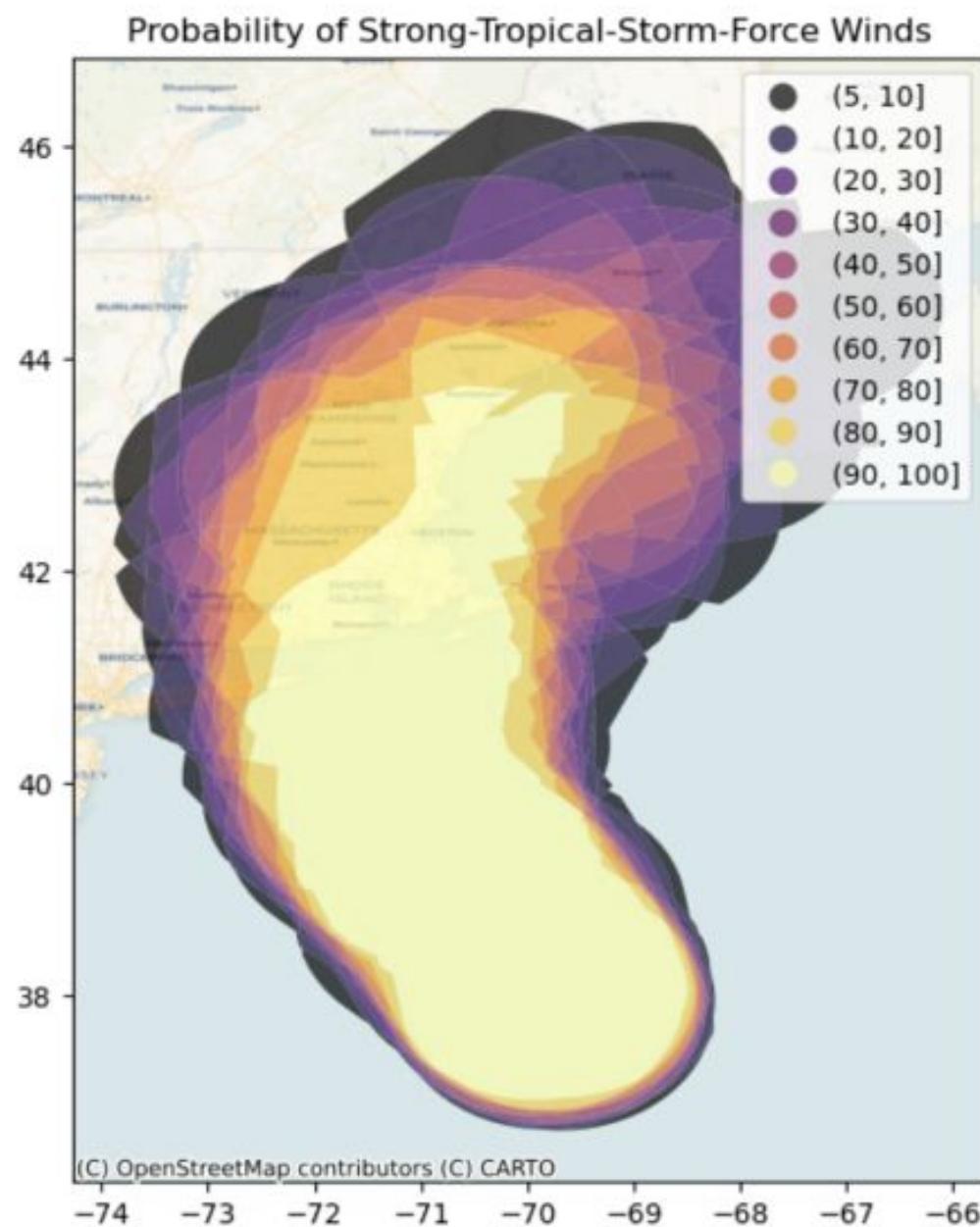
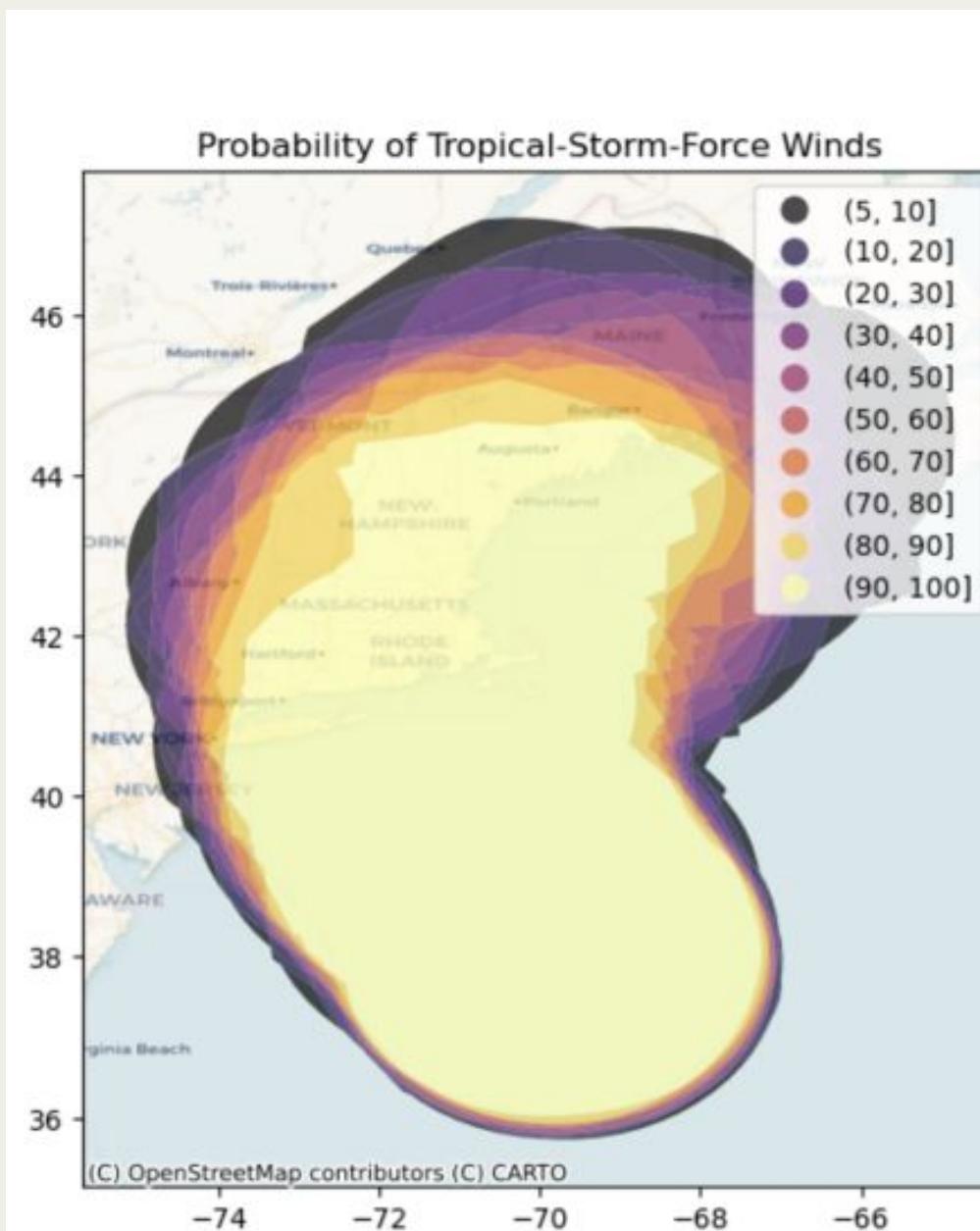
Cone of Uncertainty (CoU)



- What is it?
- How will it be used?
- Why is it important?
- What should you do?



Planning Team (Cont.)



Hurricane Force Wind Warning !!

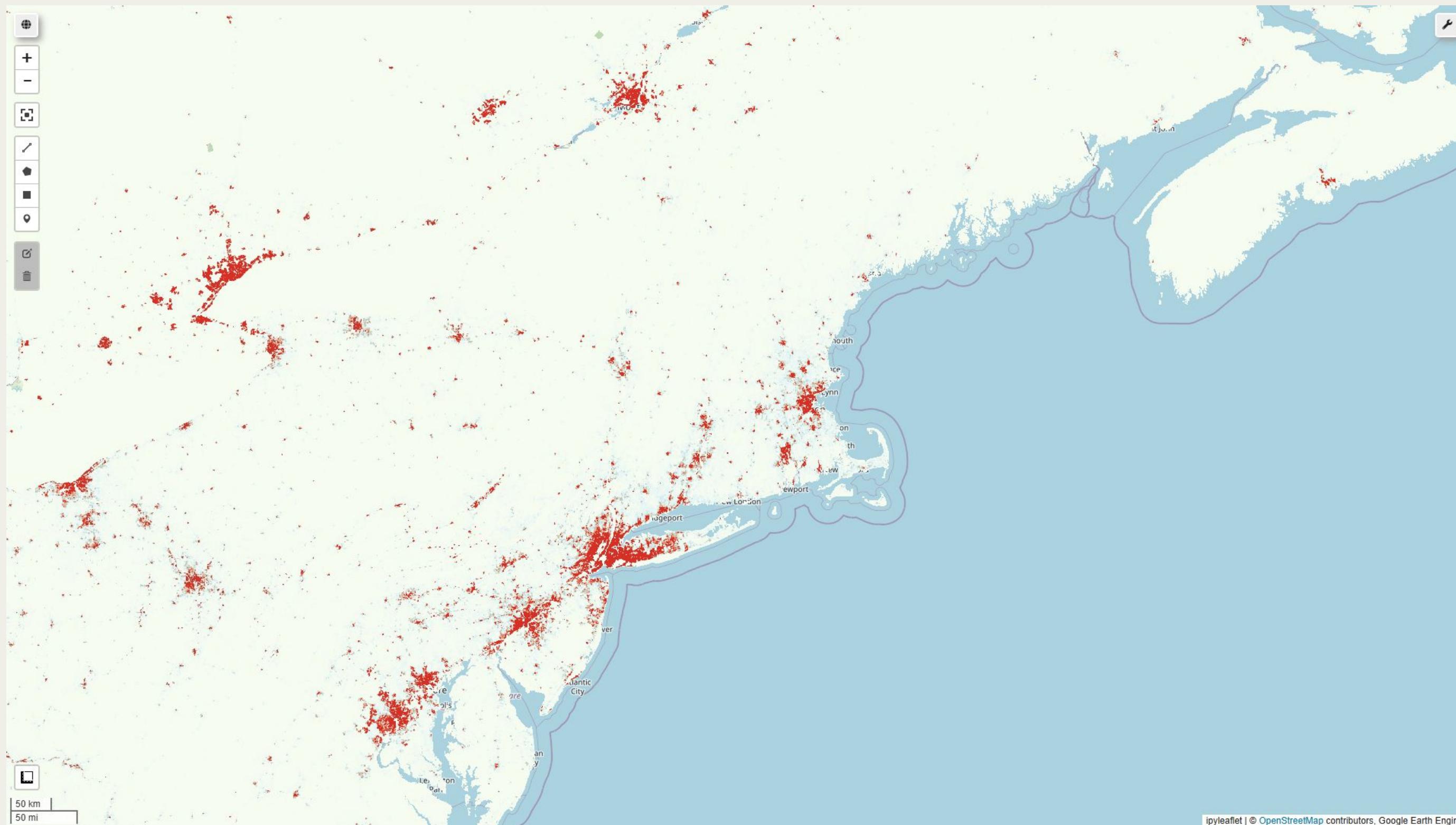
High Risk Area with Wind Speeds of 74+ mph
Evacuate the area immediately

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Planning Team (Cont.)

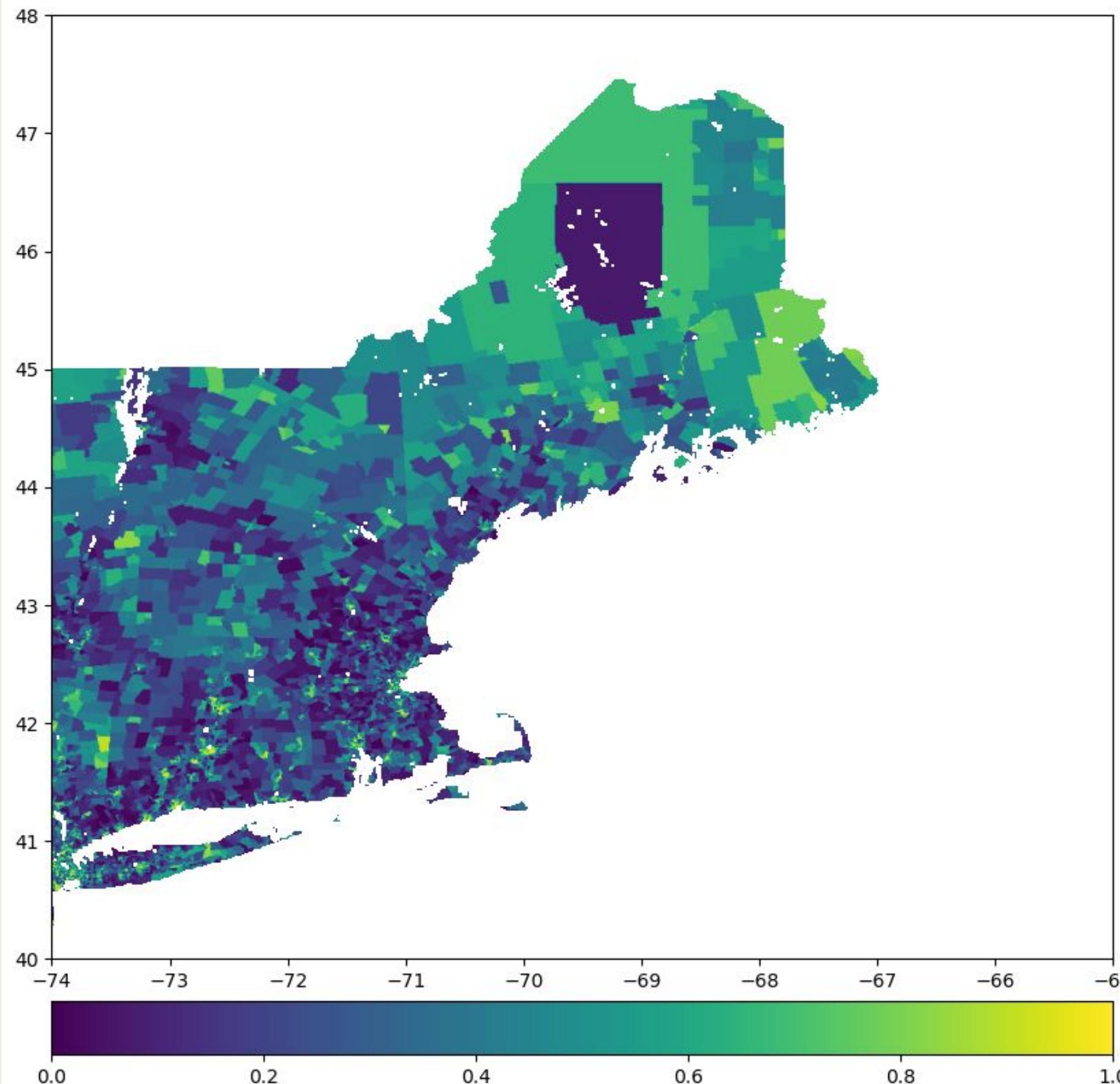
Map of Population Density



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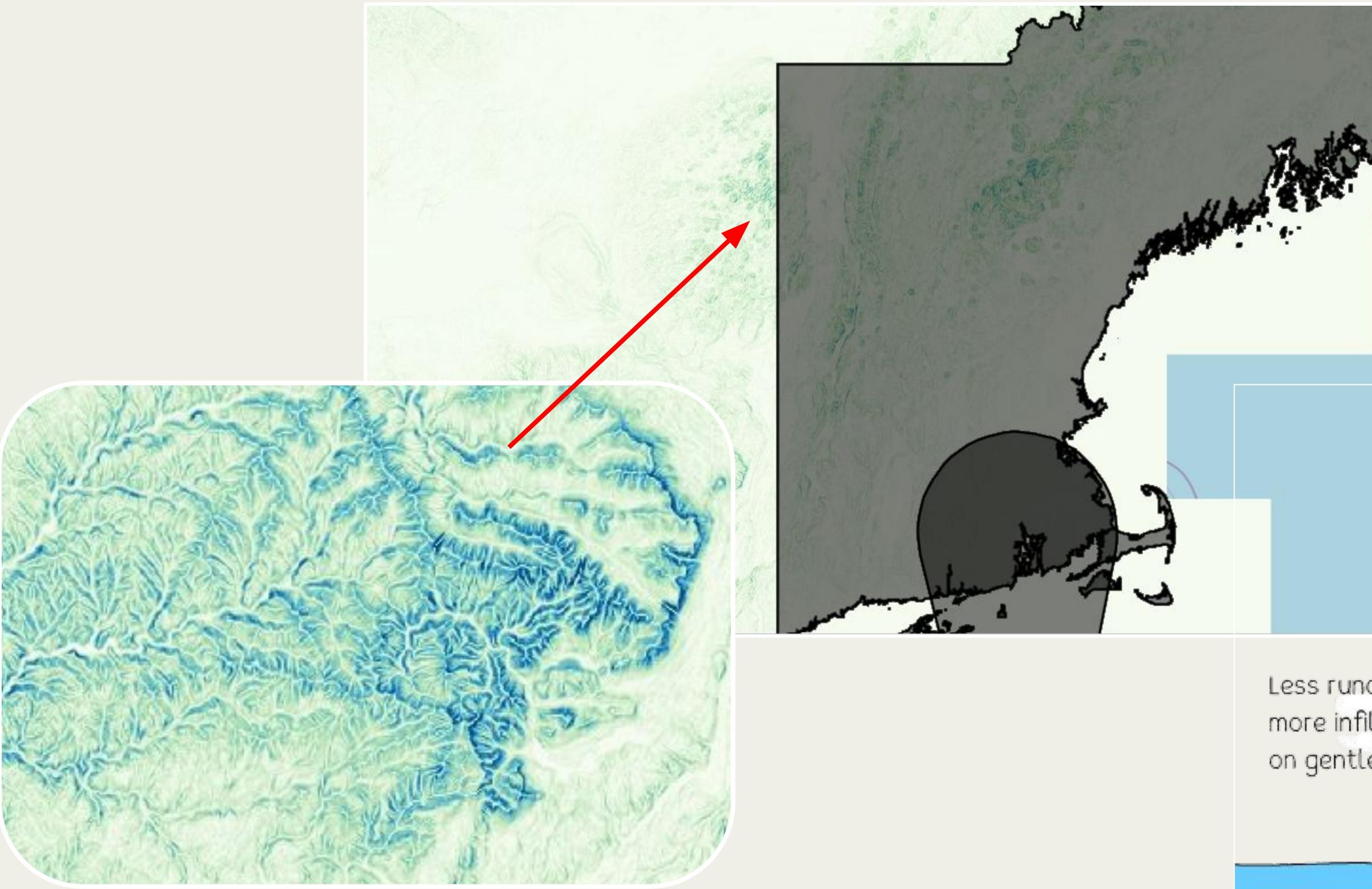
Planning Team (Cont.)



Social Vulnerability Index (SVI)

- Values closer to 0 indicate more vulnerability (dark)
- Values closer to 1 indicate less vulnerability (light yellow)
- Threshold = 0.5

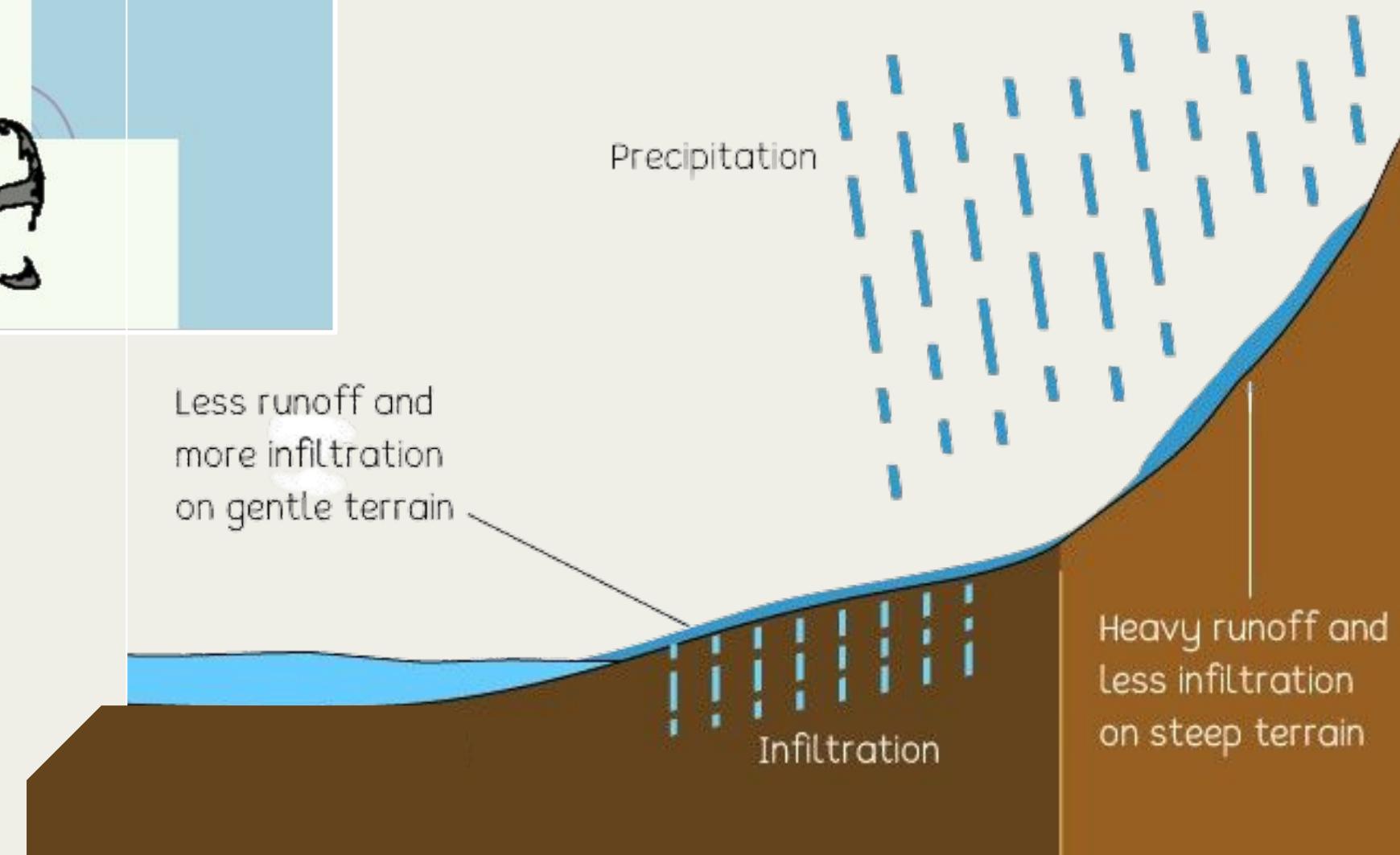
Planning Team (Cont.)



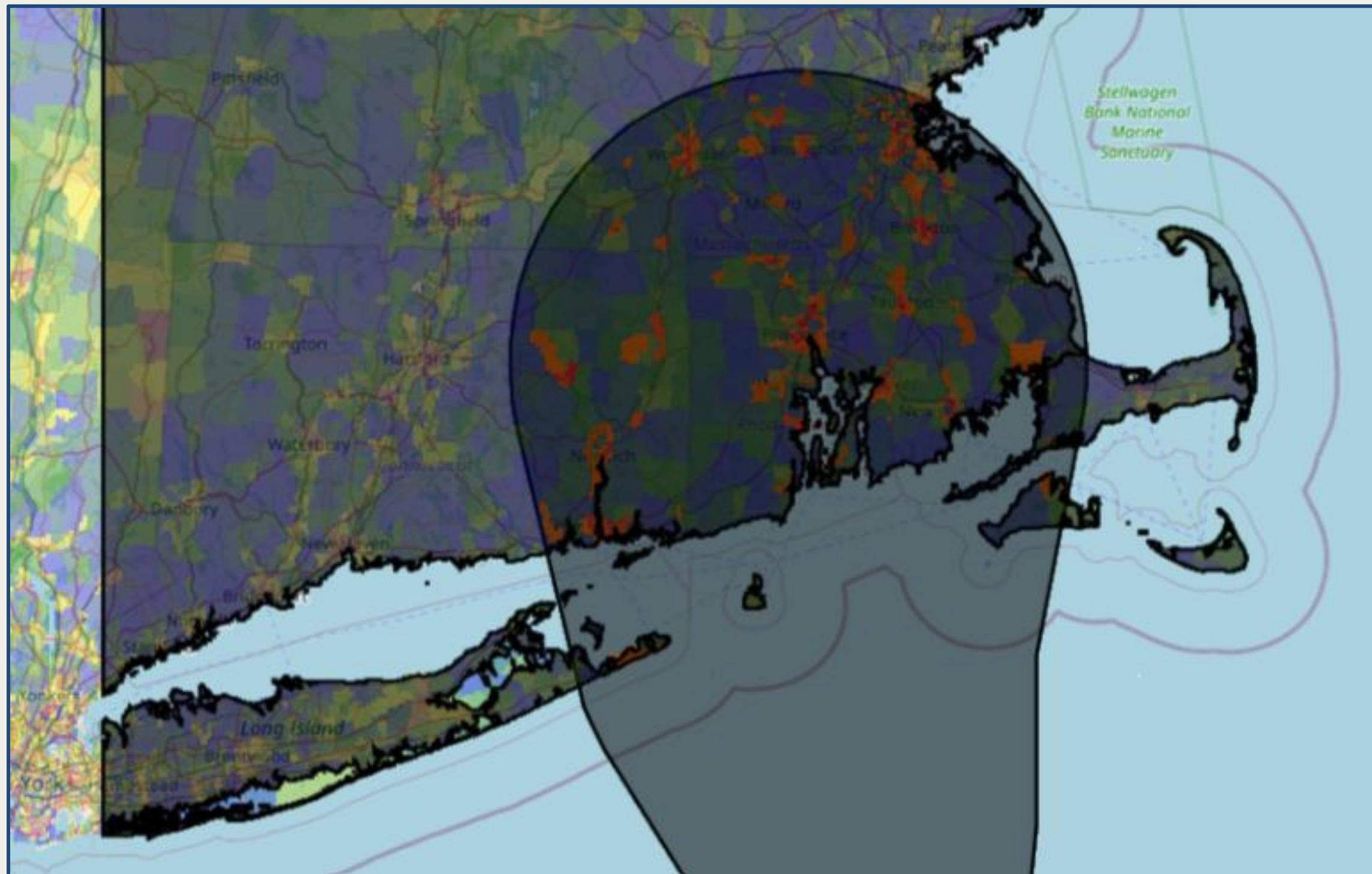
Slope Map

Slope Threshold: $> 5\%$

Darker blue areas show higher slopes



Planning Team (Cont.)



Final Map

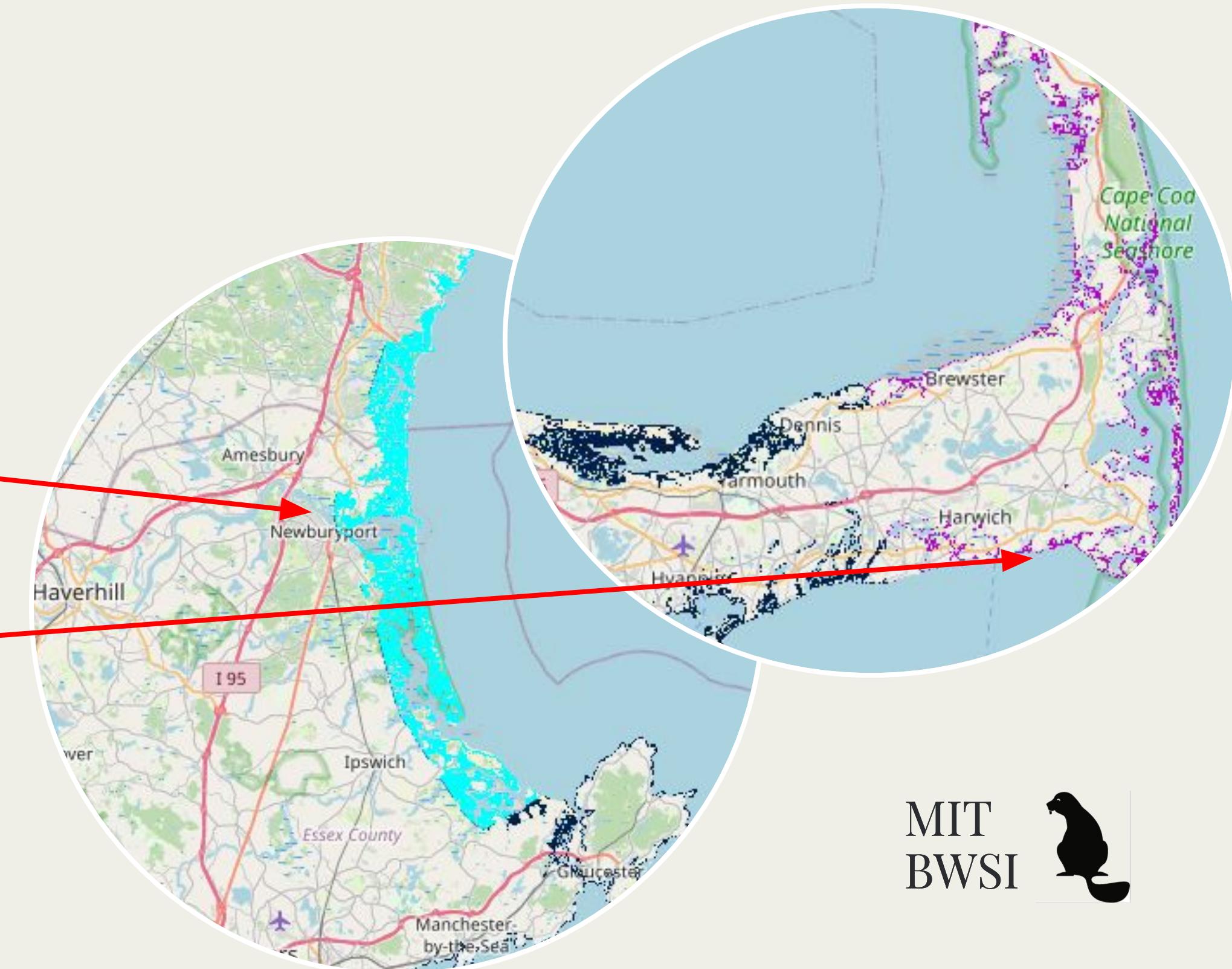
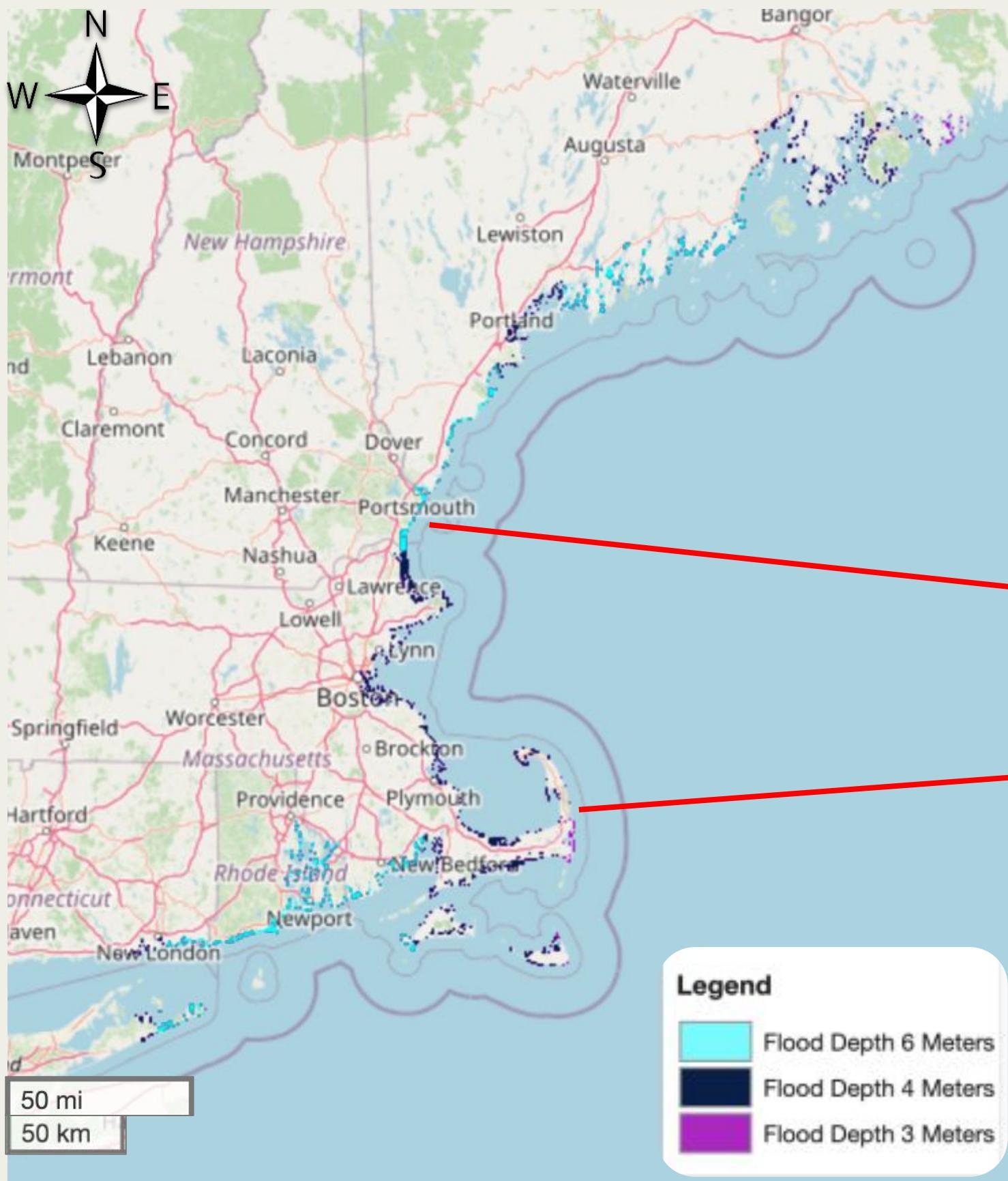
Population exposed: **5,353,787**

Estimated population inside the cone with slopes less than 5% and SVI below 0.5:
1,638,907



Planning Team (Cont.)

Flood Depth Map

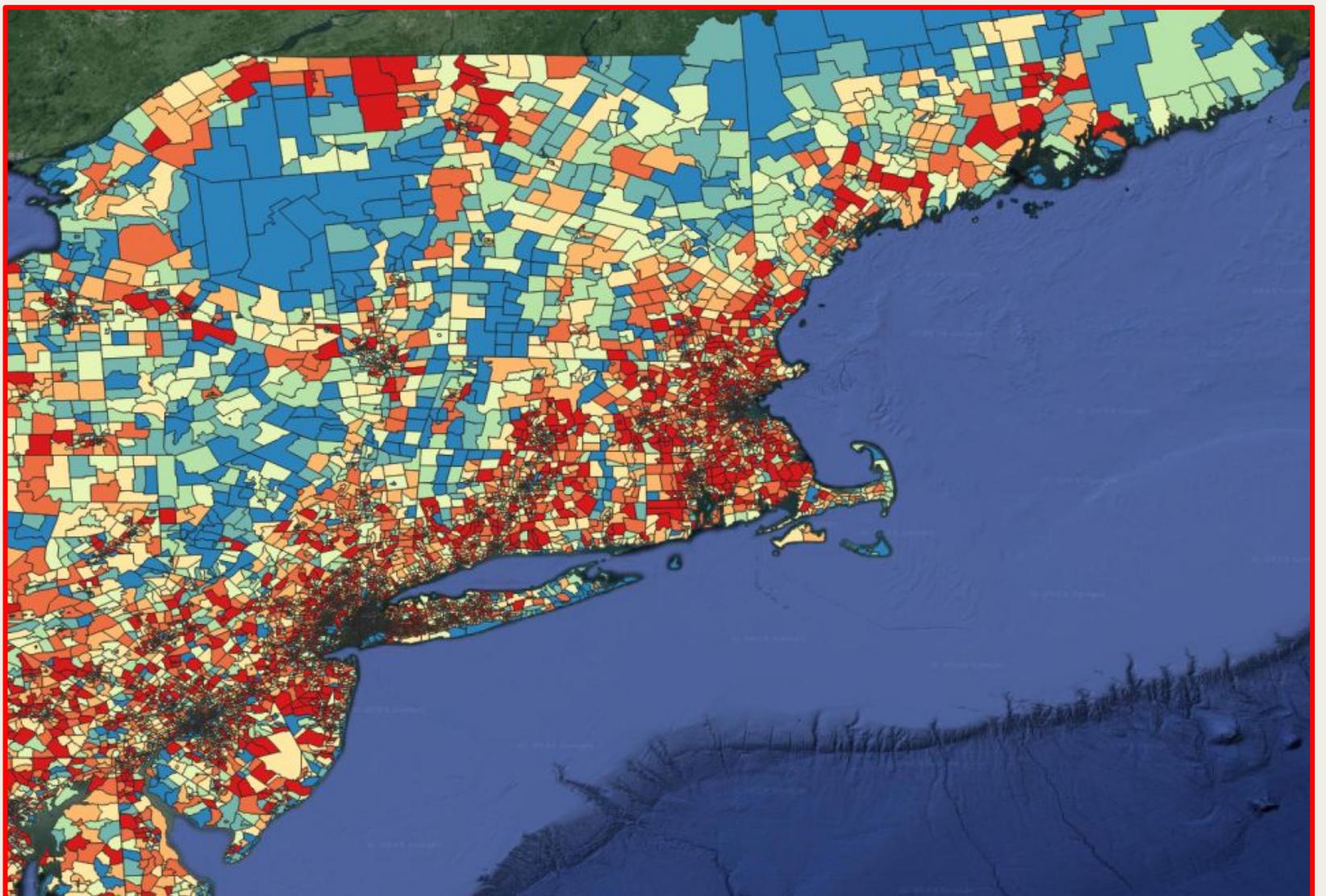


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Challenges

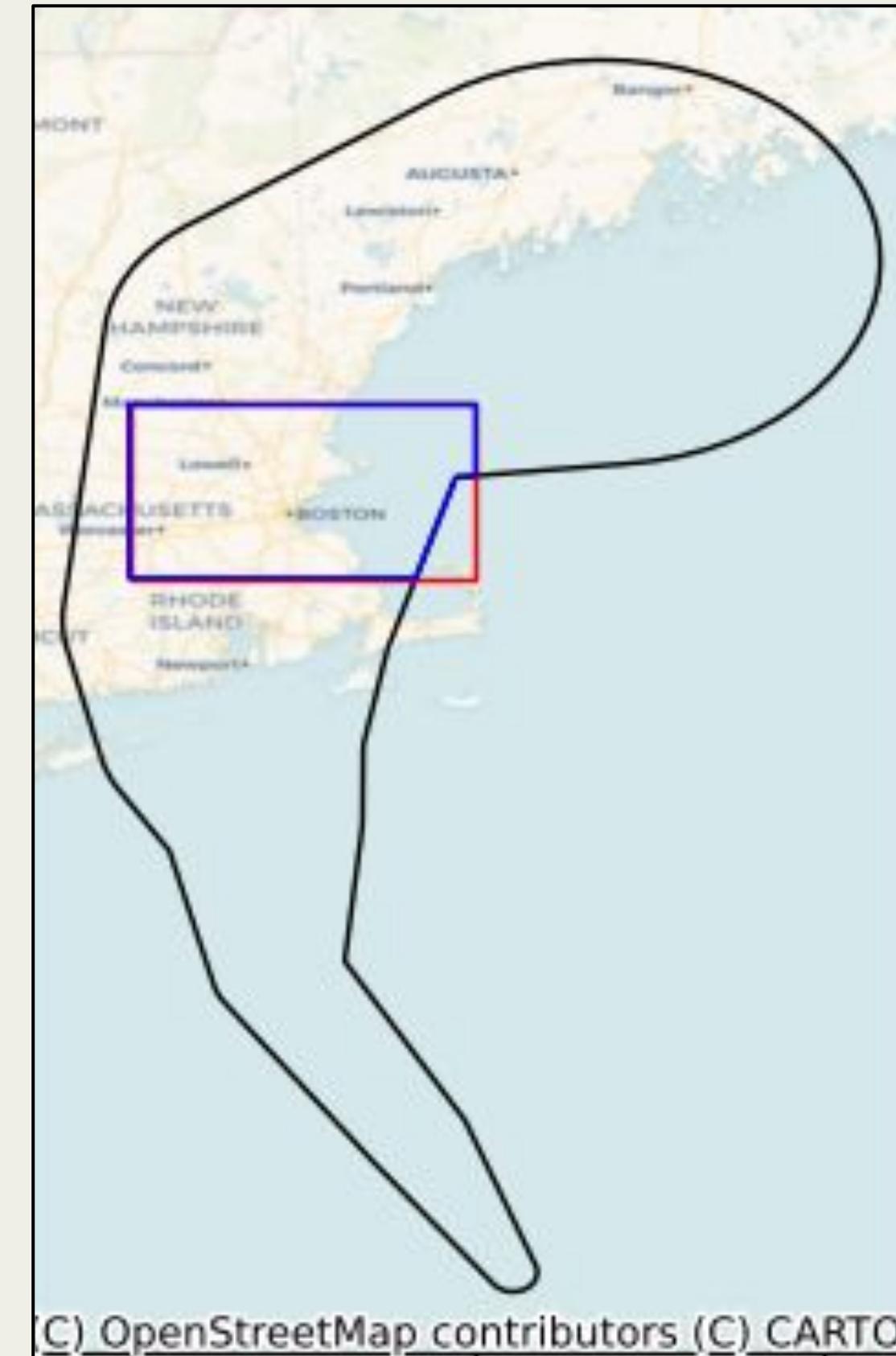
- Other teams need the cone of uncertainty to complete their work
- There was trouble getting the map to work
- There were a lot to do, with too little time
- Creation of Flood Depth Map:
 - Trouble projecting hurricane cone onto DEM raster tiles





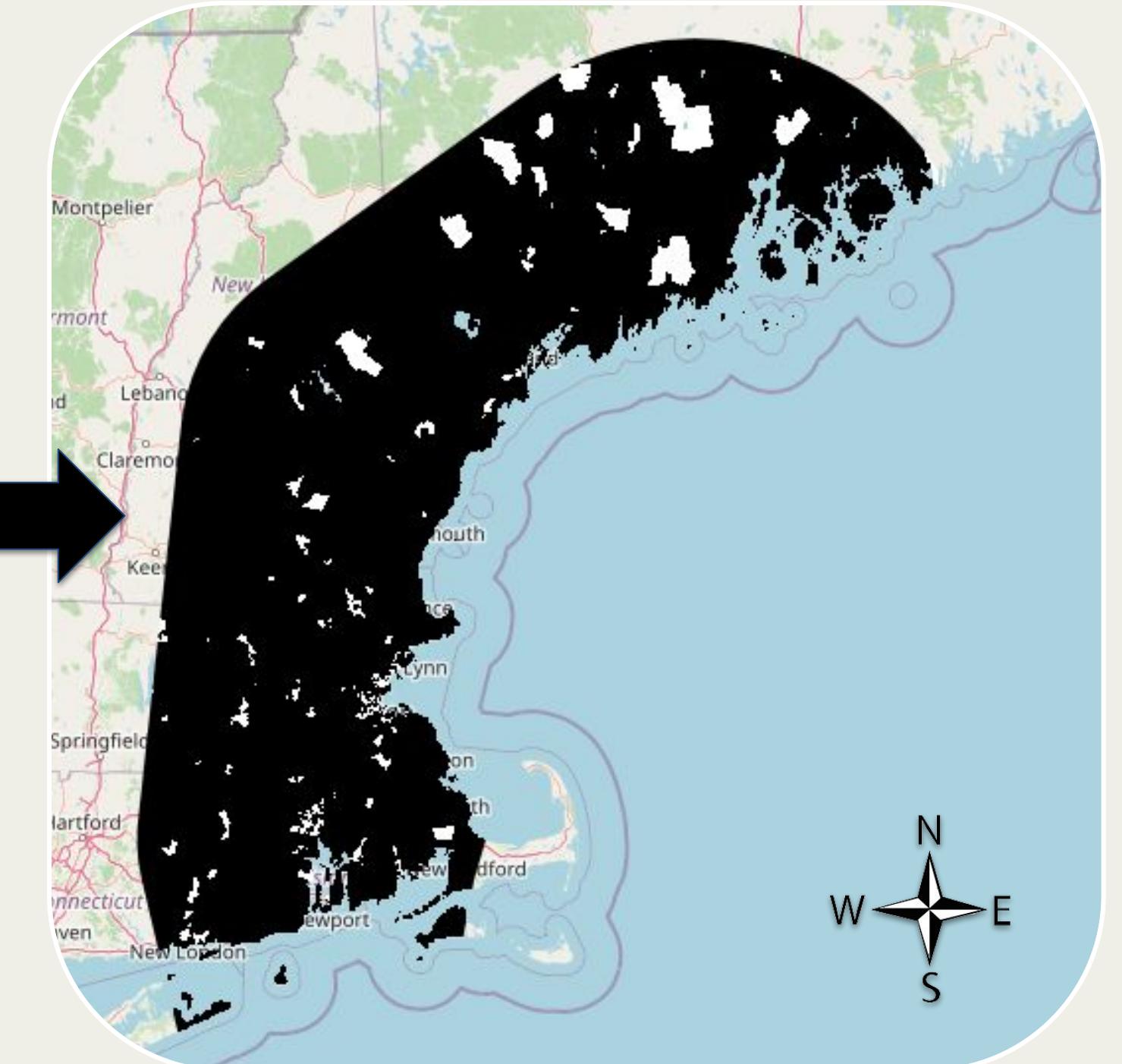
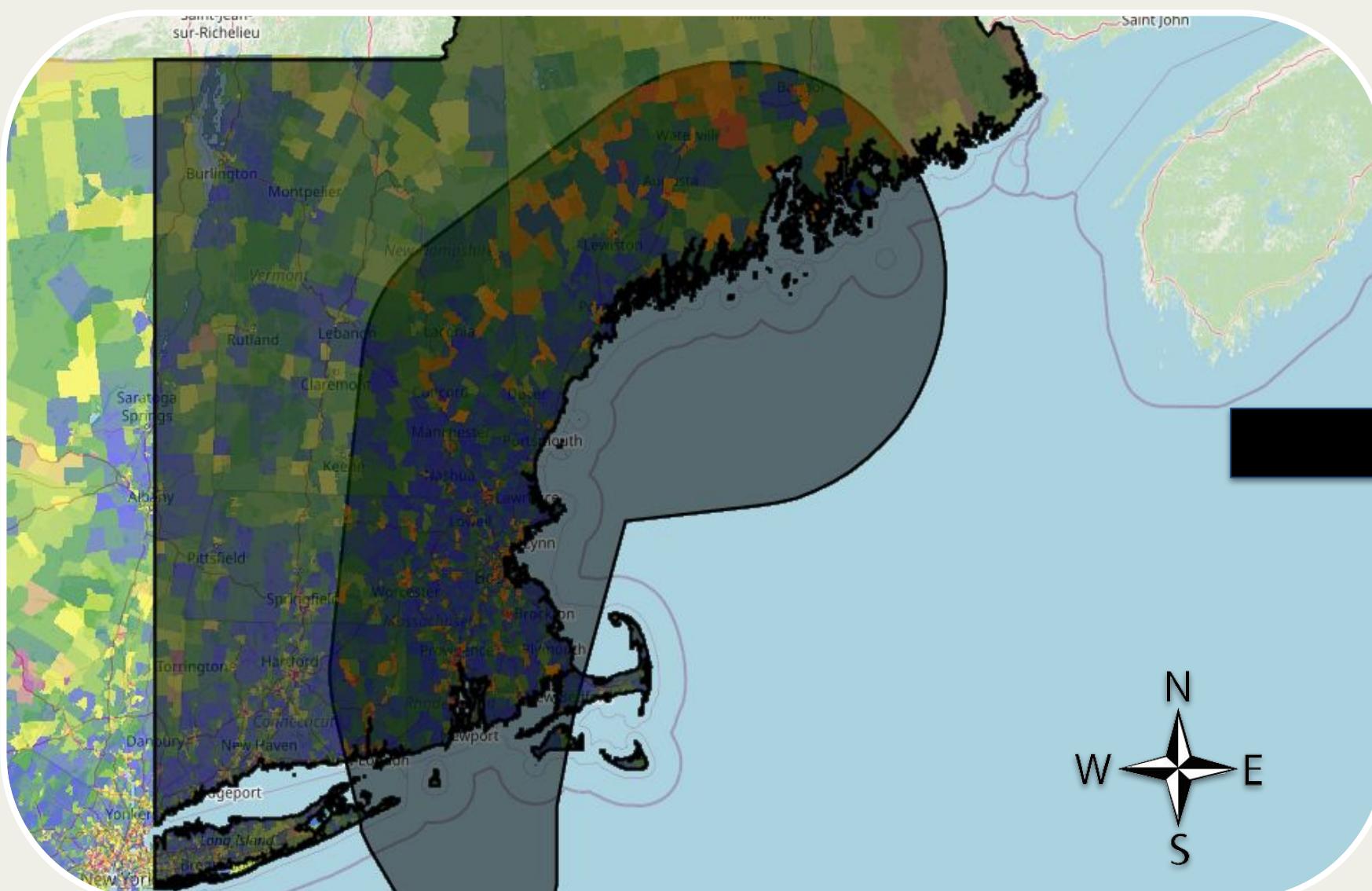
Planning Team

- The first attempt at creating evac. zones
- It encompasses Boston, and the greater area around the city.
- The northern areas of Rhode Island are also being evacuated.
- Approximately 1.6 million people are in the evac. zone.
- However, it needed to be changed





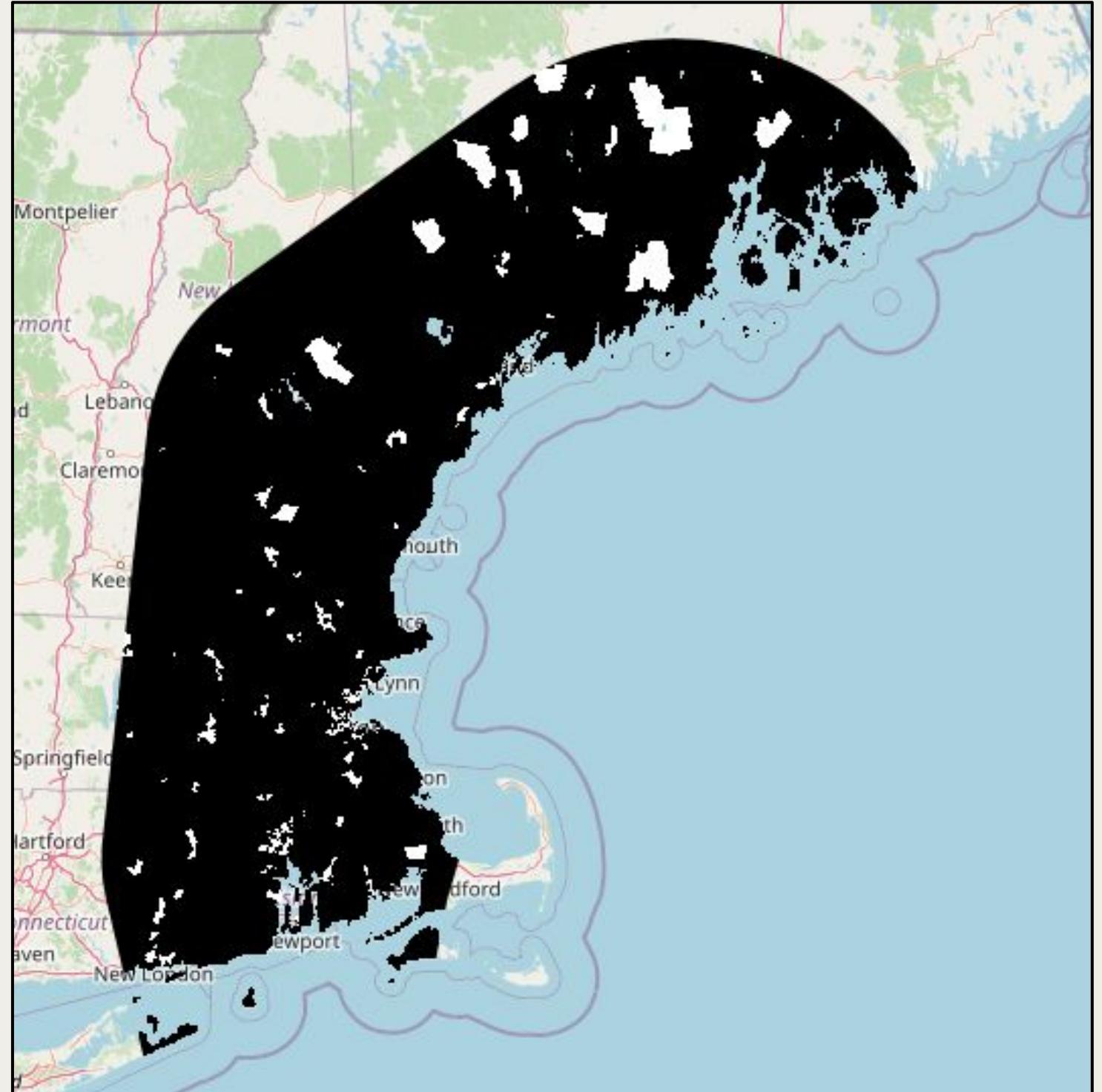
Planning Team



New Plan

Evacuation plans

- Based on current data, we believe that the people should head west or south
- Avoid going North
- **White = Need evacuation ASAP**
- Black = Impacted but not evacuated
- 1.566 million people



Day 2 Inputs

•

Day2_forecasts_024
It provides potential
wind forces at a
specific point and time.

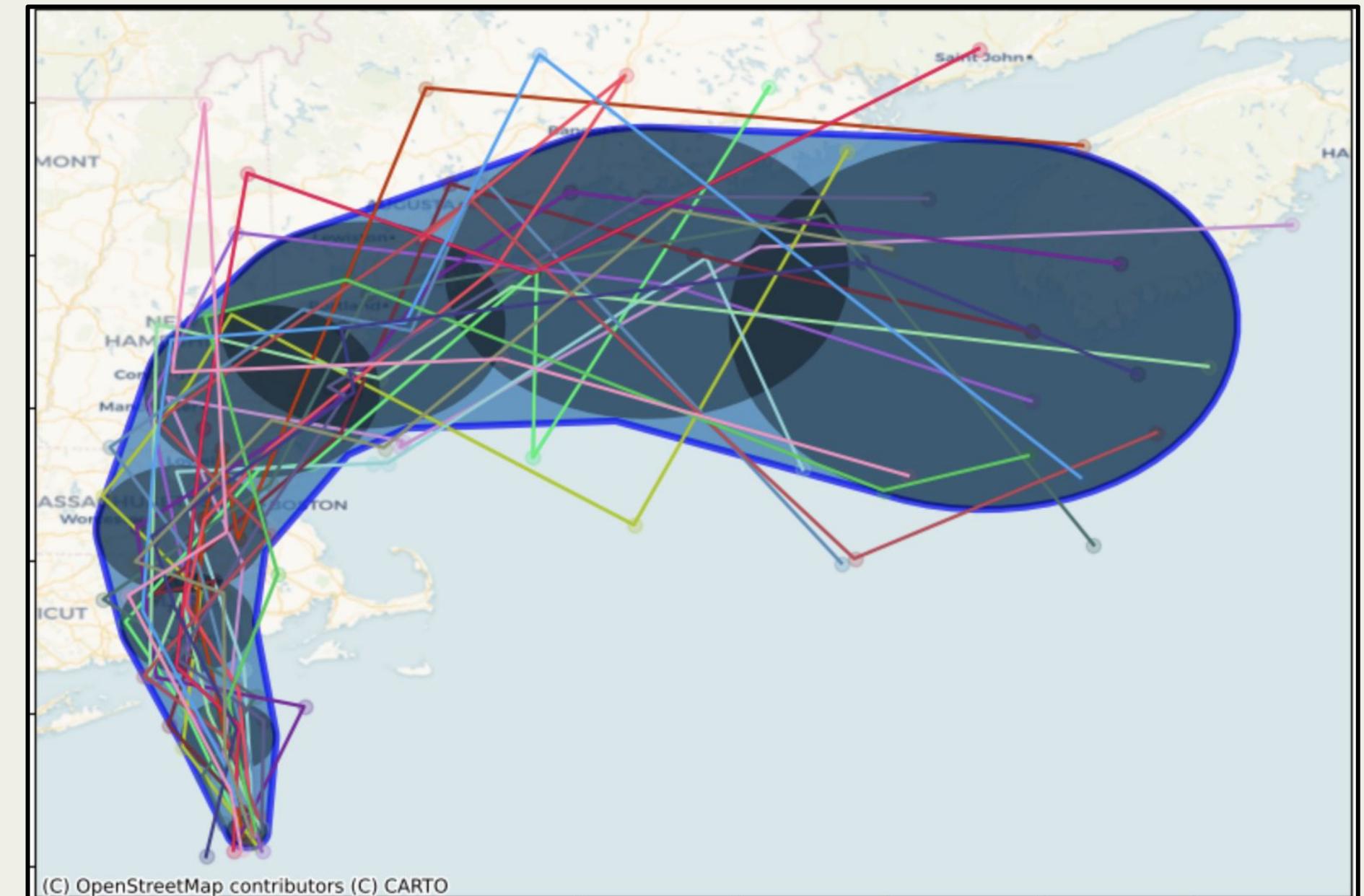
•

day2_track_past.geojson
The track of the
hurricane.



Planning Team

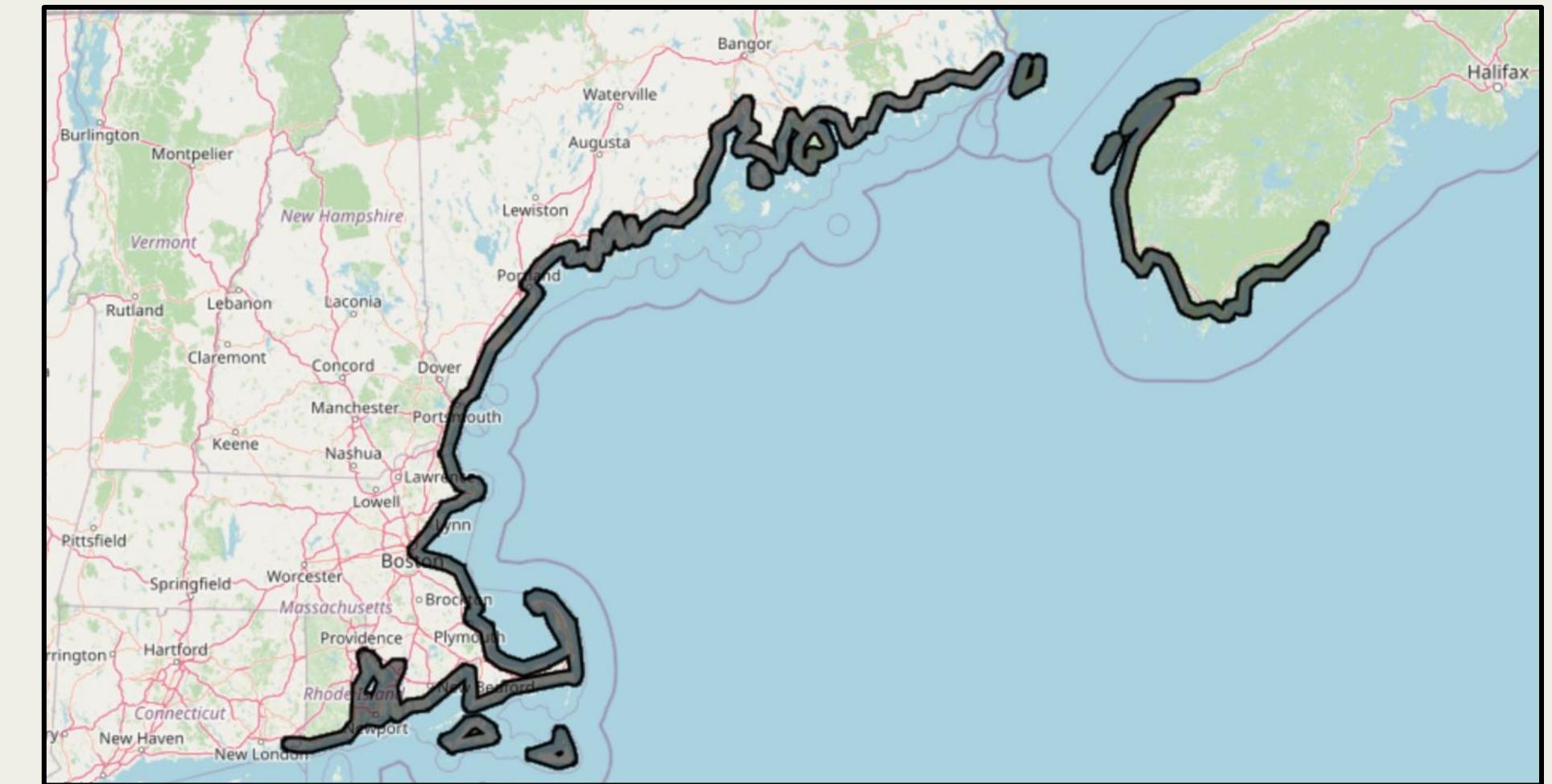
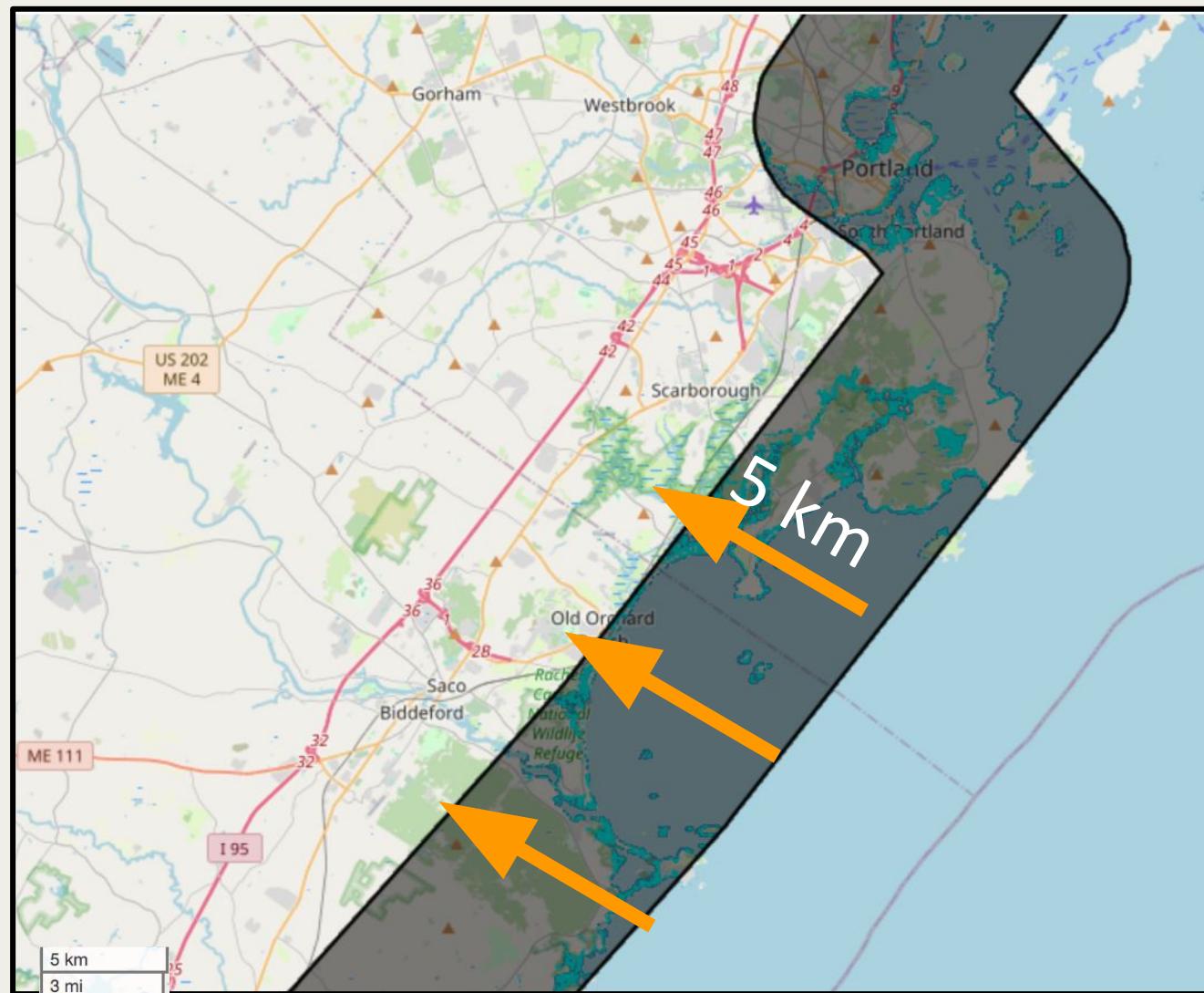
- The figure is the cone of uncertainty for day 2
- Major changes:
 - Augusta, Maine is an affected region
 - Nova Scotia will experience the aftereffects





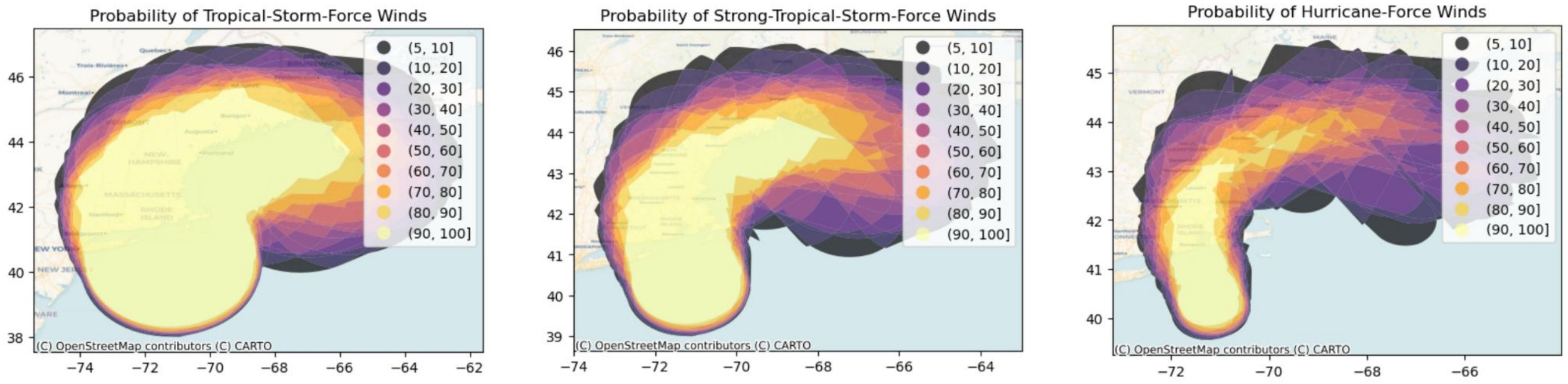
Planning Team

Coastline Map and a 5 km Buffer Zone



- **It's significance:**
 - It can be used to create an evacuation plan

Planning Team

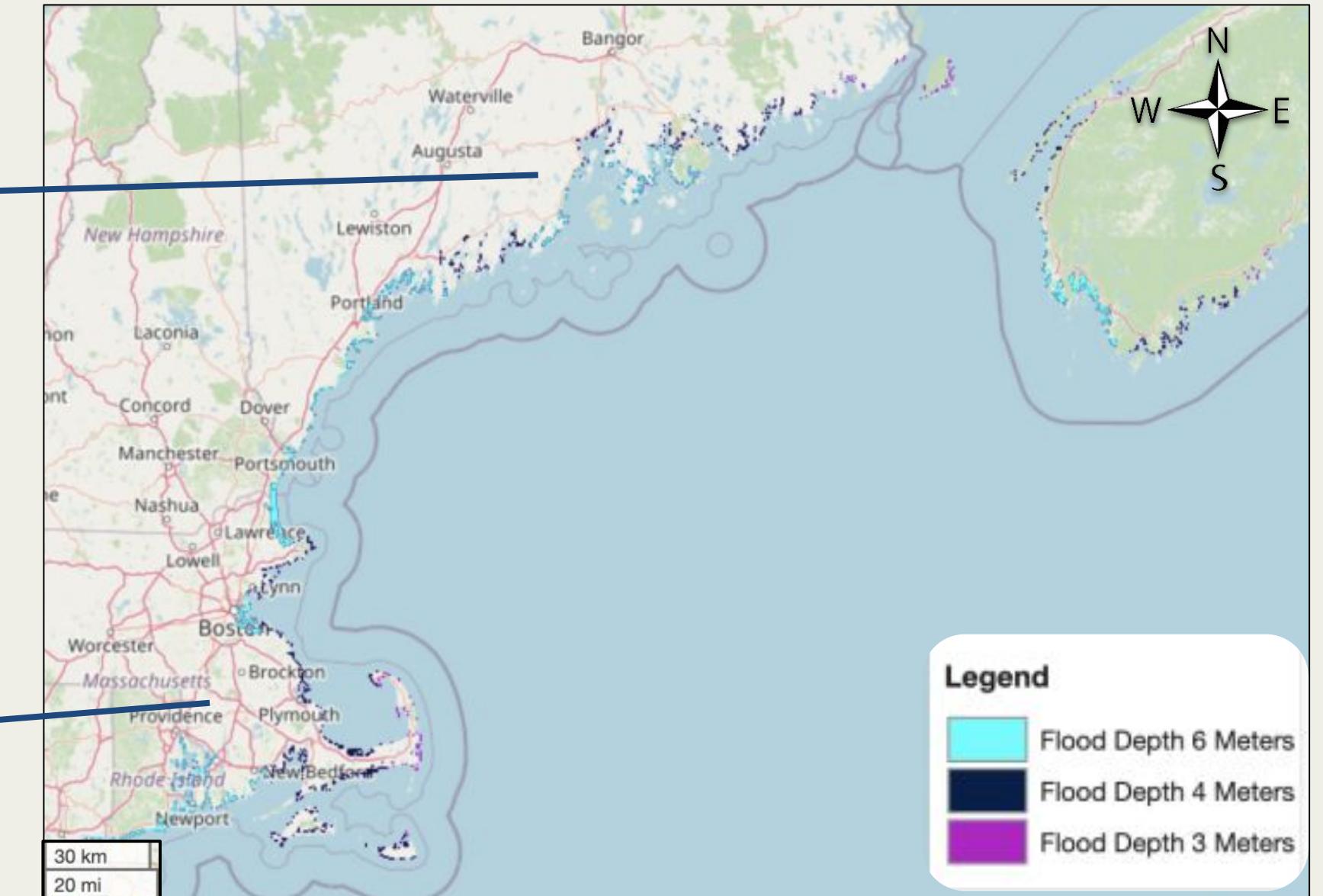
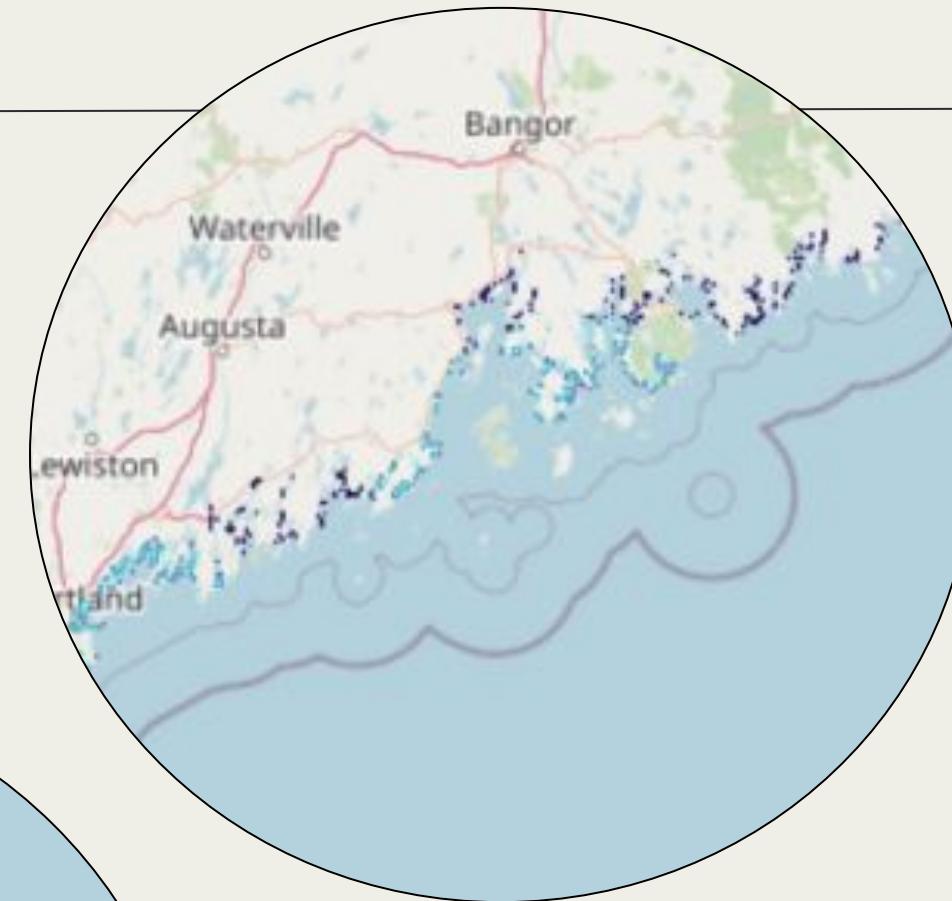


Parts of **Rhode Island** and **New Hampshire** will experience the most winds due to the hurricane shifting course.

Hurricane-Force winds are starting to increase which will cause **hazardous conditions** and cause damage in the area.



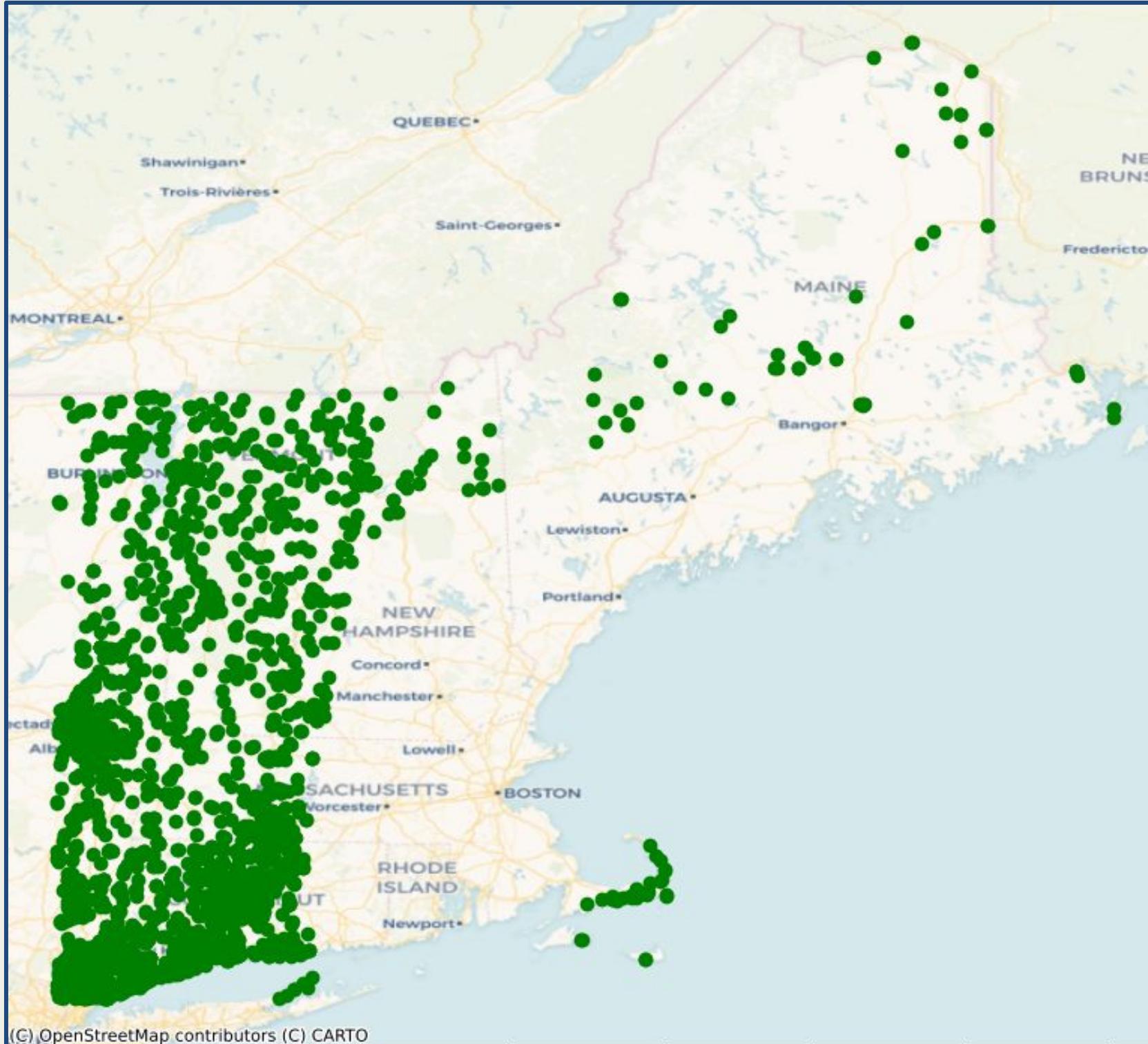
Planning Team



Flood Depth Map



Planning Team



Safe shelters

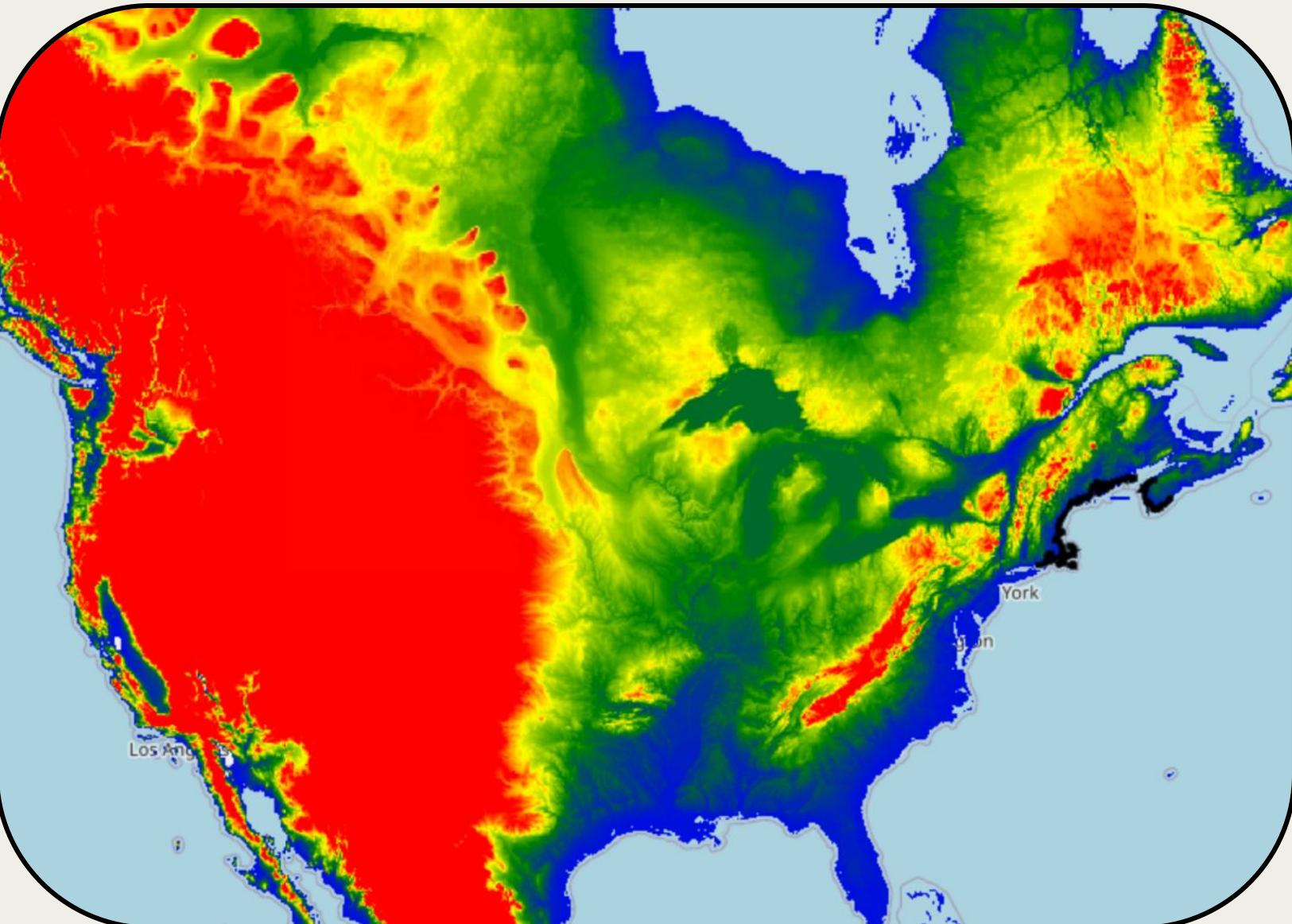
- Each safe shelter outside the Cone of Uncertainty represented by a green dot
- Helps show which shelters can be used for evacuation



Challenges:

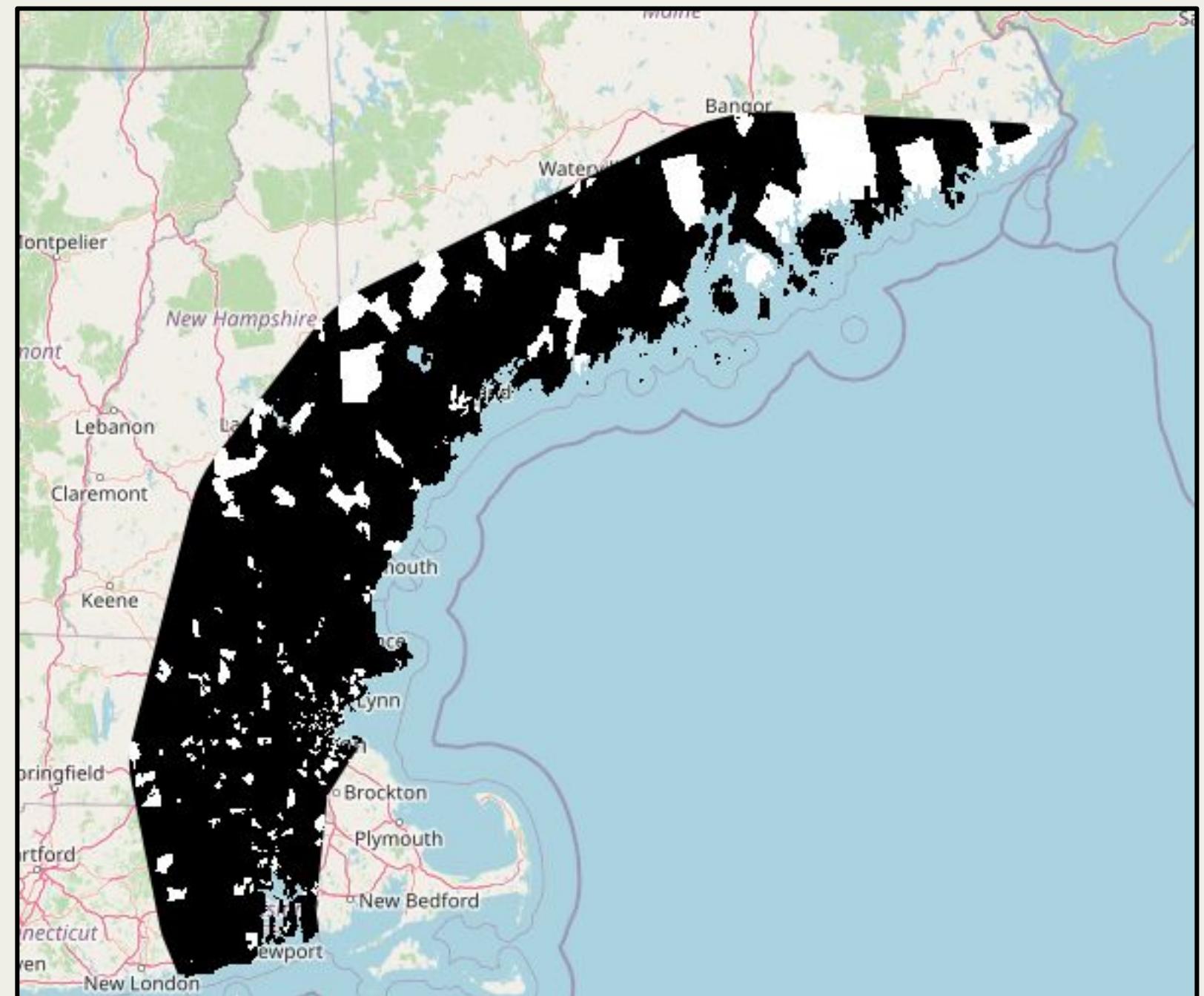
- Flood Predictions/Depth Map:
 - Obtaining Data For Elevation Ranges
 - Obtaining Data for SVI (Social Vulnerability)
 - Storm Surge Data:
 - Troubling clipping coastline to only get area within hurricane cone
 - Trouble buffering coastline
- Getting Estimation of People We Can Evacuate:

DEM (Digital Elevation Model)



Evacuation plans

- Based on current data, we believe that the people should head west or south
- Once again, avoid going North
- **White = Need evacuation ASAP**
- Black = Impacted but not evacuated
- 1.71 million people



Day 3 Inputs

Day3_forecasts_024
It provides potential
wind forces at a
specific point and time.

day3_track_past.geojson
The track of the
hurricane.

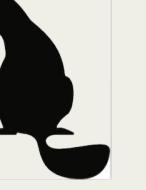
THE HURRICANE HITS TODAY



Hurricane Samtef is going to hit MIT. RIP

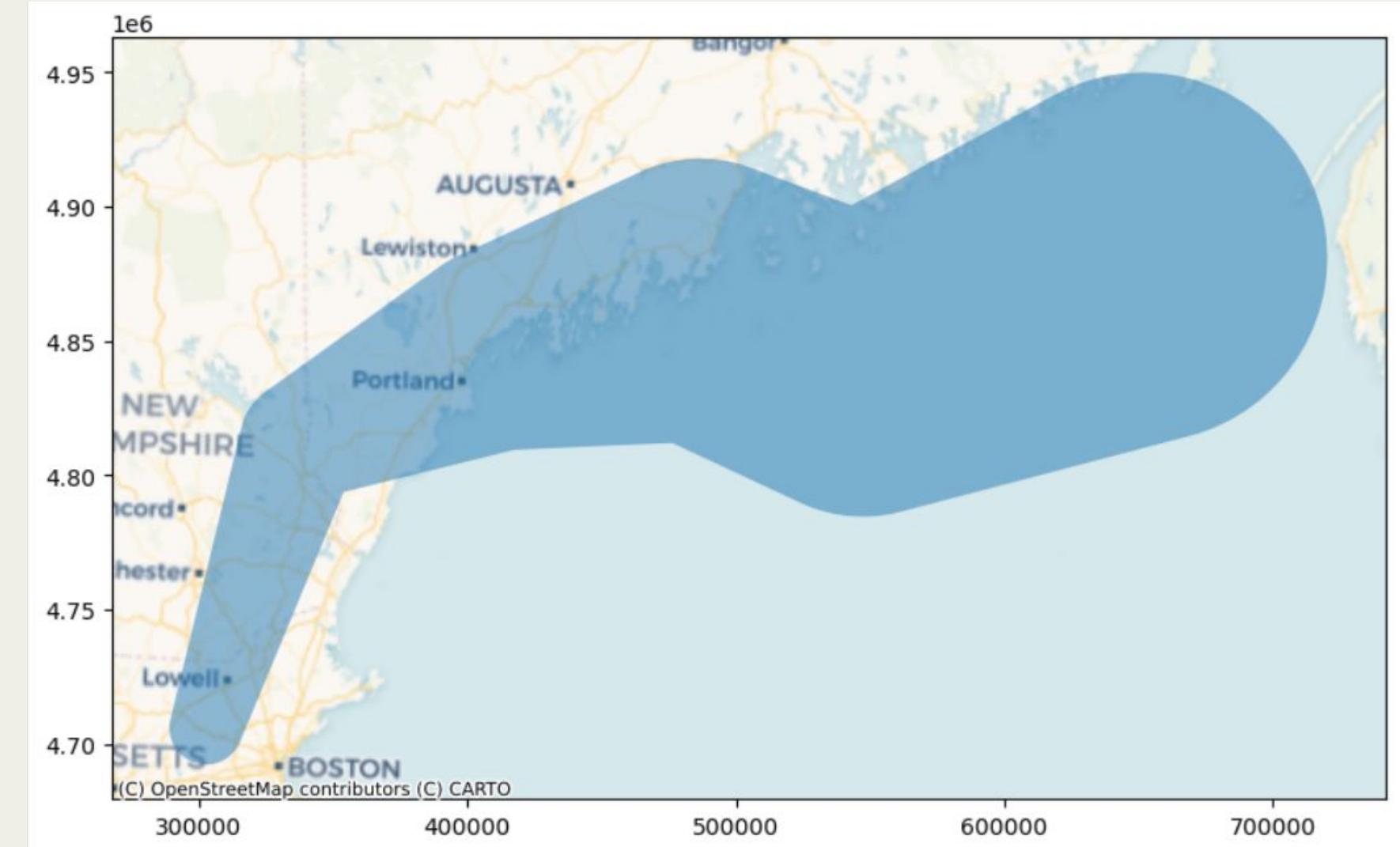
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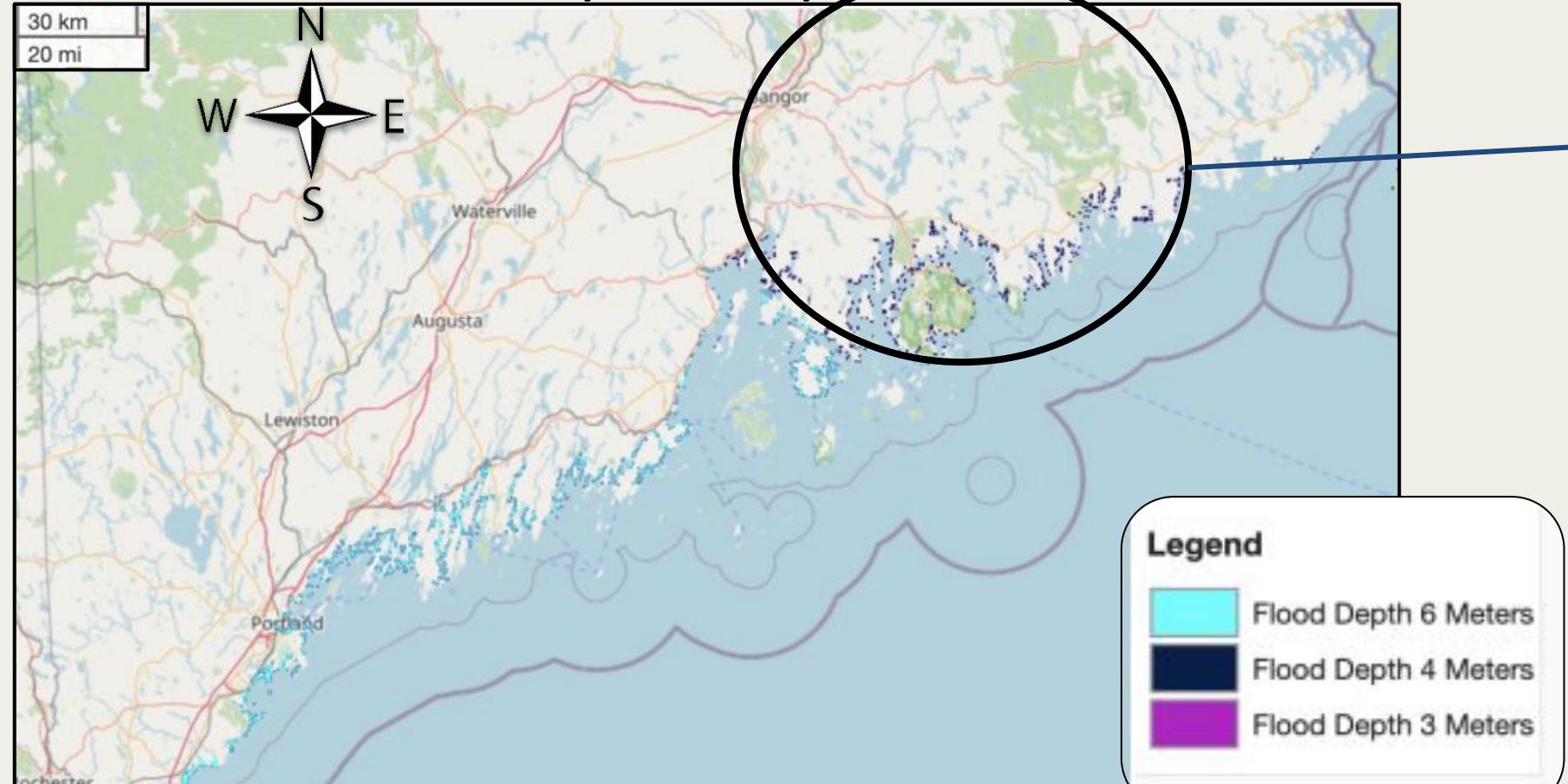


Planning Team

- The Day 3 CoU has been updated. The hurricane follows the predicted path on Day 2.
 - The only major change is the sudden shift to the south after passing Augusta, Maine.

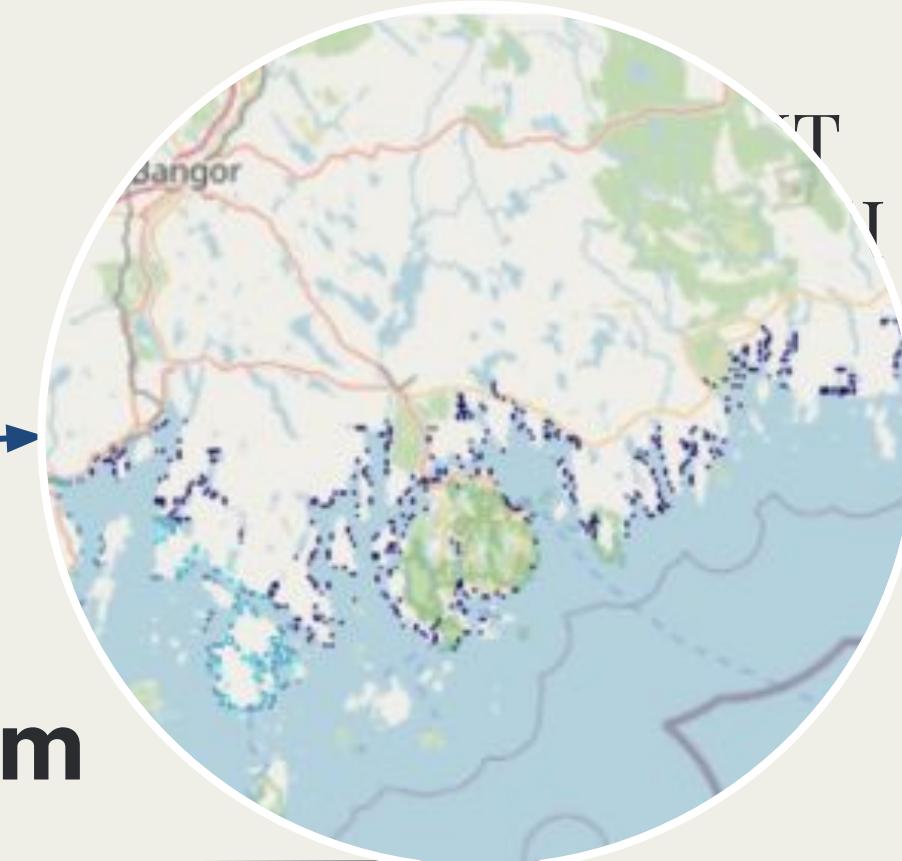
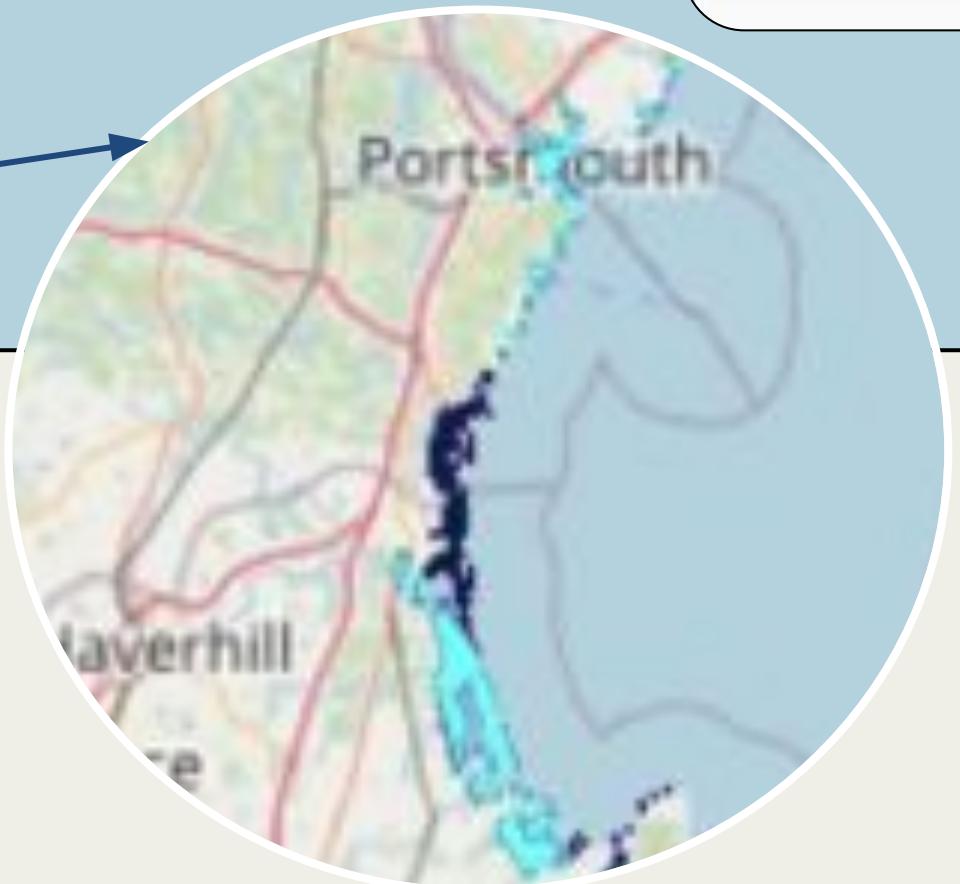


Flood Depth Map



Planning Team

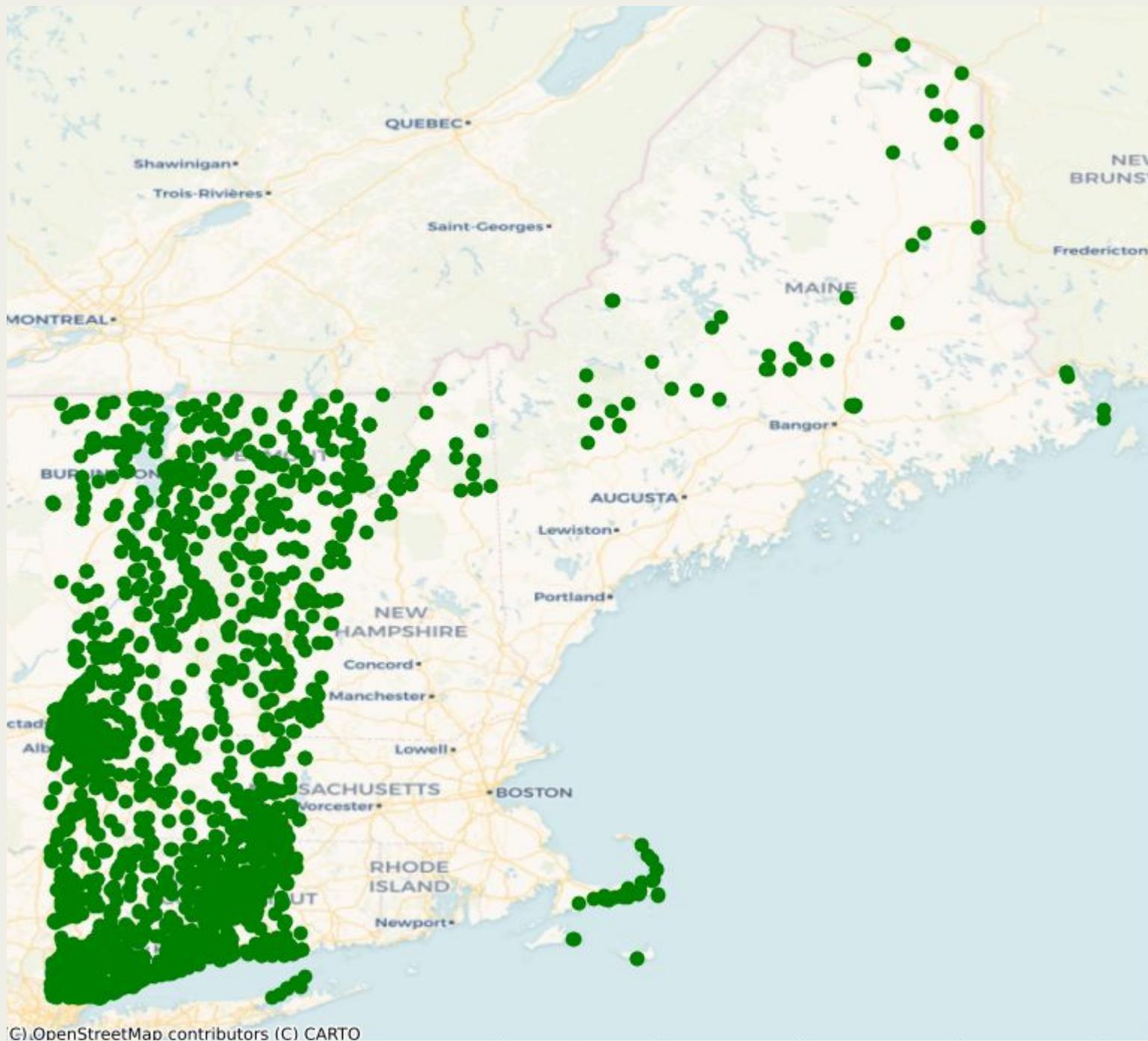
- The **light blue** represents **6 meters** of expected flooding
- The **dark blue** represents **4 meters** of expected flooding.
- The **purple** represents **3 meters** of expected flooding



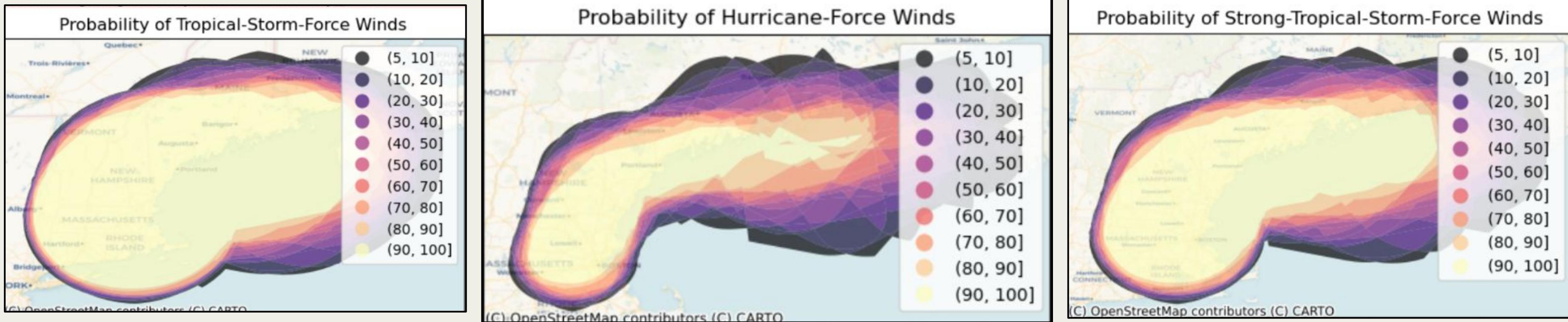


Planning Team

Unimpacted shelters available for aid after day 3



Planning Team



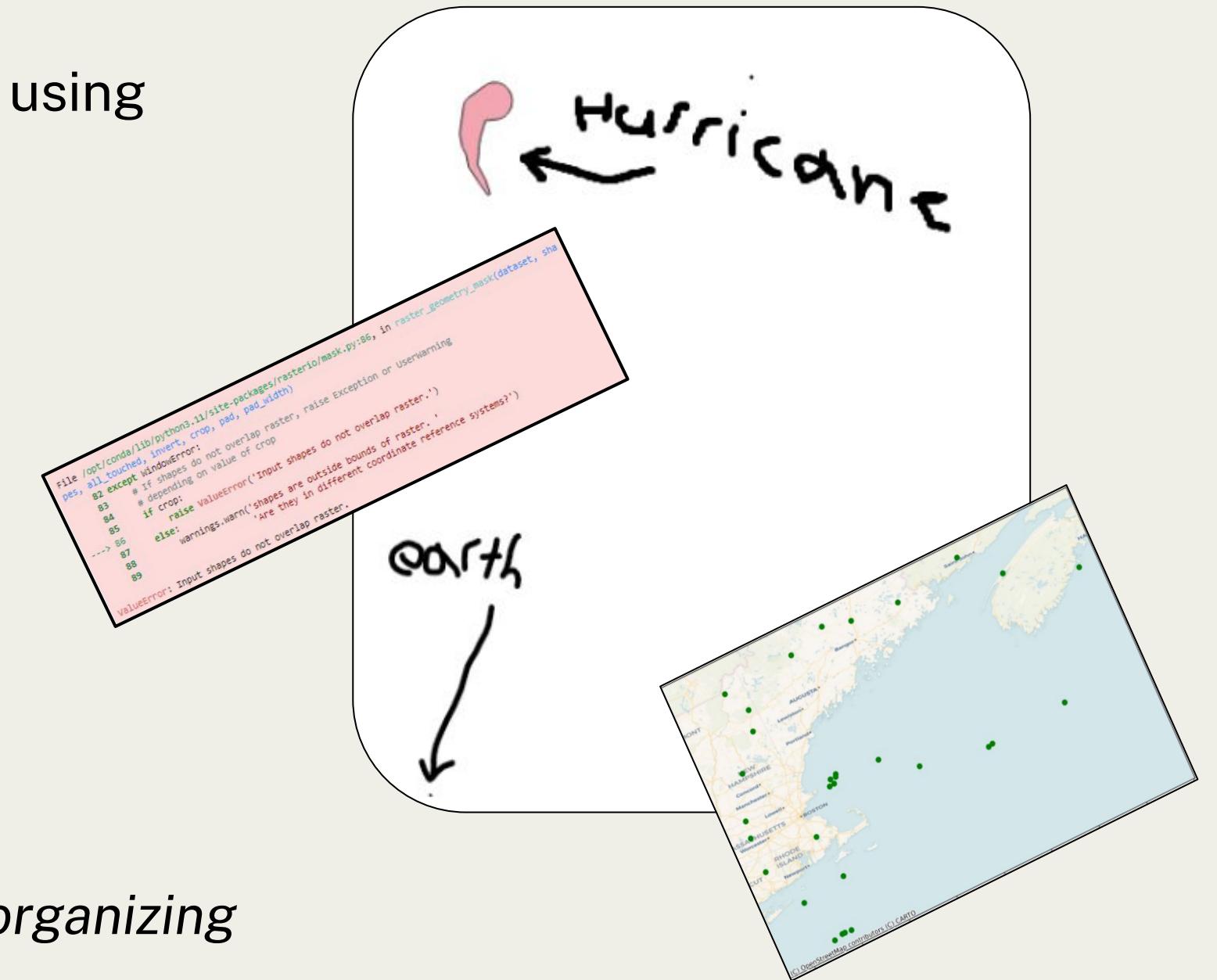
Maine & New Hampshire will experience the most winds due to the hurricane shifting course. Parts of Massachusetts, Rhode Island will also continue to experience tropical force wind.

Hurricane-Force winds have suddenly expanded, meaning that areas of **western NH and MA will experience further damage**.

Challenges:

- **Evacuation Zones:**
 - Knowing Evacuation Zones, troubling highlighting them using polygons
- **Plotting Safe Shelters:**
 - Time Constraint for Logistics Team
 - Some Shelter locations were showing up in the ocean
 - Used Outdated Information for first attempt
- **Others:**
 - Large Datasets; GEE & other softwares not cooperating
 - Making Presentable maps within short amount of time
 - Distribution of Work (*Some teammates full with task, re-organizing workload*)
 - Getting Intersections of any features

Day 3 Issues:



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Evacuation plans

- Based on current data, we believe that the people should head west or south
- Avoid going North
- **White = Need evacuation ASAP**
- Black = Impacted but not evacuated



Day 4 Inputs

●

Day4_forecasts_024
It provides potential
wind forces at a
specific point and time.

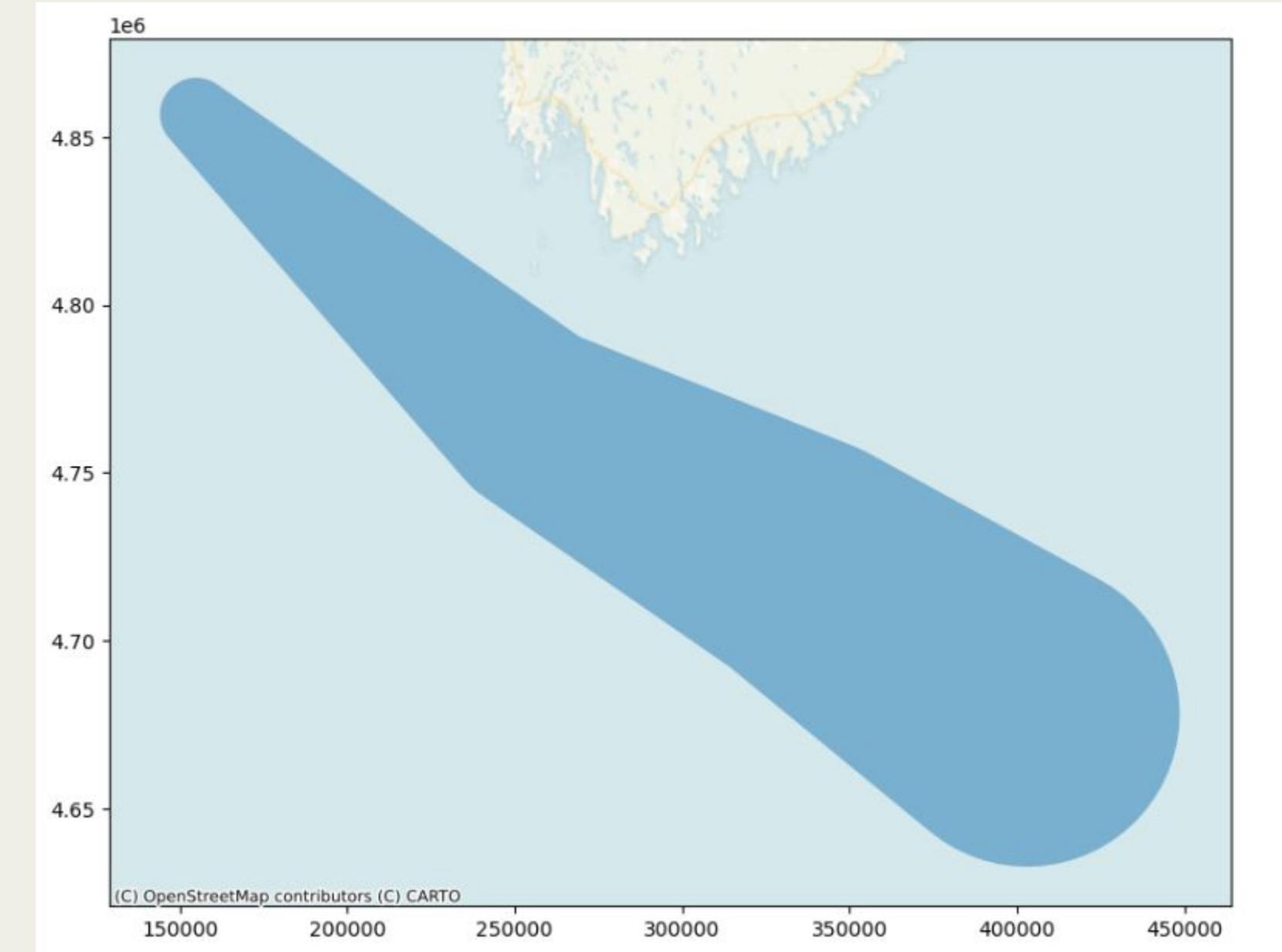
●

day4_track_past.geojson
The track of the
hurricane.



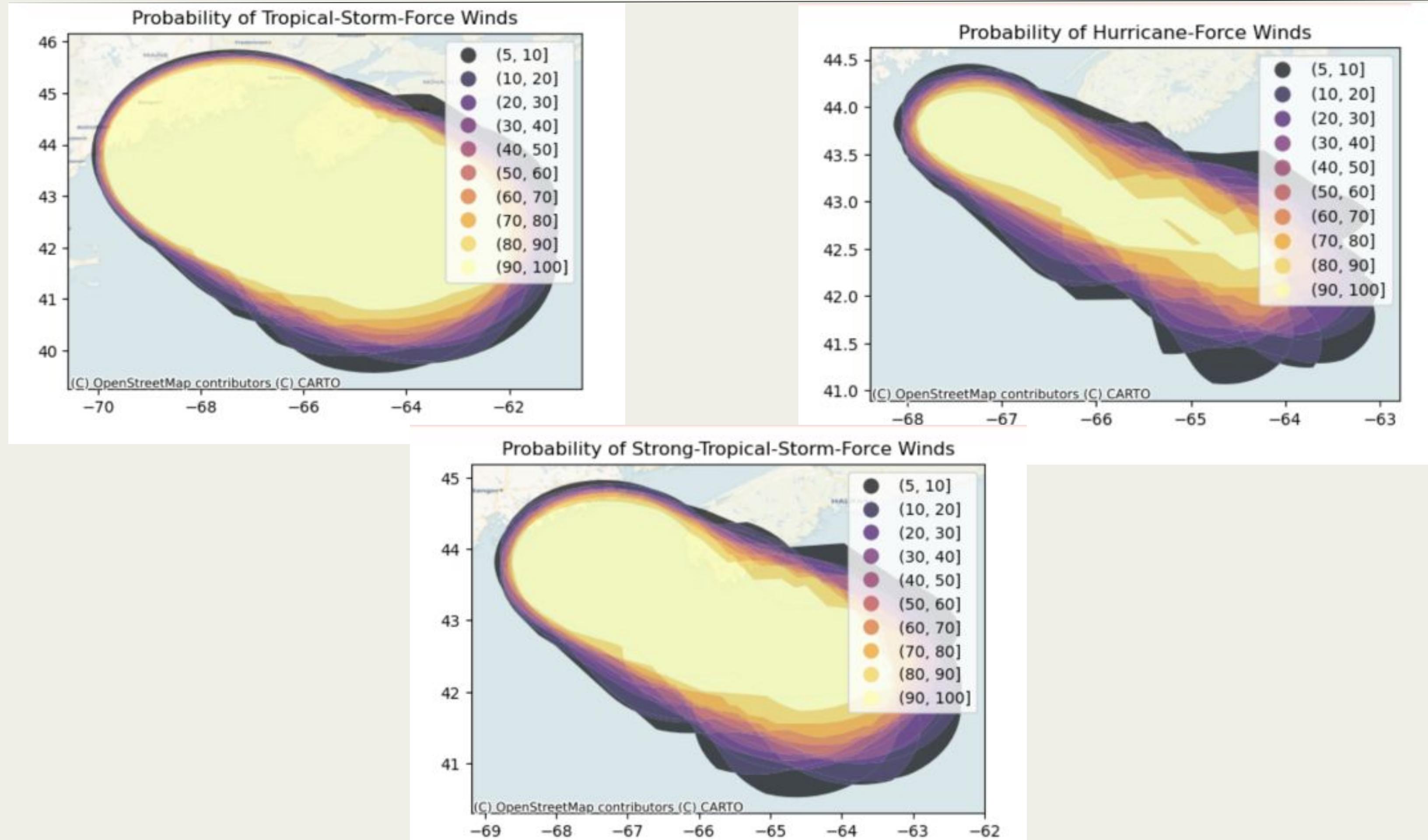
Planning Team

- The Day 4 CoU has been updated. The hurricane is now going away from the mainland, passing Nova Scotia.
 - This implies that the hurricane is nearly over and relief aid can begin to arrive soon.





Planning Team



Logistics Team

Resource distributions

Logistics

Team

- Logistics Team is provided:
 - 40 trucks to deliver resources
 - Trucks can carry 1200 units of resources
- Constraints:
 - Trucks take 20 minutes to unload resources
 - Truck routes cannot take longer than 12 hours
 - Trucks must start and end at a distribution center
 - Resources must arrive within 72 hours
- Hospitals require 500 resource units
- Shelters require 200 resource units

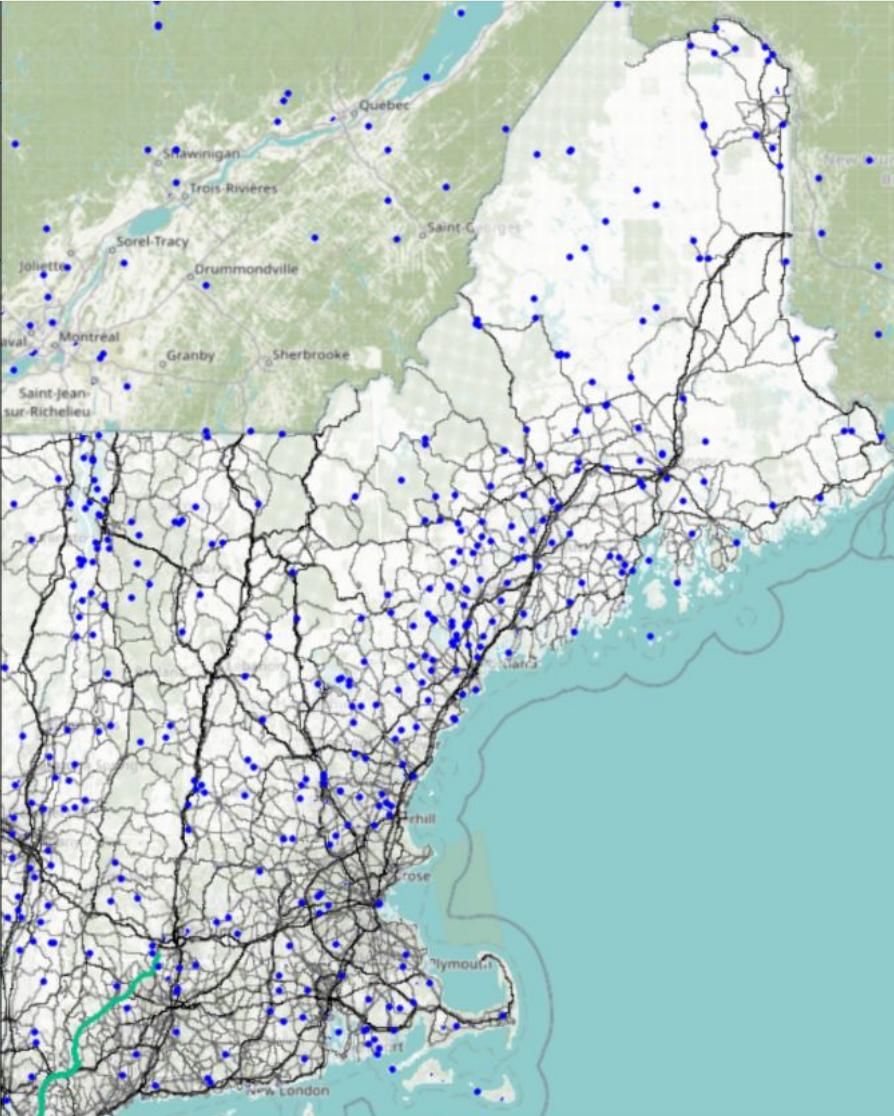
DAY 1

Inputs

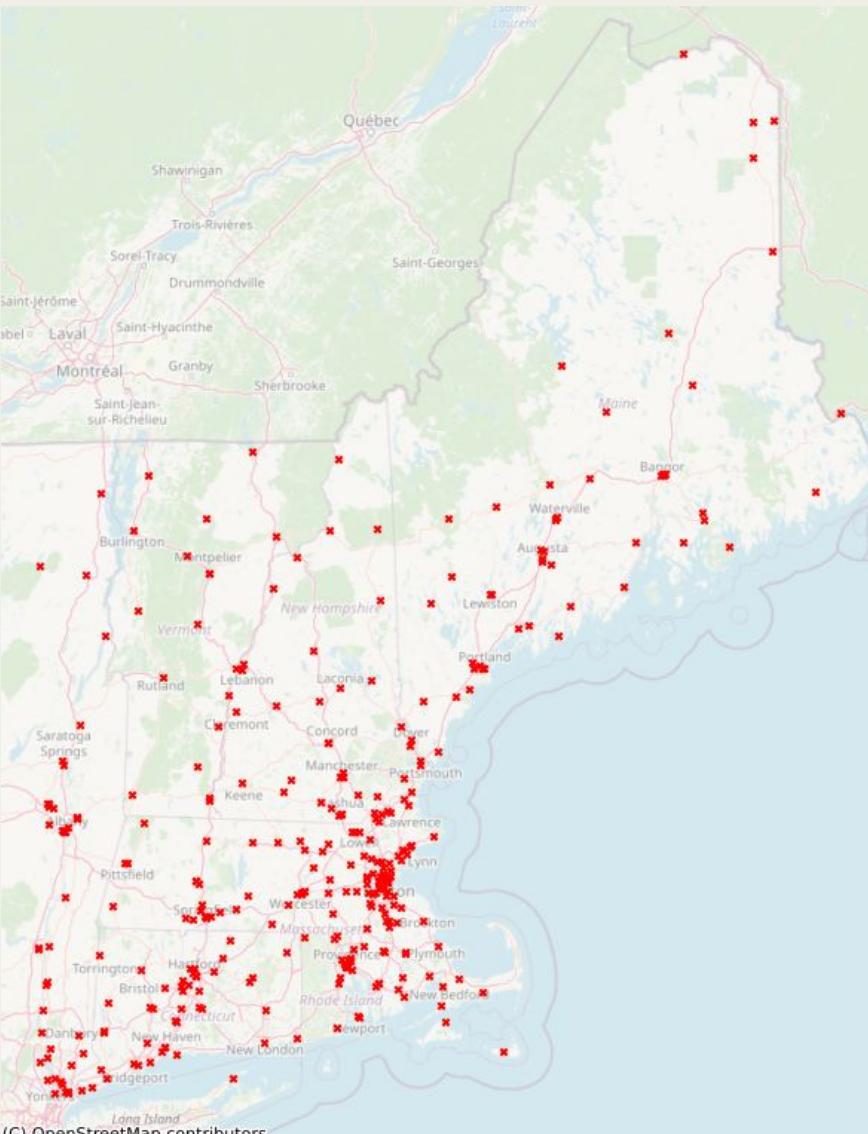
Hospitals_2024.geojson	Shelters_2024.geojson	Game_grid_2024.geojson
Geojson file that contains the locations of the hospitals.	Geojson file that contains the locations of the shelters we can use.	The game grid is based off of the Military Grid Reference System that divides the world into small grid squares representing area.

Logistics

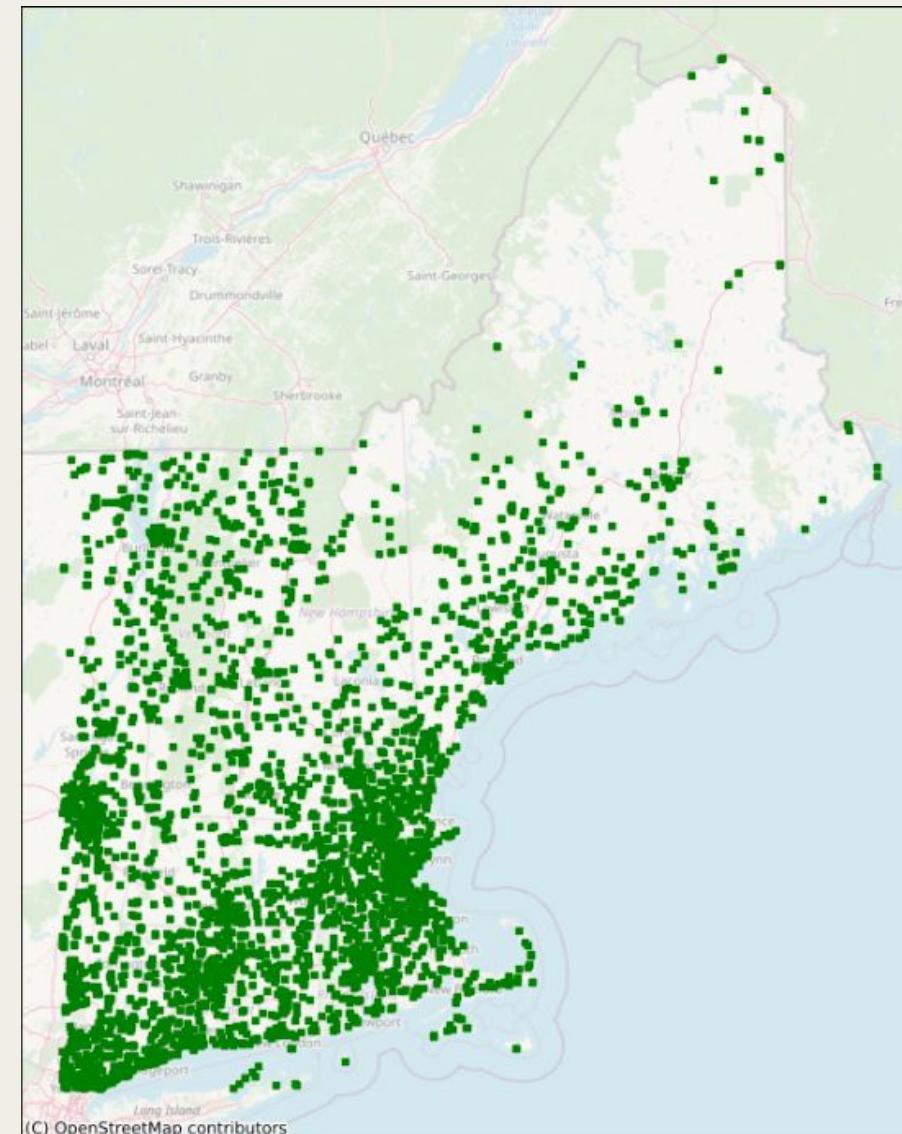
Air fields



Team Hospitals

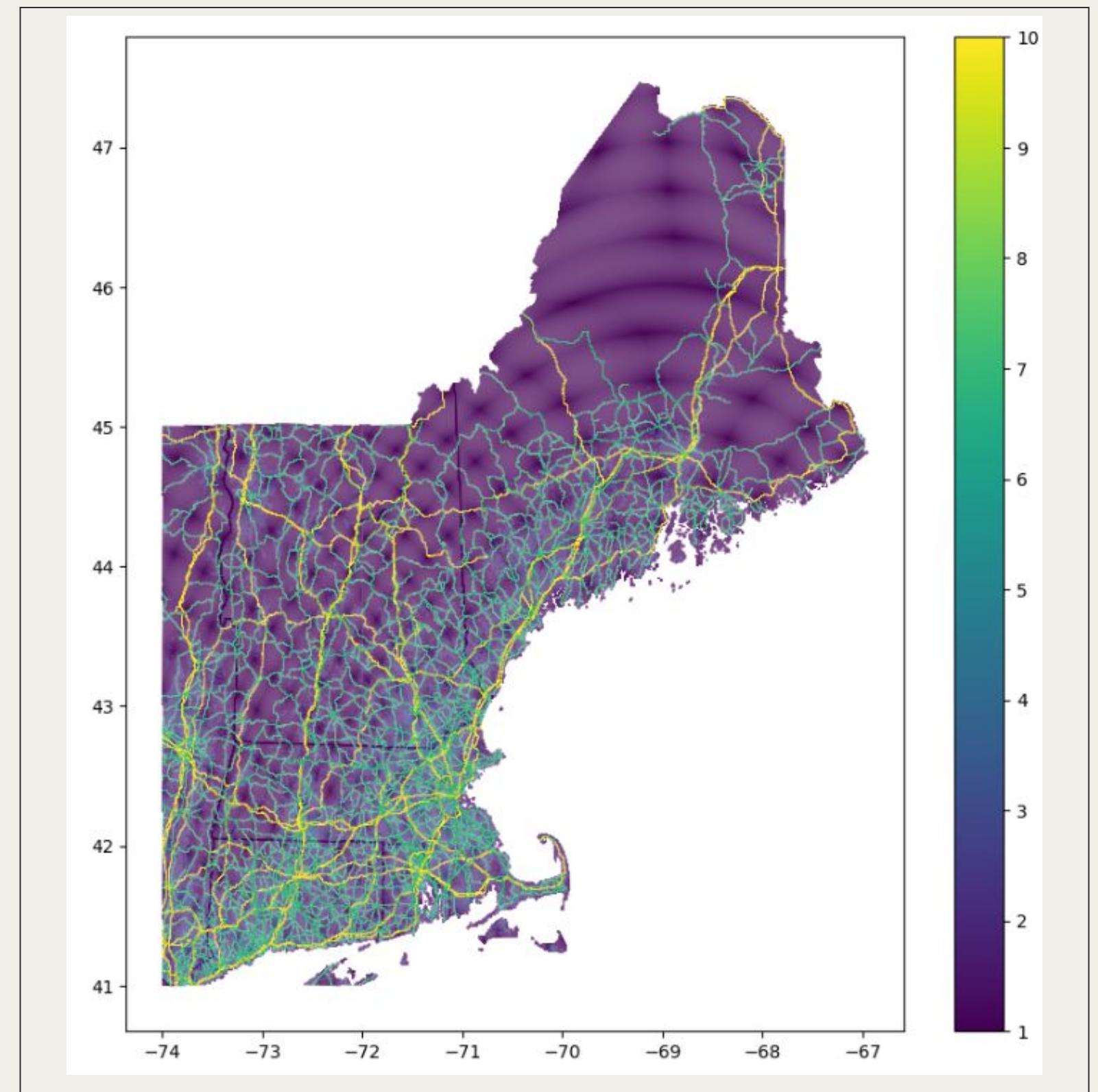


Shelters



Transport Score

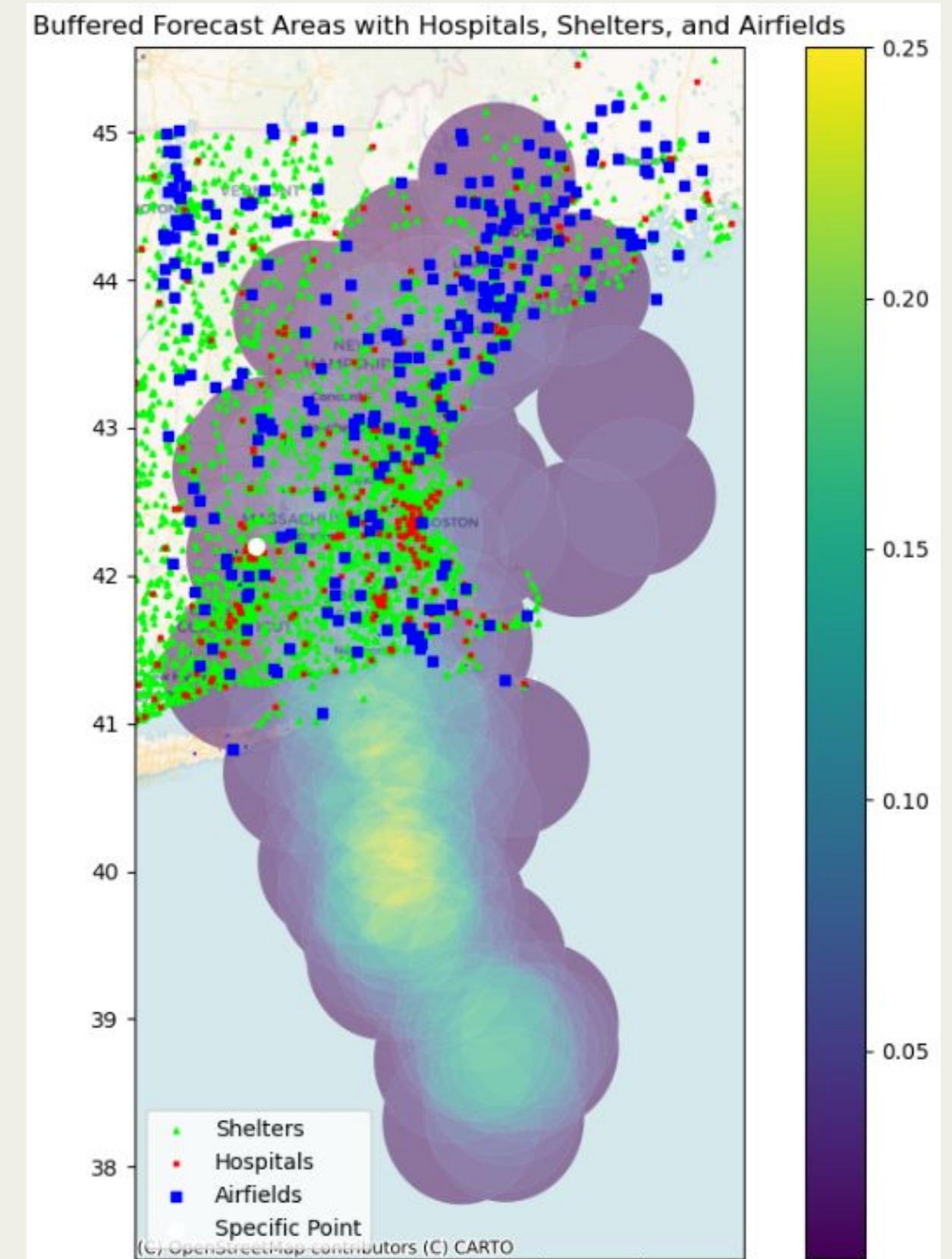
- Logistics Team received this map on Day 1
- Gives a transport score for each cell
- Higher number = Higher efficiency





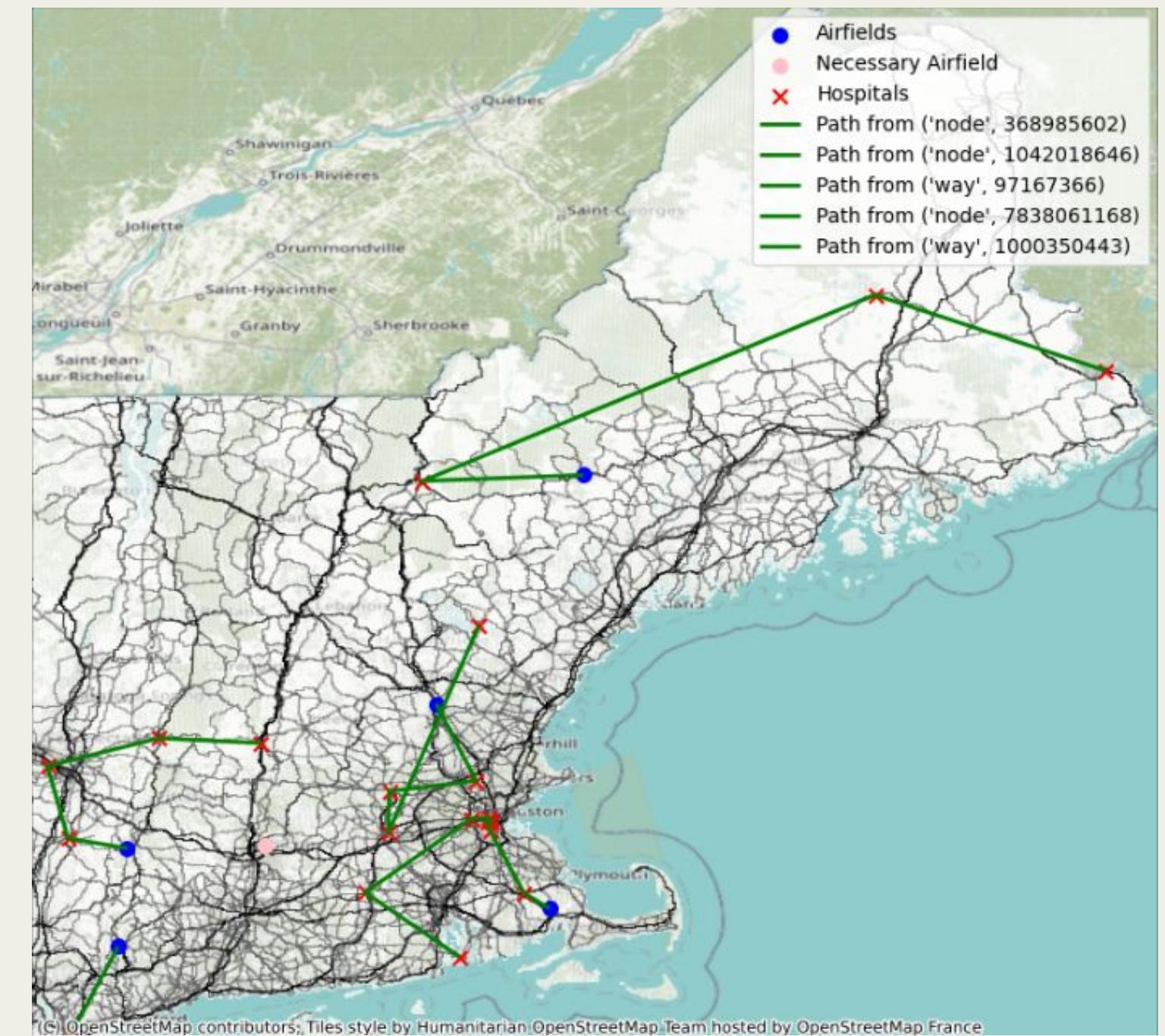
Hurricane Map

- Airfields, Shelters, and Hospitals
- Team can figure out:
 - Distribution Centers
 - Impact of hurricane



Airfield paths

- Random sample of Airfields and Hospitals
- Greedy Path Routing



Logistic Challenges Day 1

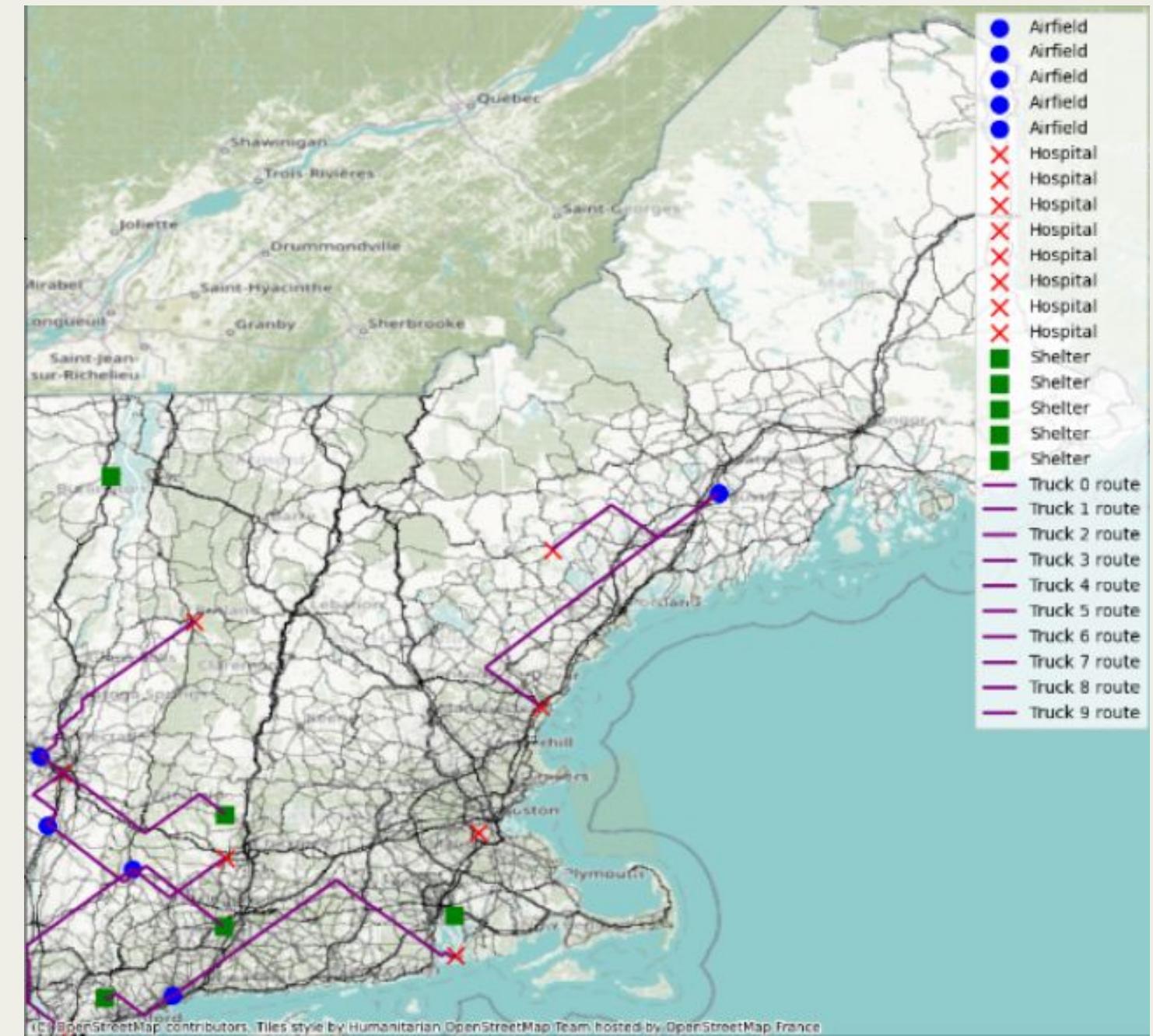
- Transport network not implemented
- Resource or time conditions were not considered
- Each airbase/distribution center only had one truck



DAY 2

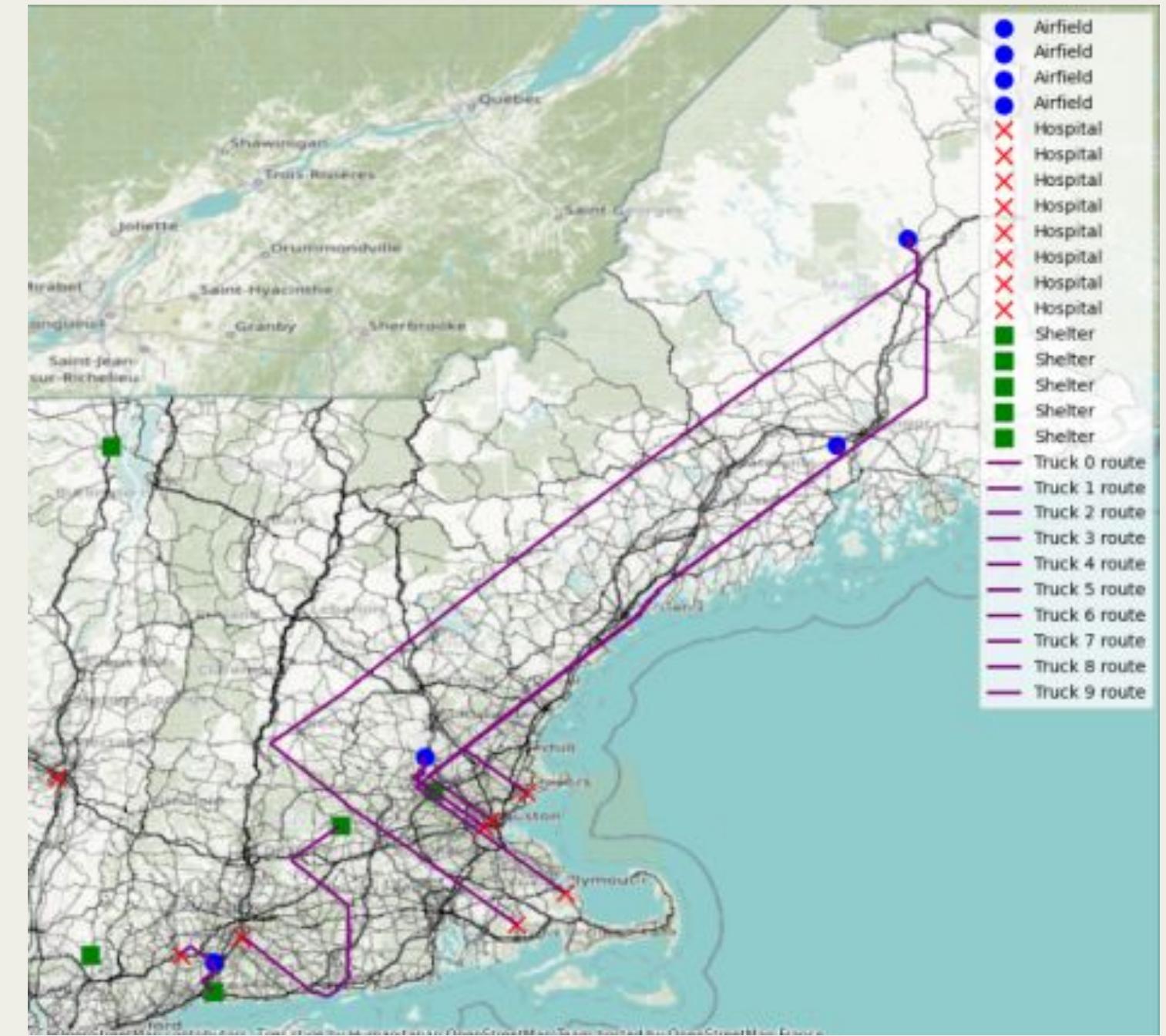
Transport Time

- Create code to calculate time for trucks to reach destination
- Times were not working



Challenges

- Problem with the truck routing algorithm
- Trucks are supposed to restock at the distribution centers if they run out of supplies
- Trucks stopped delivering if they ran out of supplies



DAY 3

THE HURRICANE HITS TODAY



Hurricane Samtef is going to hit MIT. RIP

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Logistics Team: Day 3 Distribution Centers

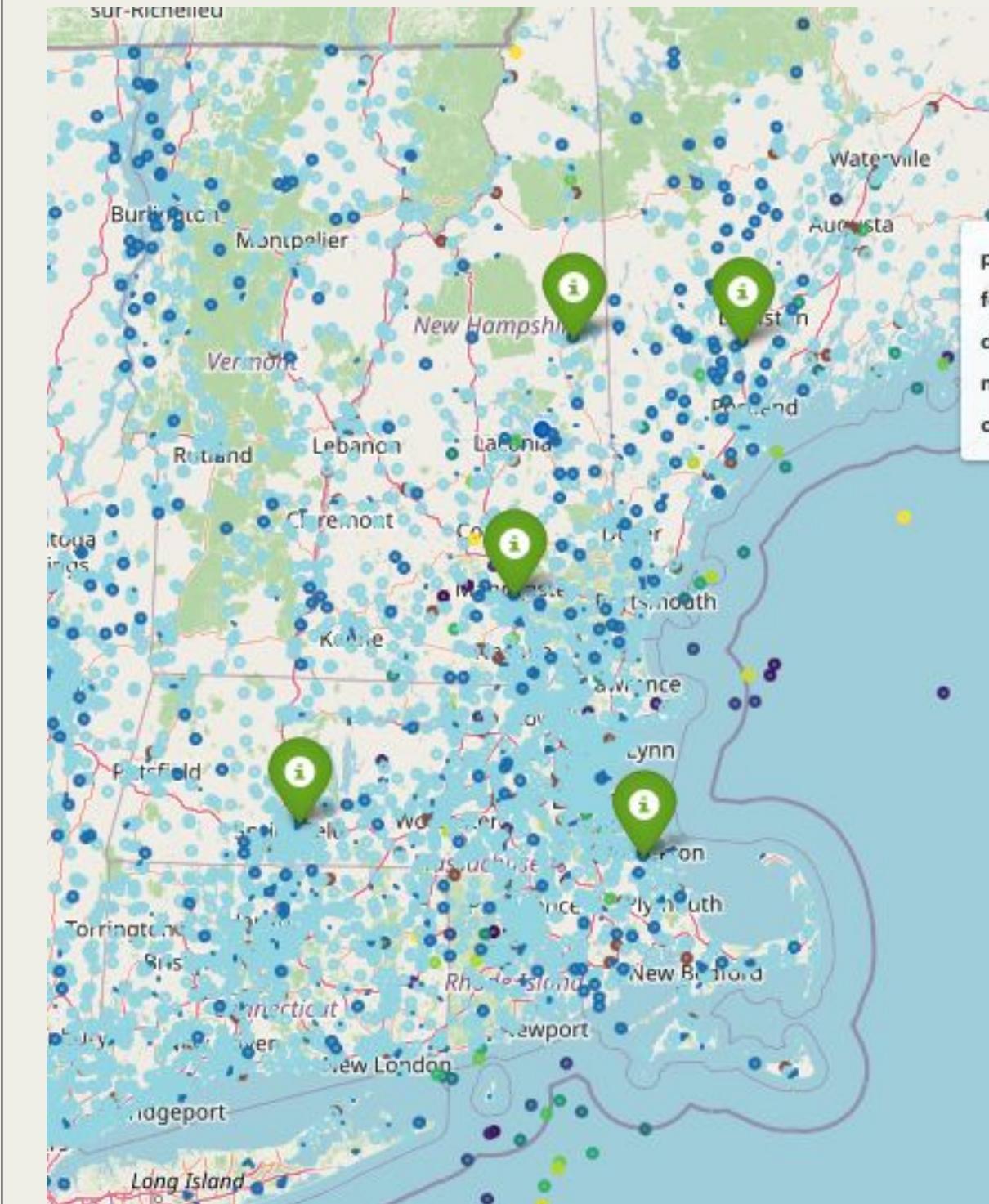
Westover Air Reserve Base: 42.1991, -72.5436

Evans Seaplane Base: 43.0373333, -71.4698333

Pheasant Field: 42.075401, -70.815

Leavitt Airport: 43.9725667, -71.1698

Cliff Dow Airport: 43.94944, -70.32027



Light blue = shelters
Dark blue = air bases

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Shelters and Hospitals

- Graph of shelters and hospitals based on region

The number of shelters in **Pheasant Field Region** are: 469

The number of hospitals in **Pheasant Field Region** are: 71

The number of shelters in **Westover Air Reserve Base Region** are: 453

The number of hospitals in **Westover Air Reserve Base Region** are: 40

The number of shelters in **Evans Seaplane Base Region** are: 436

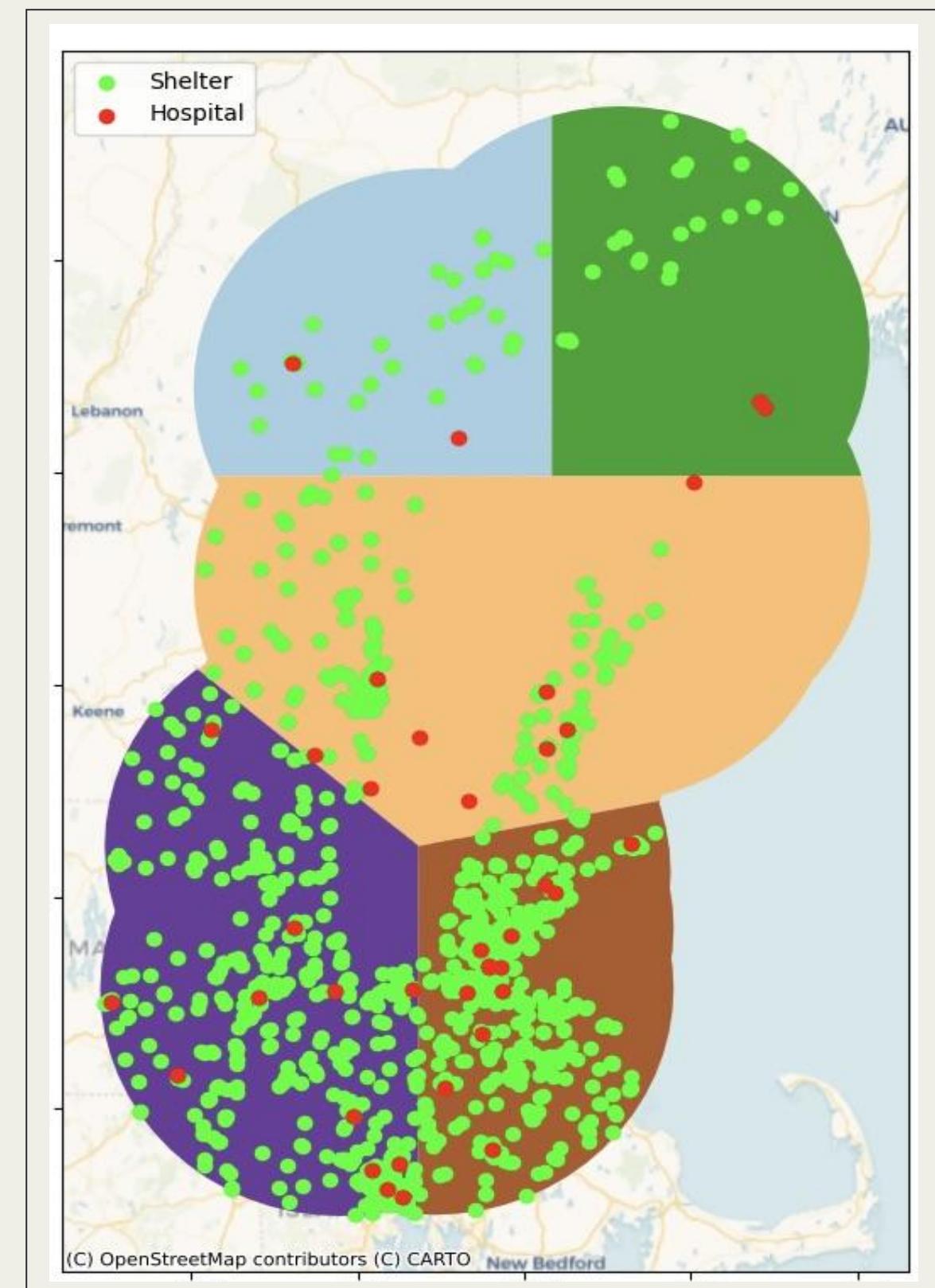
The number of hospitals in **Evans Seaplane Base Region** are: 35

The number of shelters in **Cliff Dow Airport Region** are: 116

The number of hospitals in **Cliff Dow Airport Region** are: 11

The number of shelters in **Leavitt Airport Region** are: 45

The number of hospitals in **Leavitt Airport Region** are: 4



Initial Resource Distribution

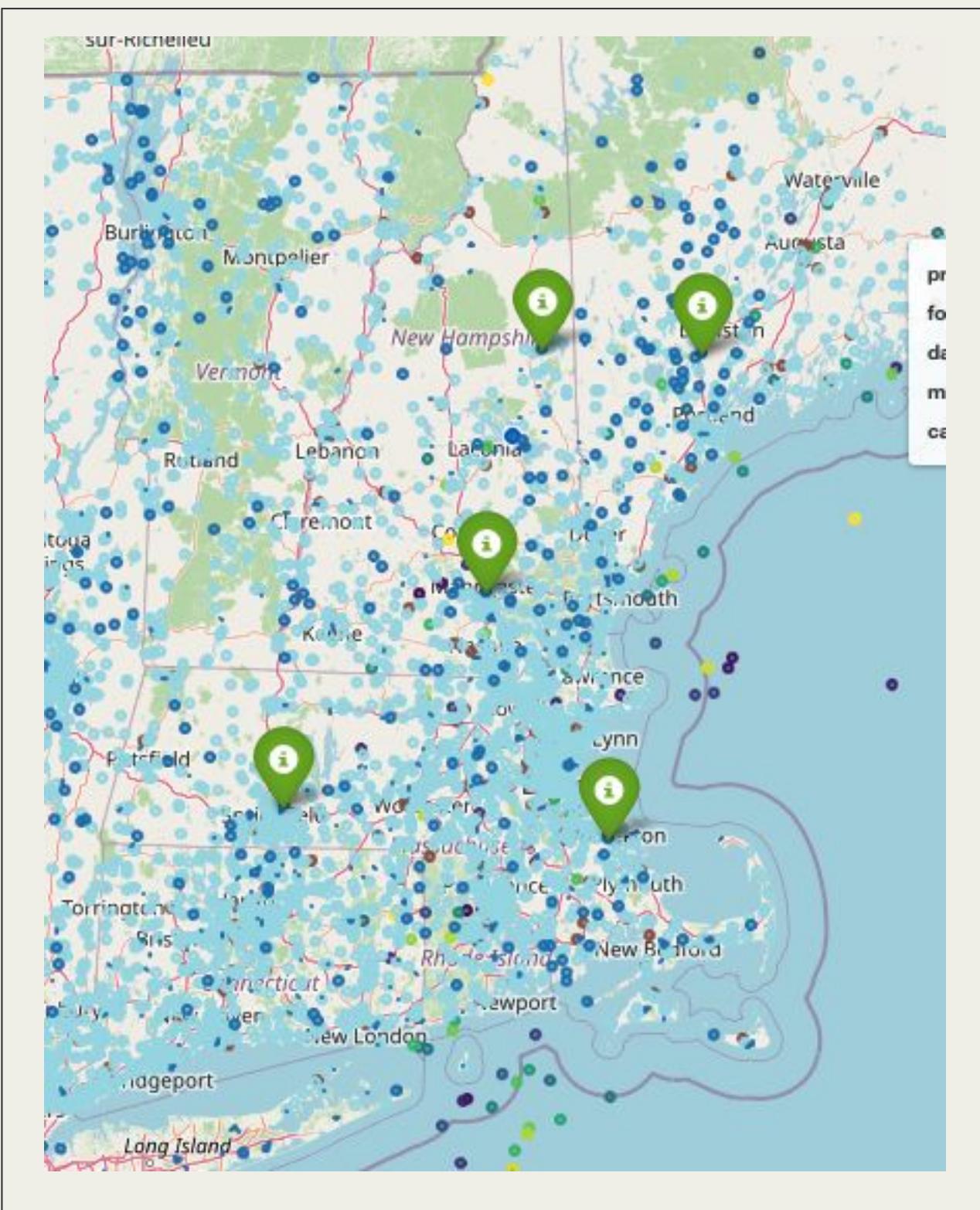
Resources in Pheasant Field: 48,214

Resources in Westover Air Reserve Base: 44,018

Resources in Evans Seaplane Base: 42,054

Resources in Cliff Dow Airport: 11,339

Resources in Leavitt Airport: 4,375



Light blue = shelters
Dark blue = air bases

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Weight-Adjusted Resource Distribution

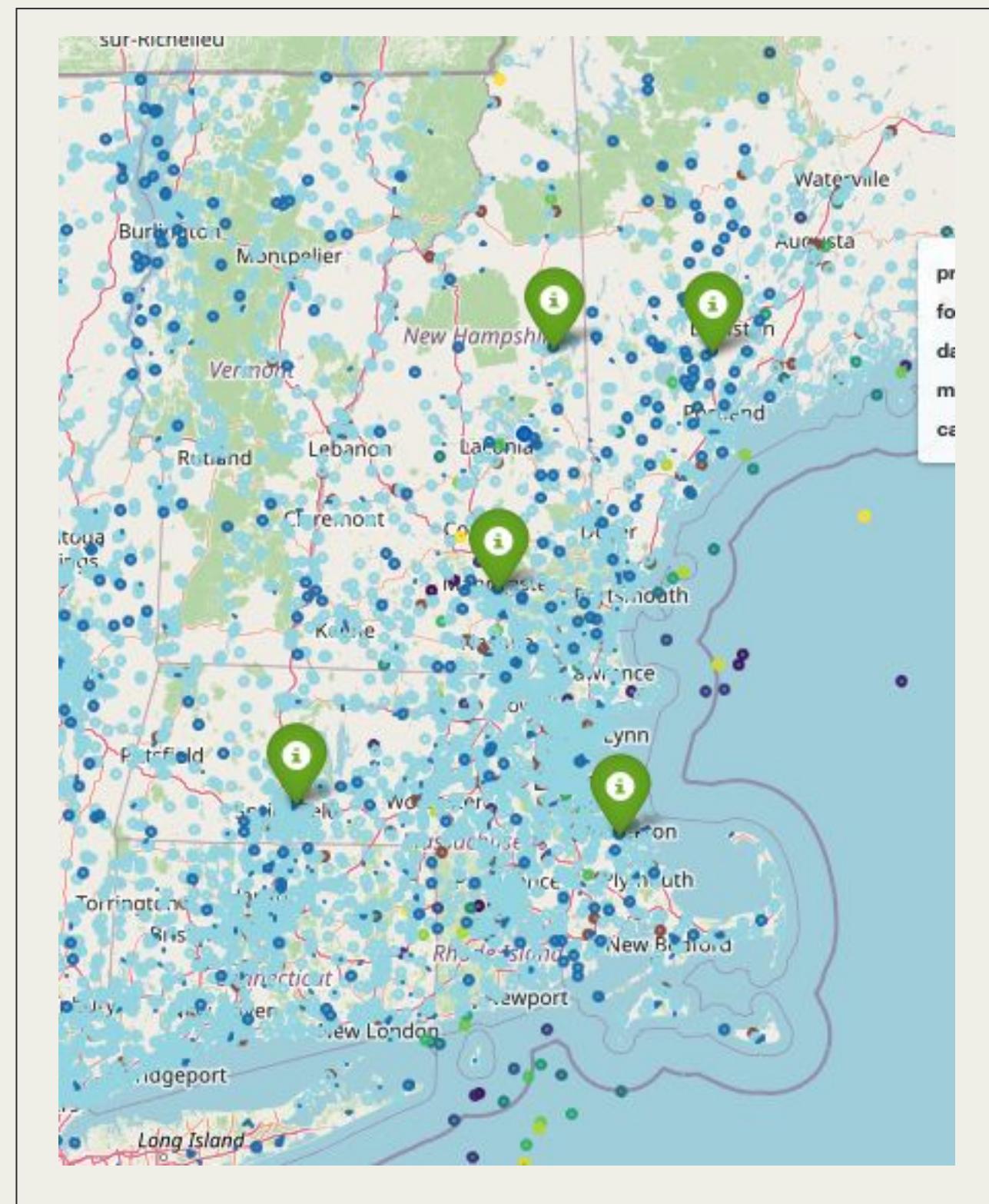
Resources in Pheasant Field: 60,388

Resources in Westover Air Reserve Base: 54,987

Resources in Evans Seaplane Base: 25,098

Resources in Cliff Dow Airport: 4,046

Resources in Leavitt Airport: 5,481



Light blue = shelters
Dark blue = air bases

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Initial Truck Amounts

Trucks in Pheasant Field: 13

Trucks in Westover Air Reserve Base: 12

Trucks in Evans Seaplane Base: 11

Trucks in Cliff Dow Airport: 3

Trucks in Leavitt Airport: 1



Weight-Adjusted Truck Amounts

Trucks in Pheasant Field: 17

Trucks in Westover Air Reserve Base: 15

Trucks in Evans Seaplane Base: 6

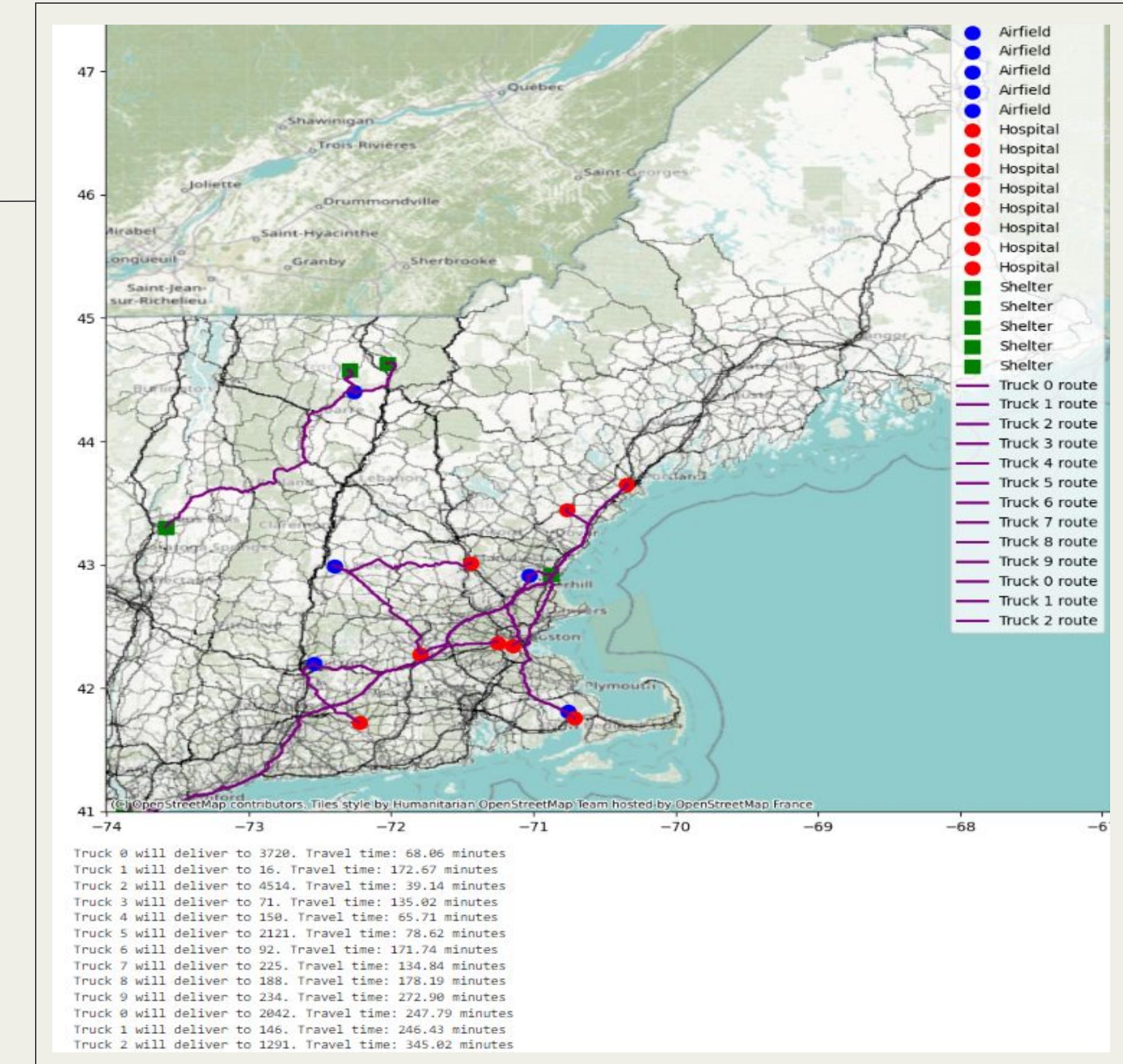
Trucks in Cliff Dow Airport: 1

Trucks in Leavitt Airport: 1



Transport Network

- Trucks not following roads
Transport network relied on a grid
- Team figured out to route with the actual roads
- More efficient than first network
- Started using the Game Grid properly



Workflow of Greedy Path Routing

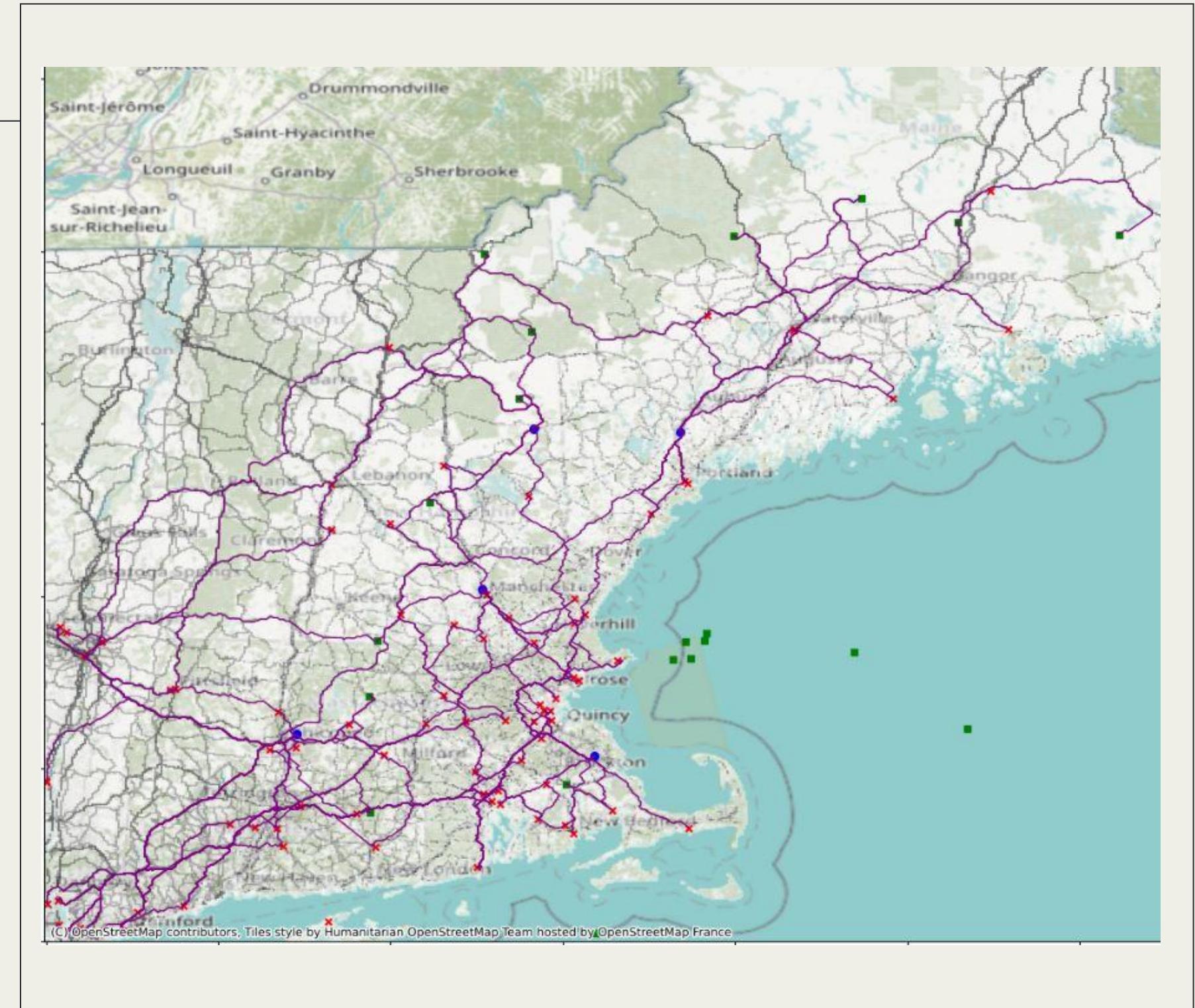
Setup: Load data, initialize airfields, hospitals, shelters, and trucks.

Network Construction: Build the transport network with travel times.

Routing: Calculate and assign routes for trucks to deliver resources.

Visualization: Plot the results to visualize the routes and resource delivery.

Reporting: Output route details, statistics, unreachable targets, total operation time, and truck servicing data.



OR-Tools

- Open-source software
- Specializes in linear
programming and
optimization



We utilized its routing capabilities which finds the optimal paths that fulfills the given constraints and conditions. With examples being distance, capacity, and time.

```
# Create and register a transit callback.
def distance_callback(from_index, to_index):
    """Returns the distance between the two nodes."""
    # Convert from routing variable Index to distance matrix NodeIndex.
    from_node = manager.IndexToNode(from_index)
    to_node = manager.IndexToNode(to_index)
    return data["distance_matrix"][from_node][to_node]

transit_callback_index = routing.RegisterTransitCallback(distance_callback)

# Define cost of each arc.
routing.SetArcCostEvaluatorOfAllVehicles(transit_callback_index)

# Add Capacity constraint.
def demand_callback(from_index):
    """Returns the demand of the node."""
    # Convert from routing variable Index to demands NodeIndex.
    from_node = manager.IndexToNode(from_index)
    return data["demands"][from_node]
```

Output:

```

Objective: 7692
dropped reload stations: []
Route for vehicle 0:
 0 Load(0) -> 1 Load(500) -> 3 Load(1000) -> 4 Load(1500) -> 0 Load(1500)
Distance of the route: 1552m
Load of the route: 1500

Route for vehicle 1:
 0 Load(0) -> 6 Load(500) -> 2 Load(1000) -> 10 Load(1500) -> 0 Load(1500)
Distance of the route: 1712m
Load of the route: 1500

Route for vehicle 2:
 0 Load(0) -> 11 Load(500) -> 15 Load(1000) -> 12 Load(1500) -> 0 Load(1500)
Distance of the route: 1552m
Load of the route: 1500

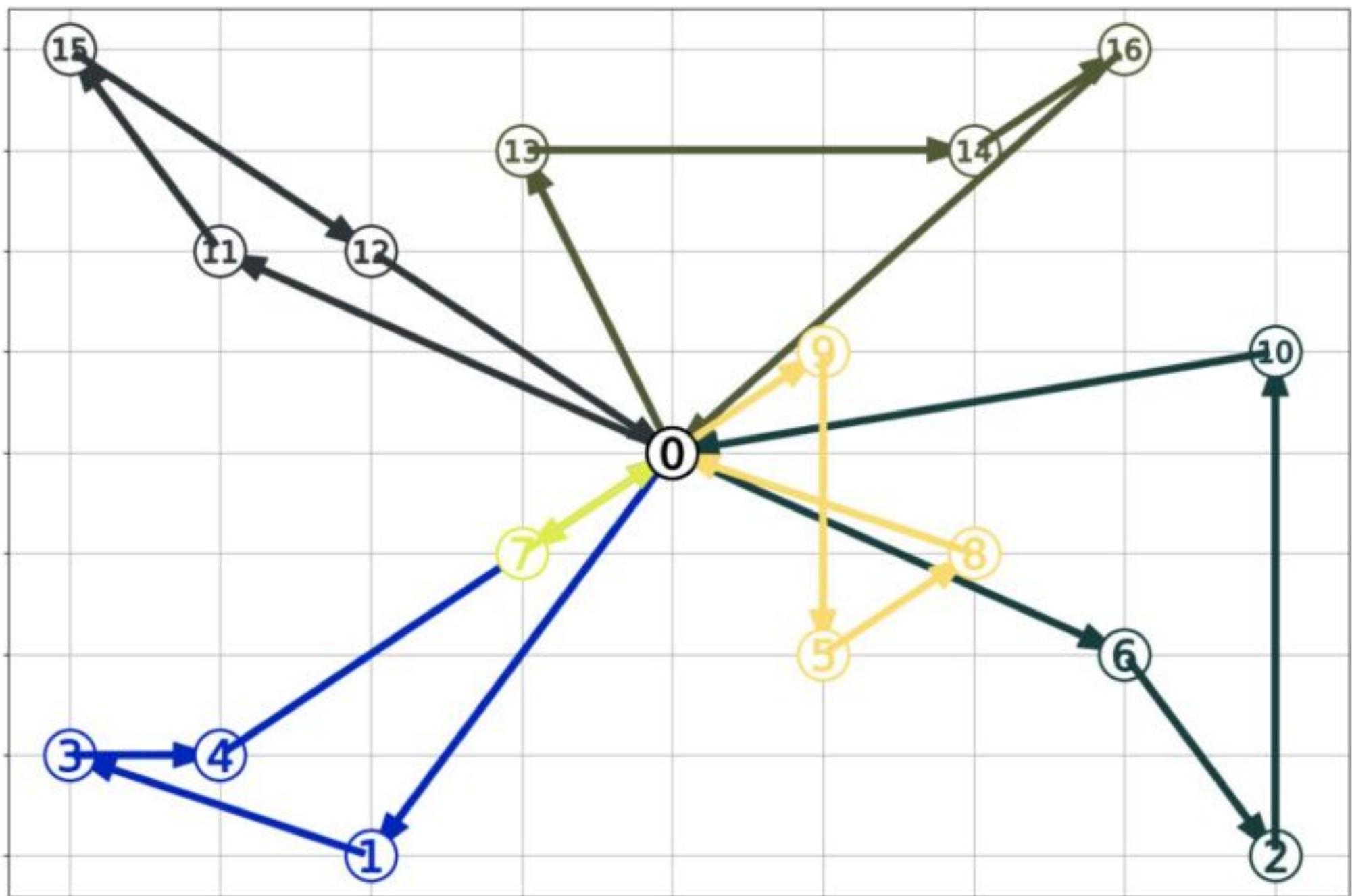
Route for vehicle 3:
 0 Load(0) -> 13 Load(500) -> 14 Load(1000) -> 16 Load(1500) -> 0 Load(1500)
Distance of the route: 1552m
Load of the route: 1500

Route for vehicle 4:
 0 Load(0) -> 7 Load(500) -> 0 Load(500)
Distance of the route: 388m
Load of the route: 500

Route for vehicle 5:
 0 Load(0) -> 9 Load(500) -> 5 Load(1000) -> 8 Load(1500) -> 0 Load(1500)
Distance of the route: 936m
Load of the route: 1500

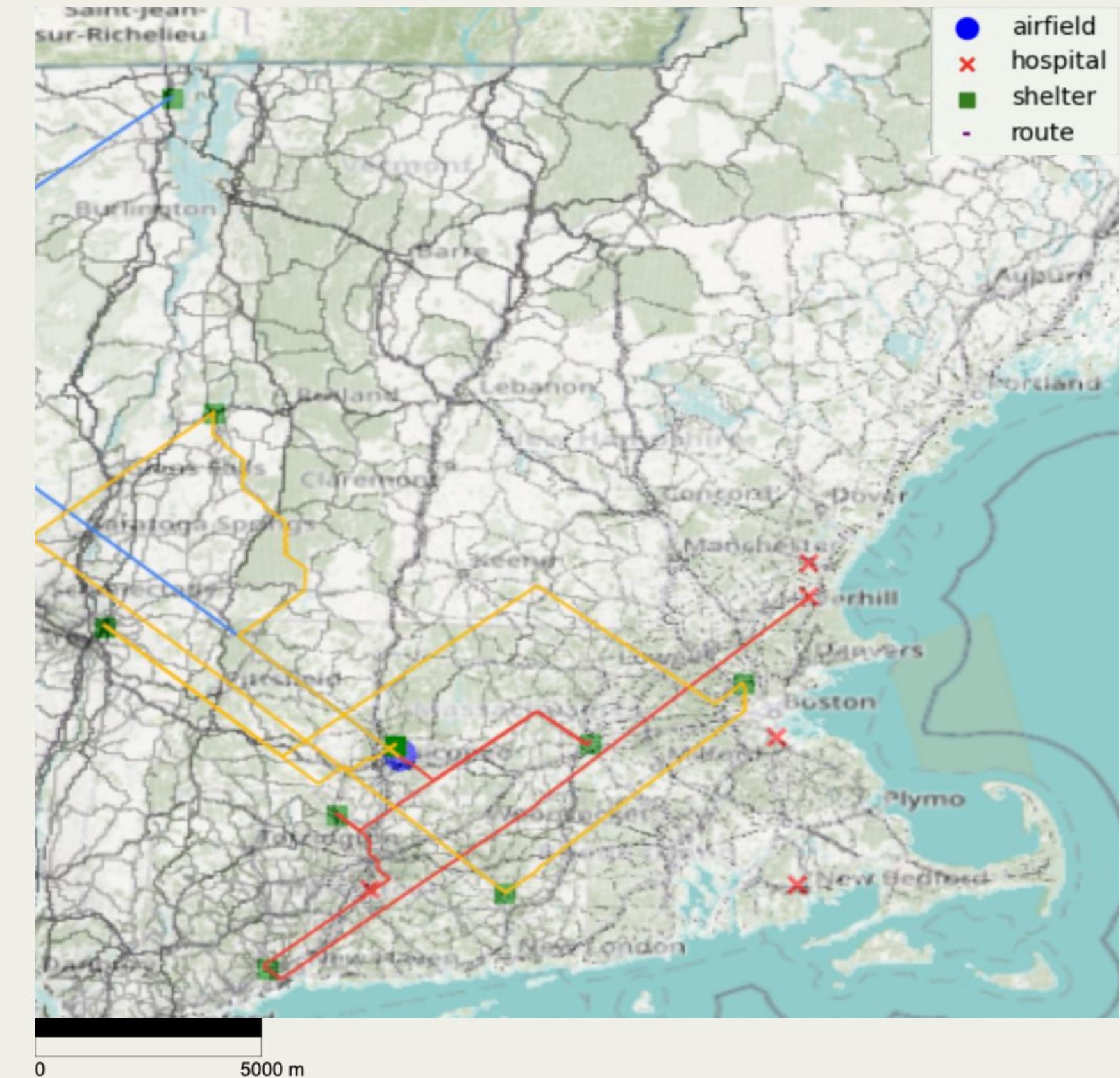
Total distance of all routes: 7692m
Total load of all routes: 8000

```



Using OR-Tools

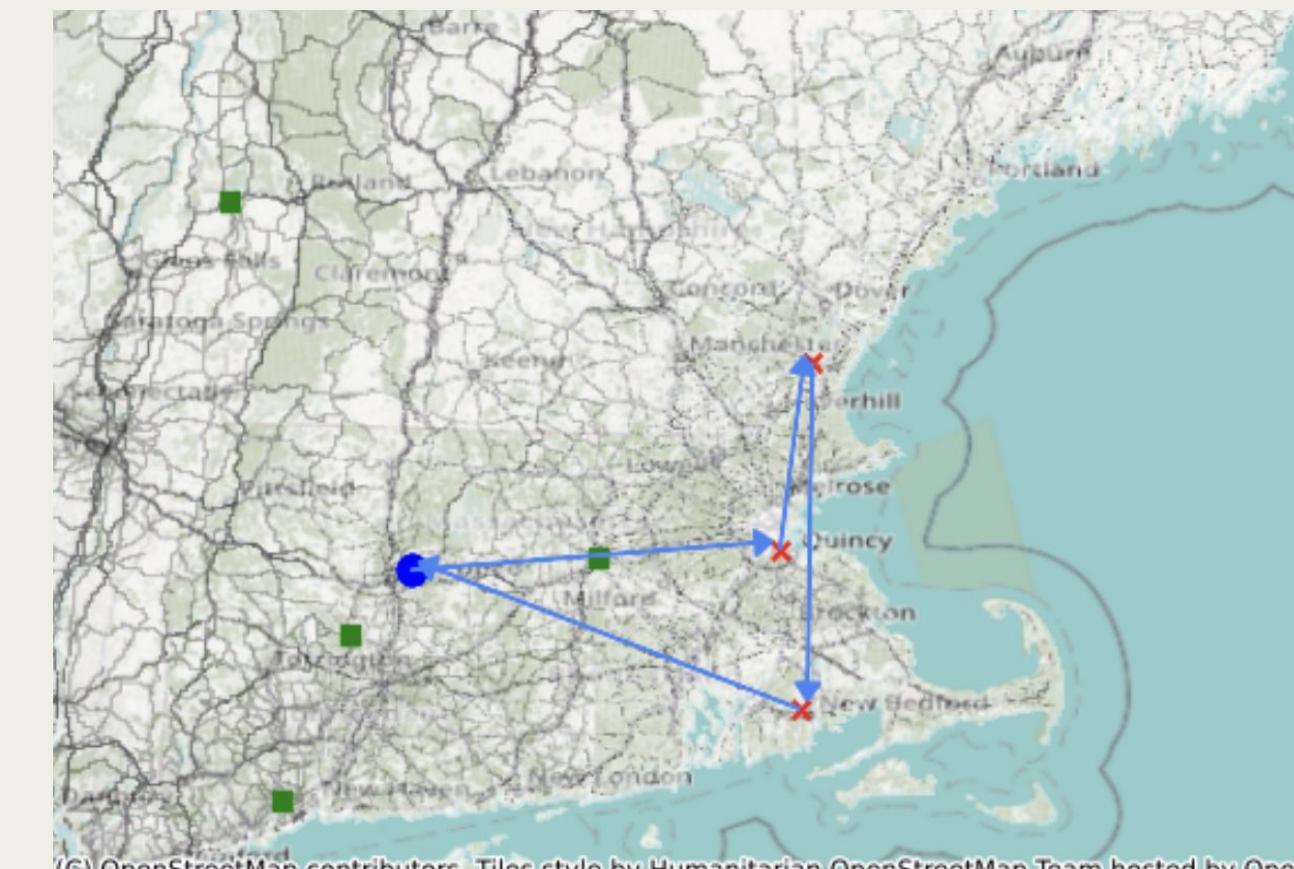
- Time matrix that shows the travel time between every location
- Each truck has capacity and time constraint
- Each location has a demand
- Air Bases have negative demand



Running OR-Tools

- OR-Tools computes routes up to 12 hours
- Update the demands based on what was fulfilled
- Run the simulation gain with updated list and repeat
- Total data creation time: 45min
- Total routing time: 20 seconds

First 12 hours



Total Route

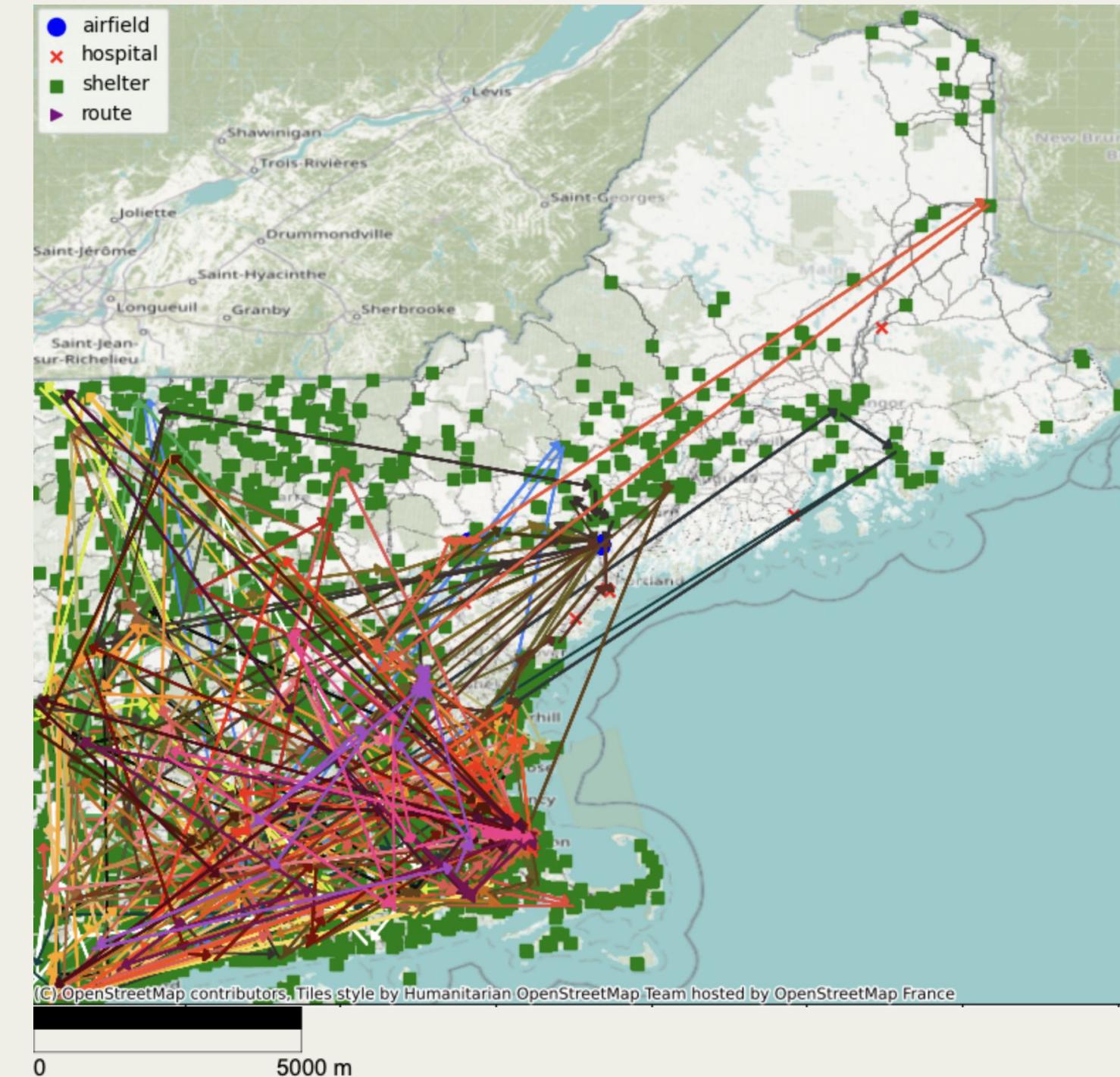


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Challenges

- Over 2.5M nodes and 4k facilities:
Optimization Required
- Ortools constraint limitation
- Ortools data limitation
- Partial unloading



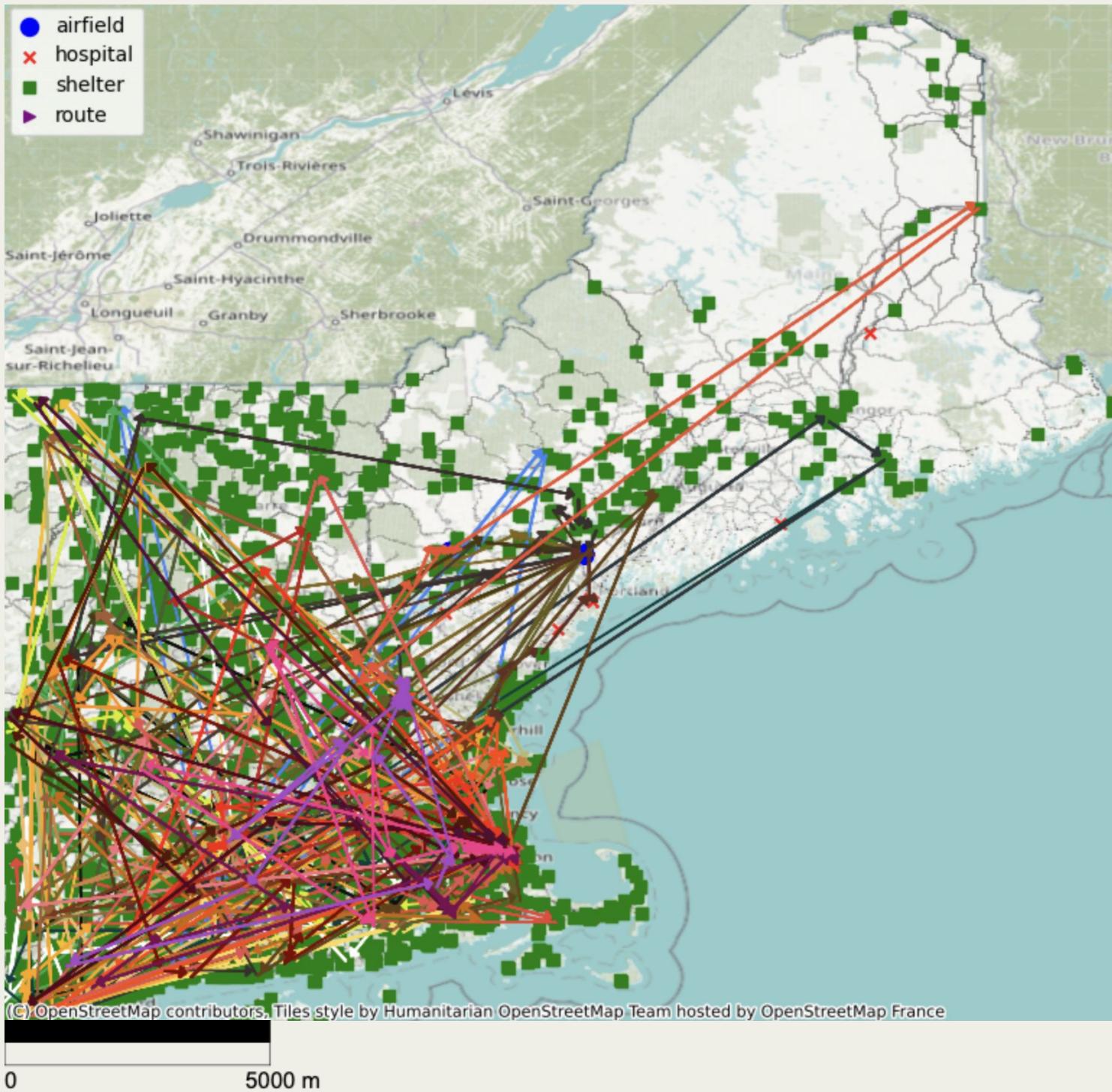
Results

Hospitals Supplied	Shelters Supplied	Total Supplied	Resources Supplied
9	458	467	96,100/150,000 (64%)

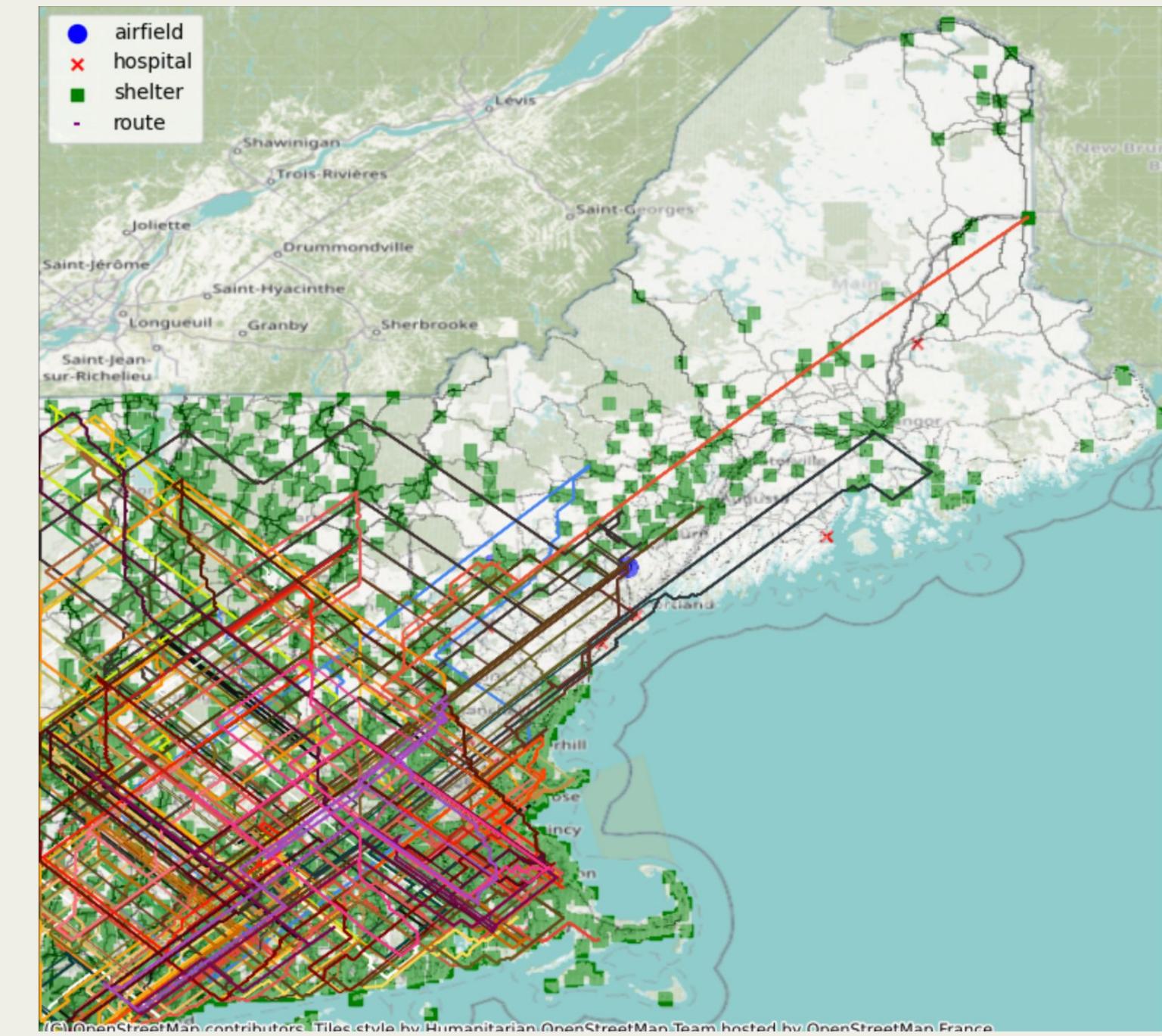
- Logistics Team only had enough resources to supply either:
 - 550 shelters
 - 300 hospitals
- We utilized all 40 trucks fully

Results

Simple route arrows



Road network outlines



Operations Team

During & Post - Hurricane Damage Analysis

Operations Team

Mission goals:

- Provide real-time situational analysis
- Gain usable intelligence for:
 - Disaster response groups
 - Government funding prioritization



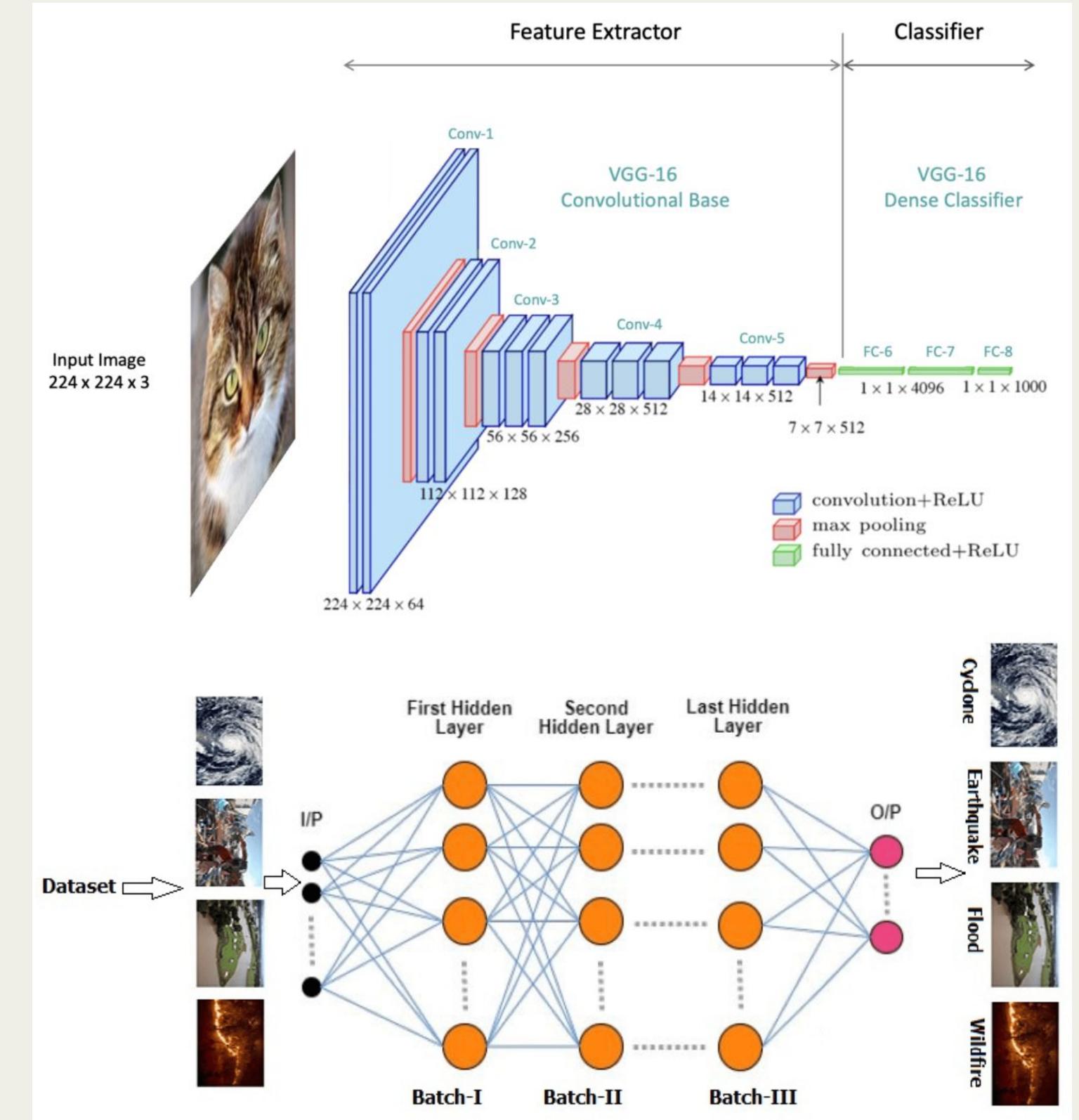
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Operations Team - Convolutional Neural Network (CNN)

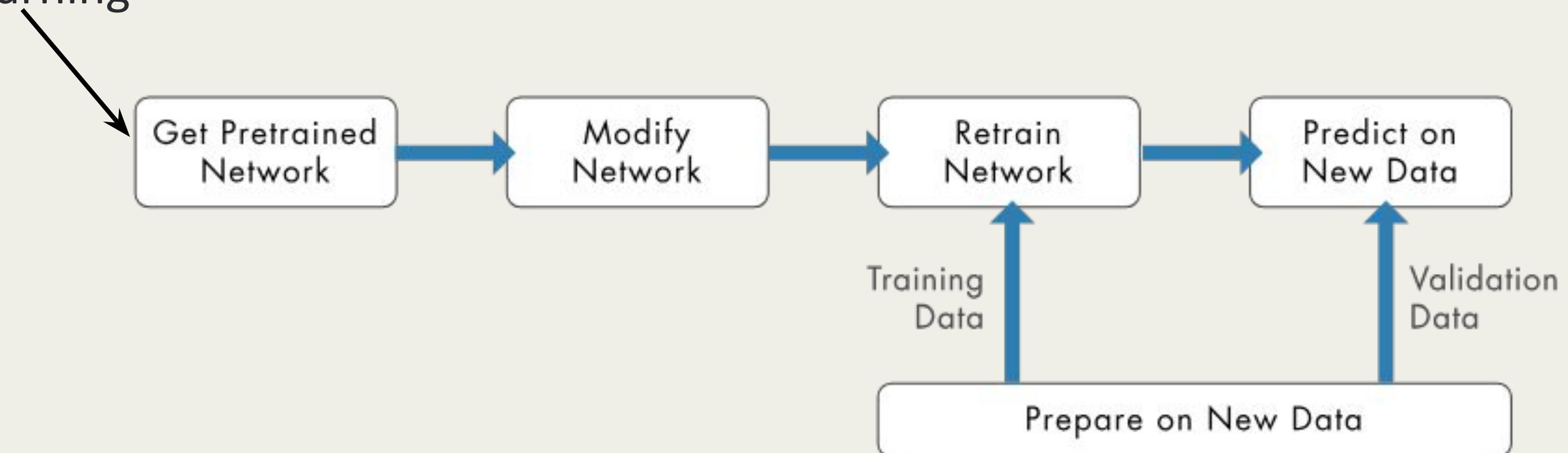
- **CNN:** deep learning that learns and adapts from image input
- Used for recognizing **damaged areas** over a large dataset
- How does it work?
 - **Input layer** = image dataset
 - **Hidden layer(s)** = code and image detection
 - **Output layer** = type and extent of damages in images





Operations Team - Training a CNN

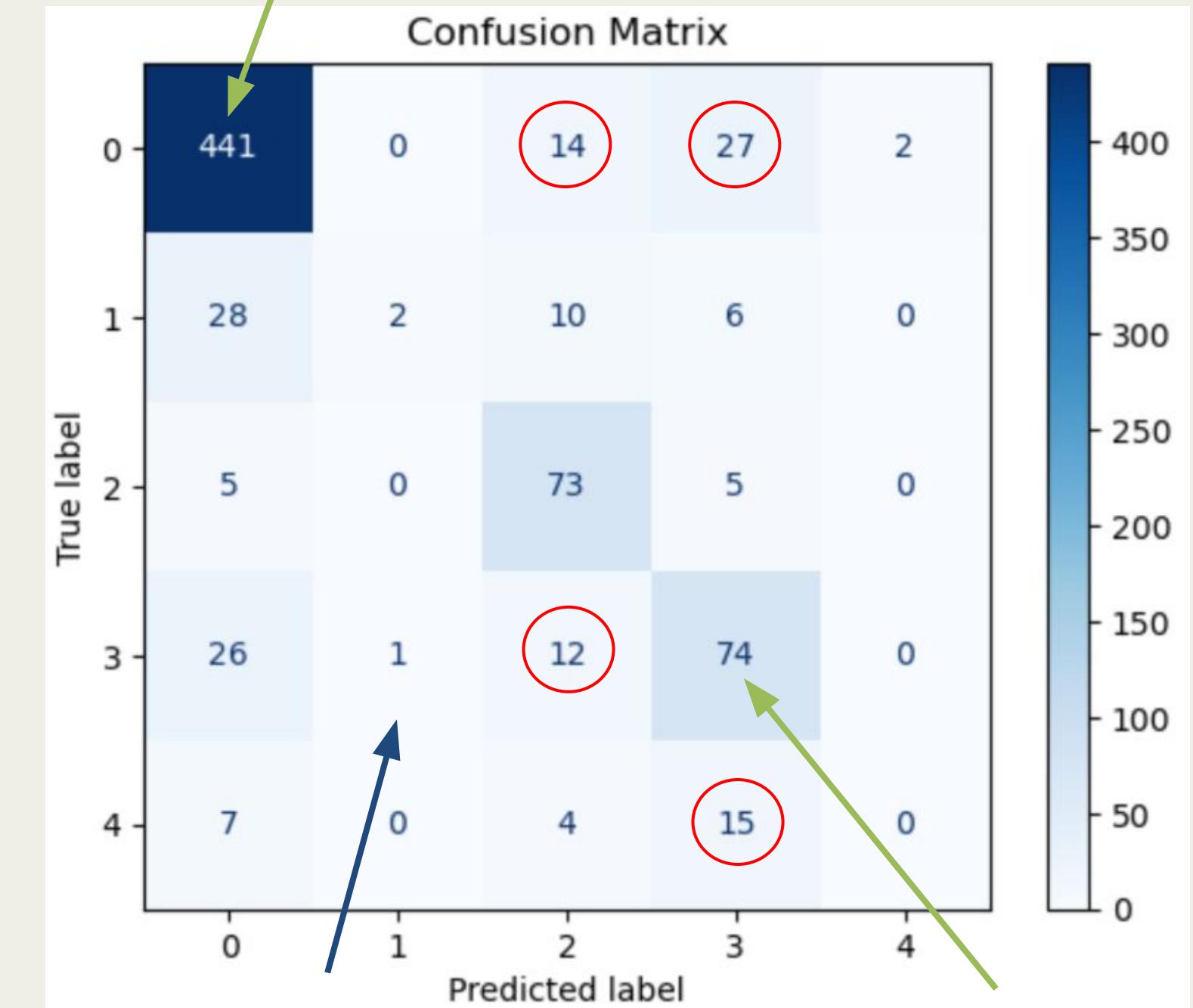
- Preprocessing
 - Modifying model to fit our situation
 - Training and testing the model
- Built based off xView3 pre-trained model
- Applied transfer learning





Operations Team- Model Accuracy

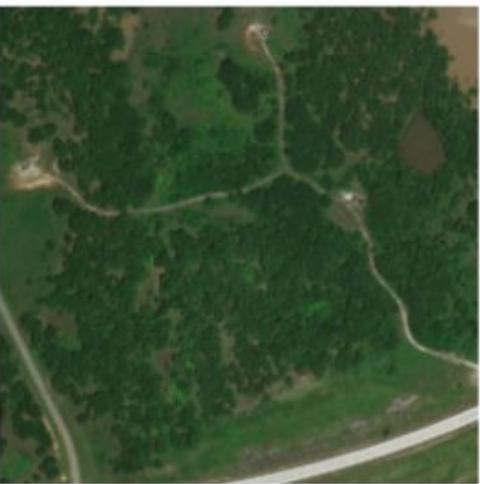
- CNN Model Accuracy: 78%
- Damage Level Classification:
 - 0 = None
 - 1 = Minor
 - 2 = Major
 - 3 = Destroyed
 - 4 = un-classified



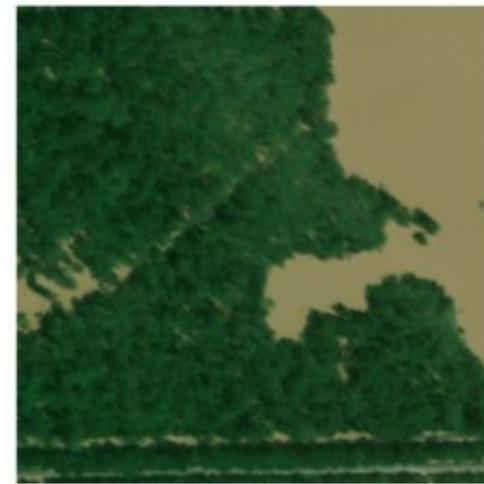


Operations Team - Model Results

Correctly Classified Images



Incorrectly Classified Images



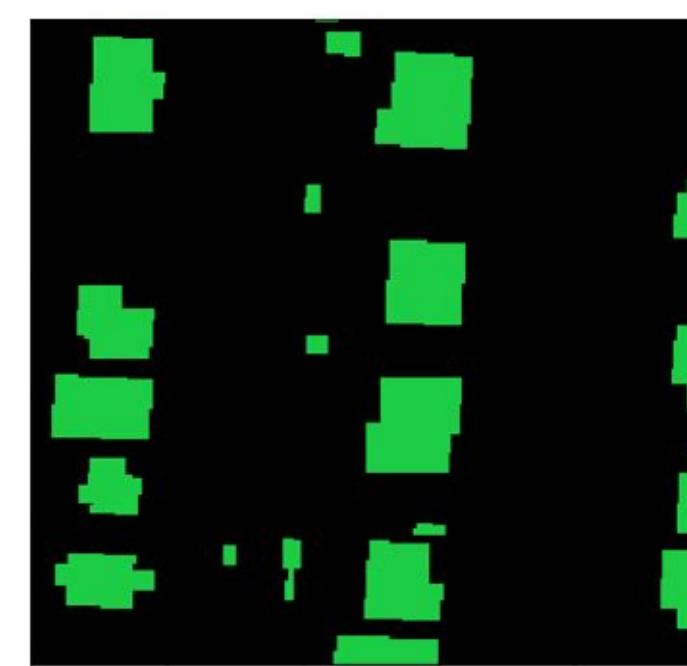
Segmentation Masks



gt_img_pre_val_id_21057



gt_img_post_val_id_21057



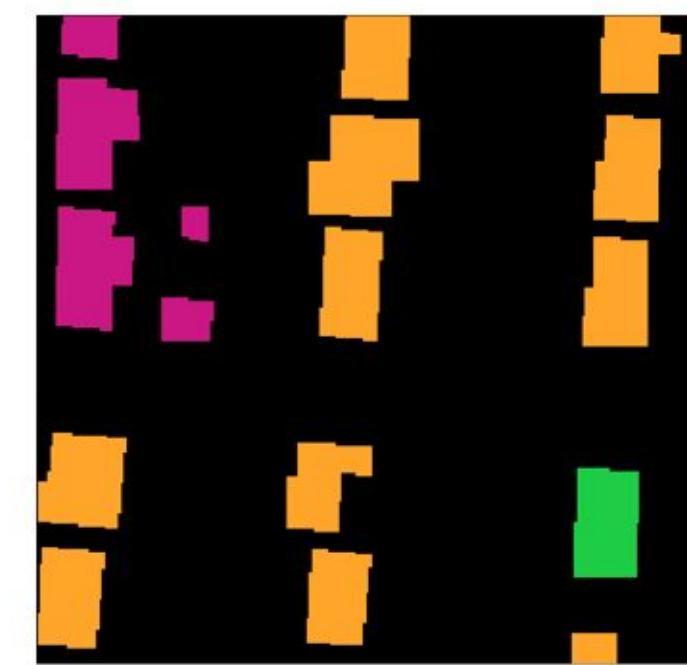
gt_dmg_mask_val_id_21057



gt_img_pre_val_id_21045



gt_img_post_val_id_21045



gt_dmg_mask_val_id_21045

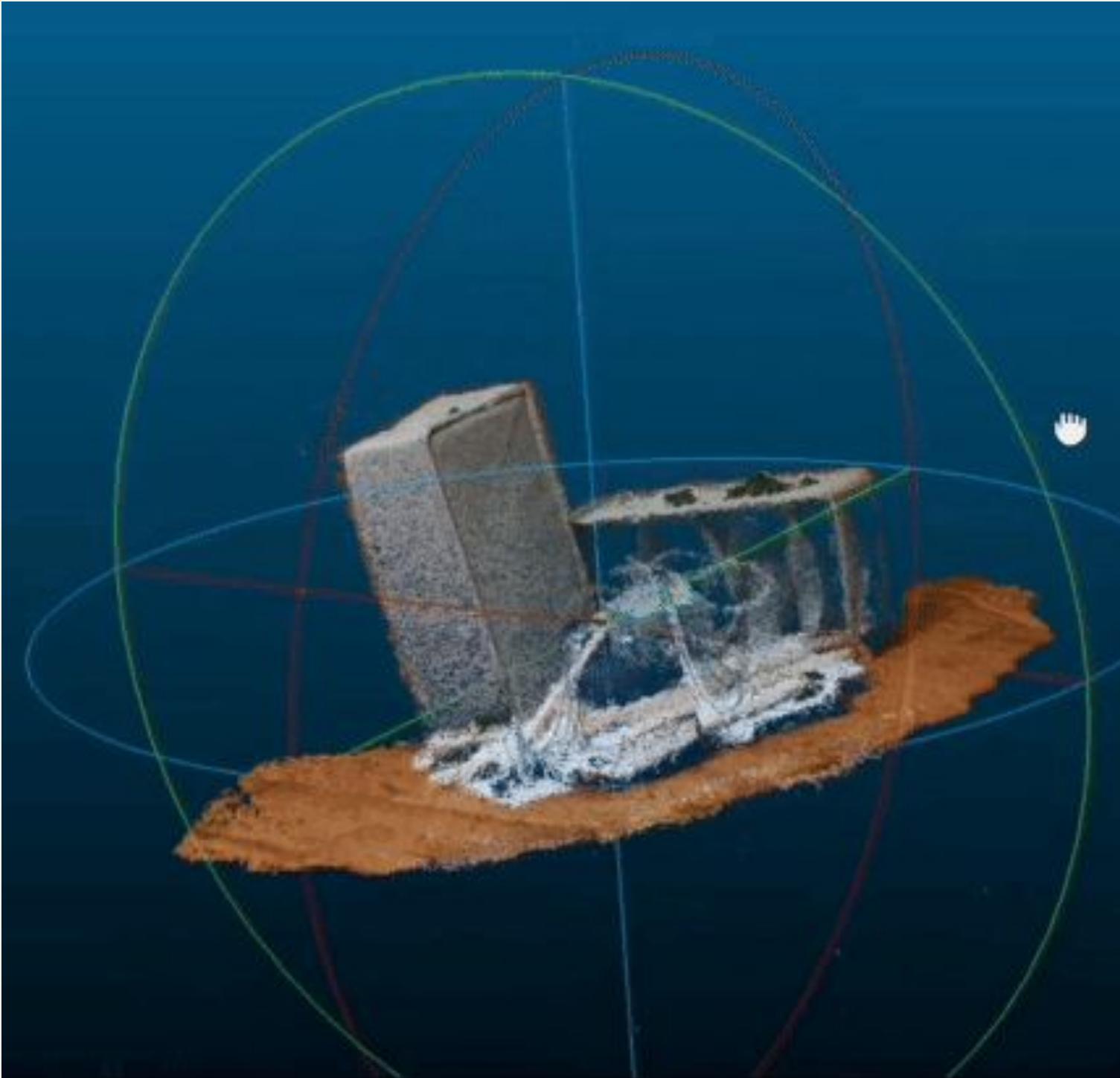
Categories

0	Background
1	No damage
2	Minor damage
3	Major damage
4	Destroyed

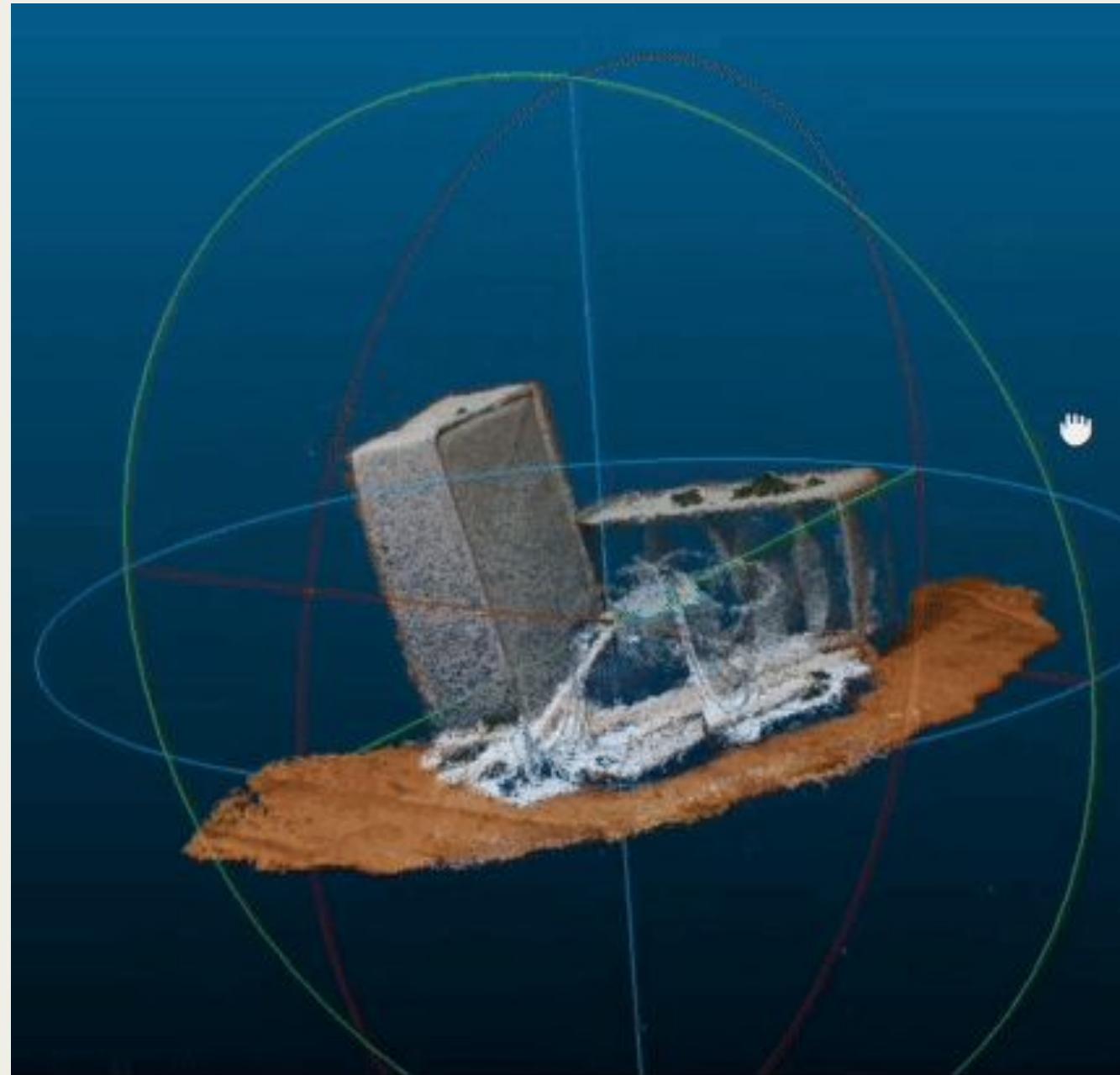
- Multi-class model = multi-level damage classification
- Severity of damage correlated with weather conditions



Operations Team- Disaster Response 3D Model



Operations Team- Disaster Response 3D Model



OpenSFM Model for Hurricane Damage

- Constructed using many overlapping 2D images at different angles.
- Advantages:
 - Easy to generate with open-source imagery
 - Accurate and aides dispatchers and rebuilders
- Use cases:
 - Pre-disaster Planning
 - Post-disaster First-Responders
- Challenges:
 - Loading model is extremely resource intensive so we used Cloud Compare software



Operations Team - Ship

A ship has gone missing near
Massachusetts!

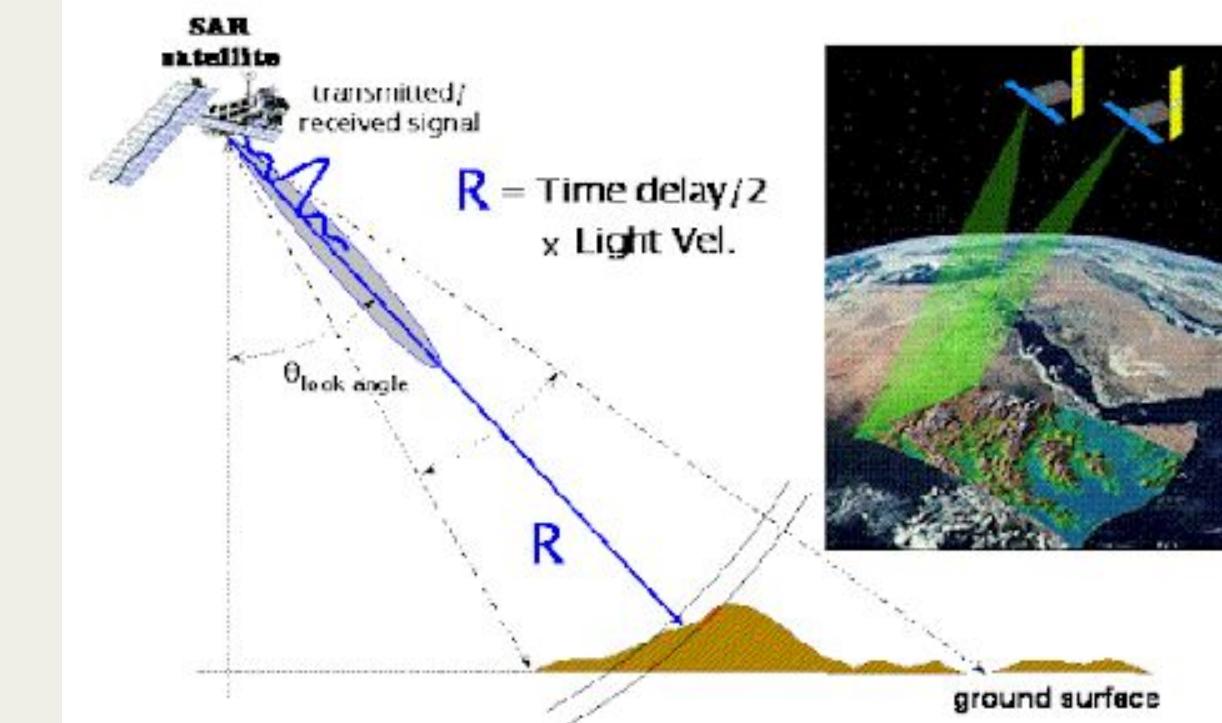
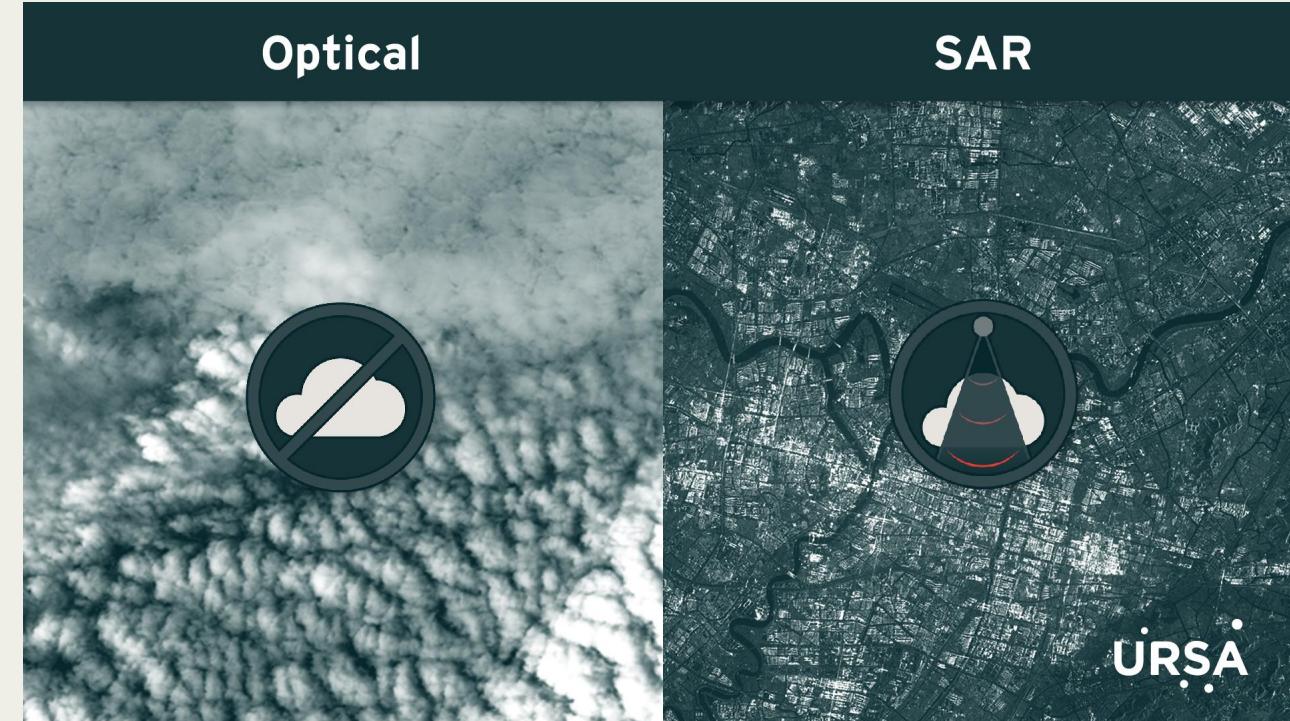


Operations Team - Ship

- Found using synthetic Aperture

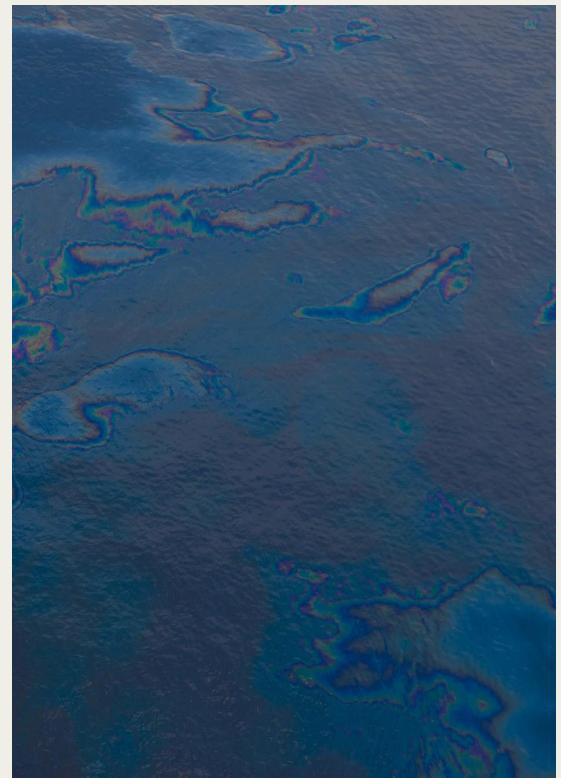
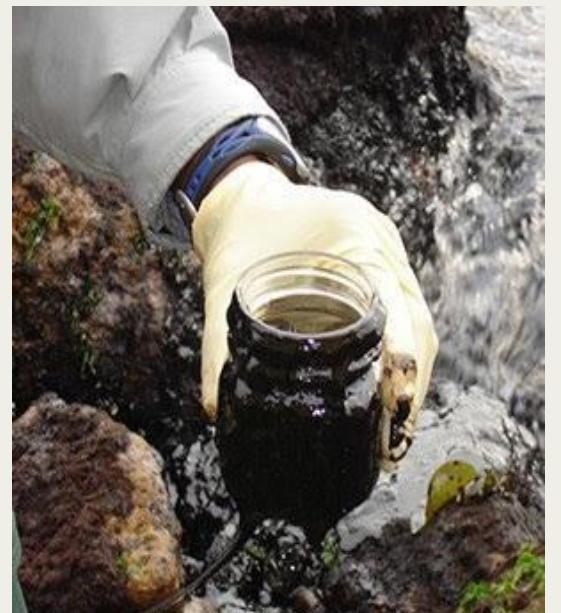
Radar (SAR) data

- Day & night
- Sees through clouds





Operations Team - Ship

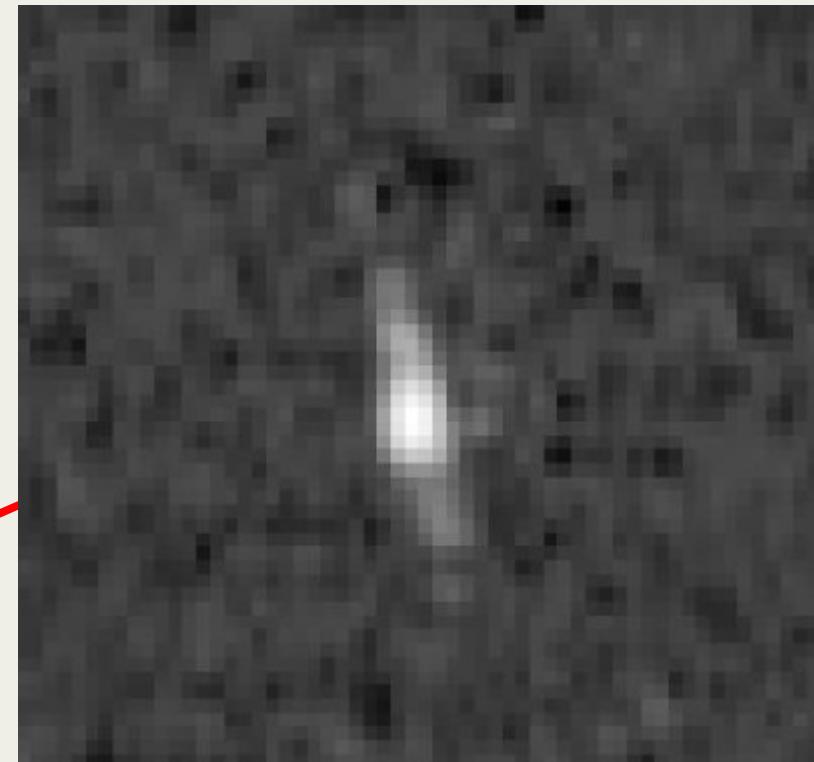
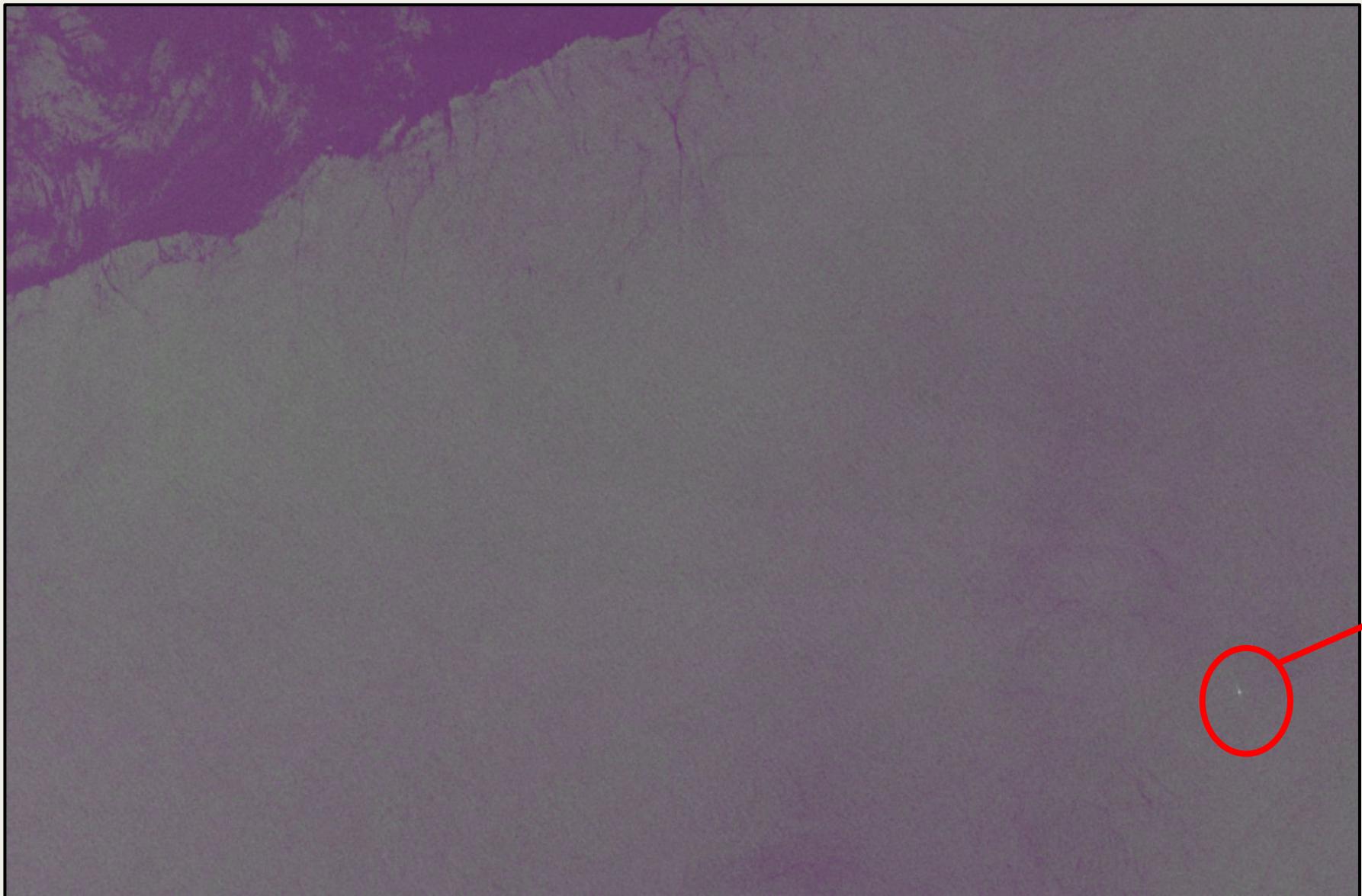


The missing ship is actually an oil tanker!!

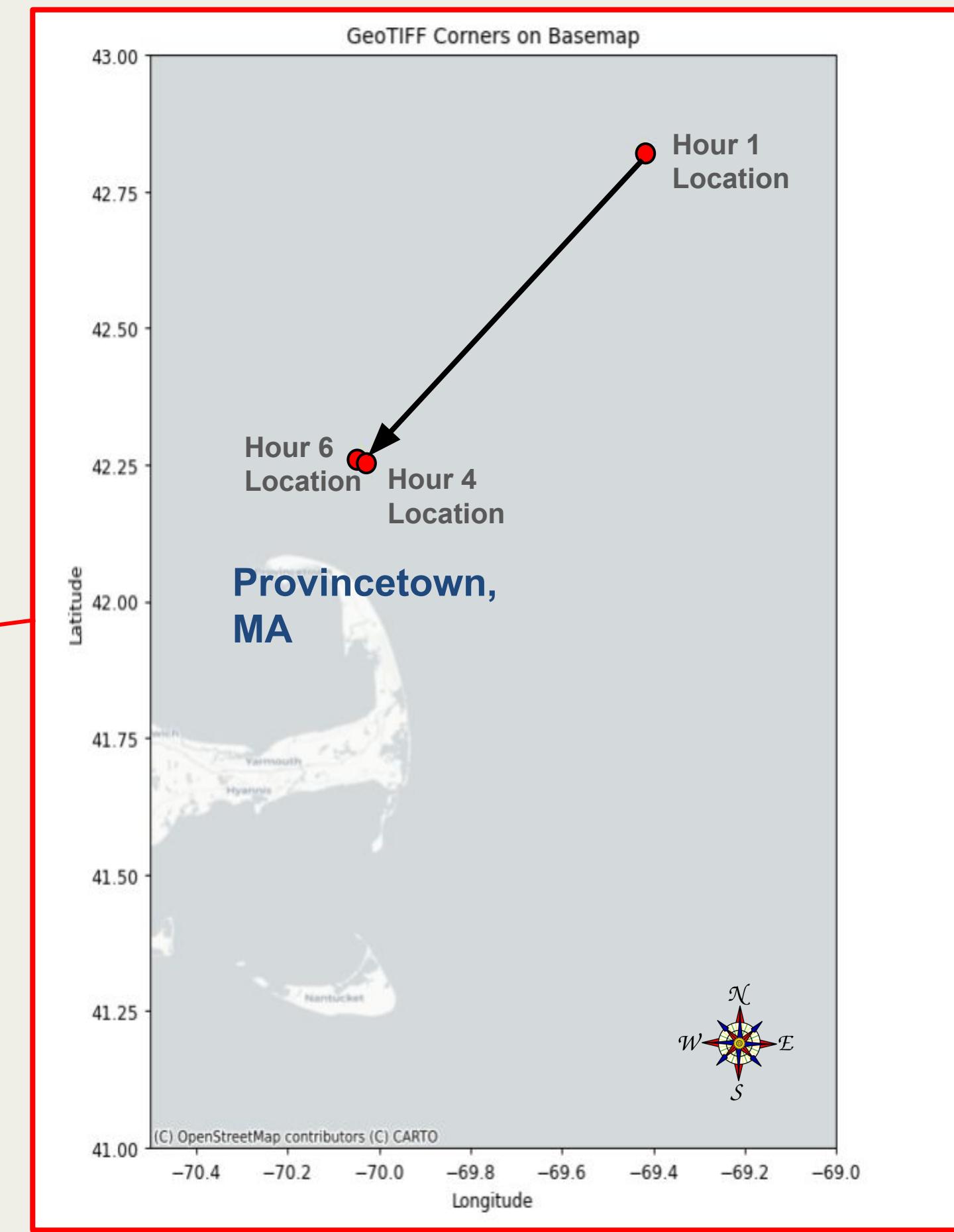
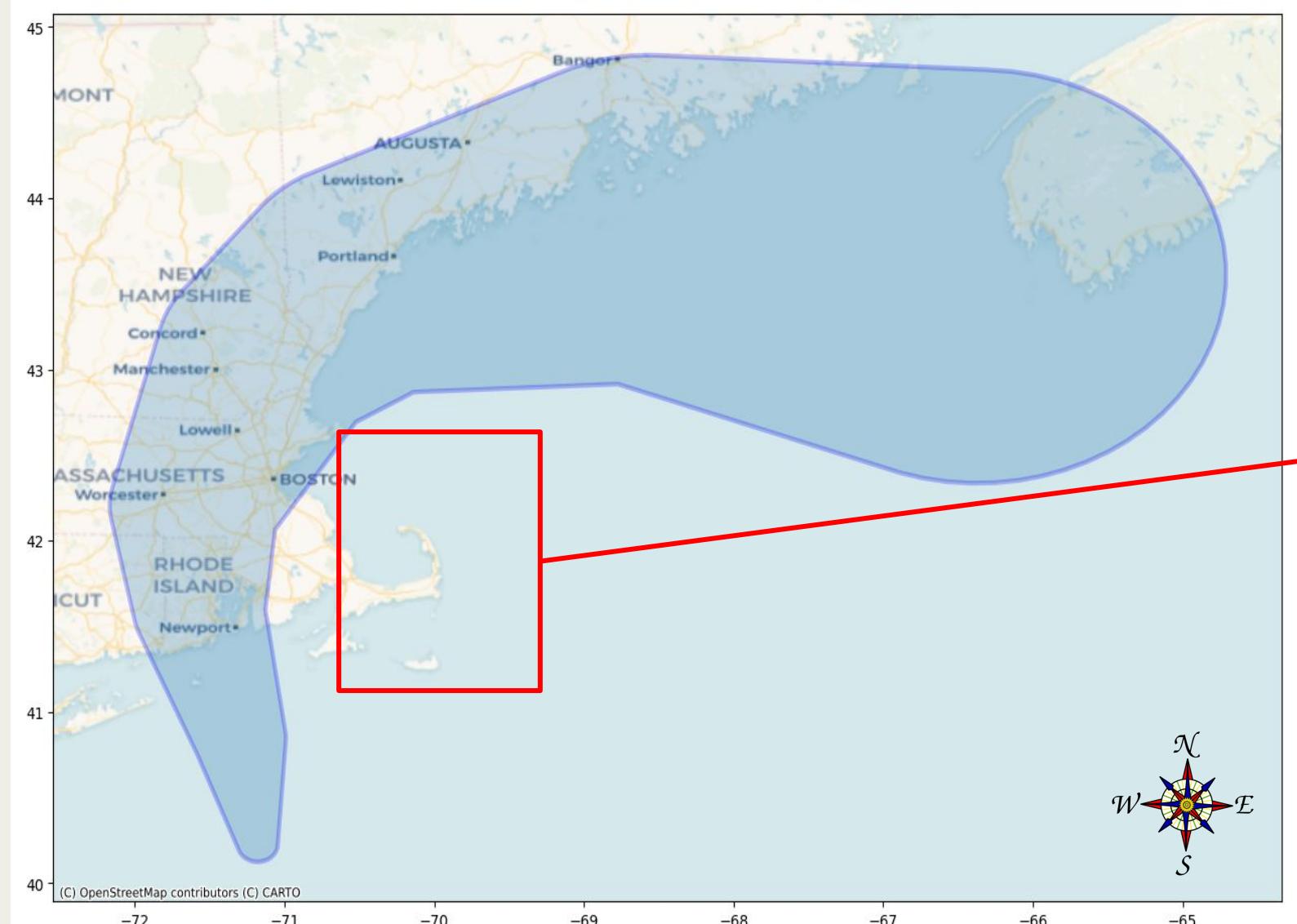


Operations Team - Ship Updates

- Used GDAL to locate the ship
- Located a white speck that could be the ship



Operations Team - Ship location





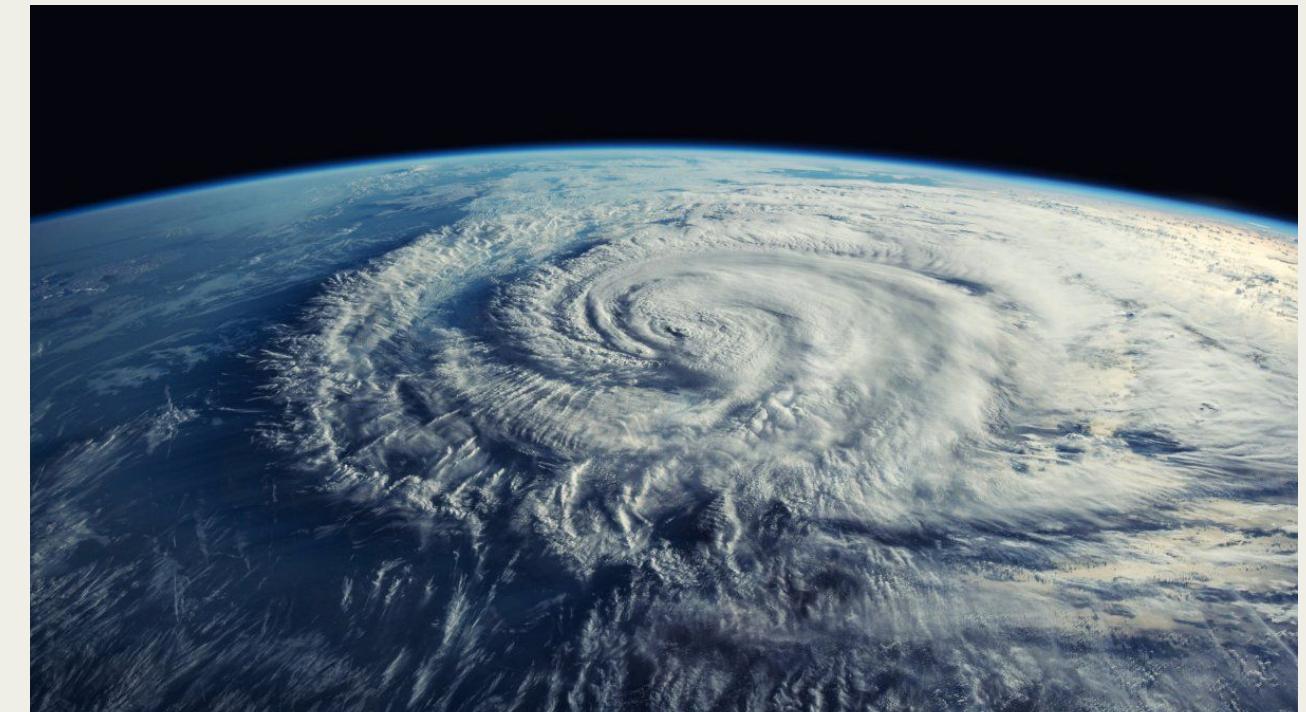
Operations Team - Challenges

Damage Classification Issues:

- Originally started with three models, narrowed down to one
- Difficulty extracting classifications from data
- Model overfitting, so tried optimization + played w/ hyperparameters

Ship Tracking Issues:

- Confirming the visual of the ship from SAR data
- Obtaining the exact locations of the ship after confirmation



Emphasis on our BWSI disaster response principles!

- Timeliness and Efficiency
- Empathy
- Equity
- Safety
- Neutrality
- Primum non nocere (first, do no harm)
- Transparency

Ultimately, our purpose is to protect life and health; to ensure respect for the human being.

Questions?



Thank you!

BWSI Remote Sensing

