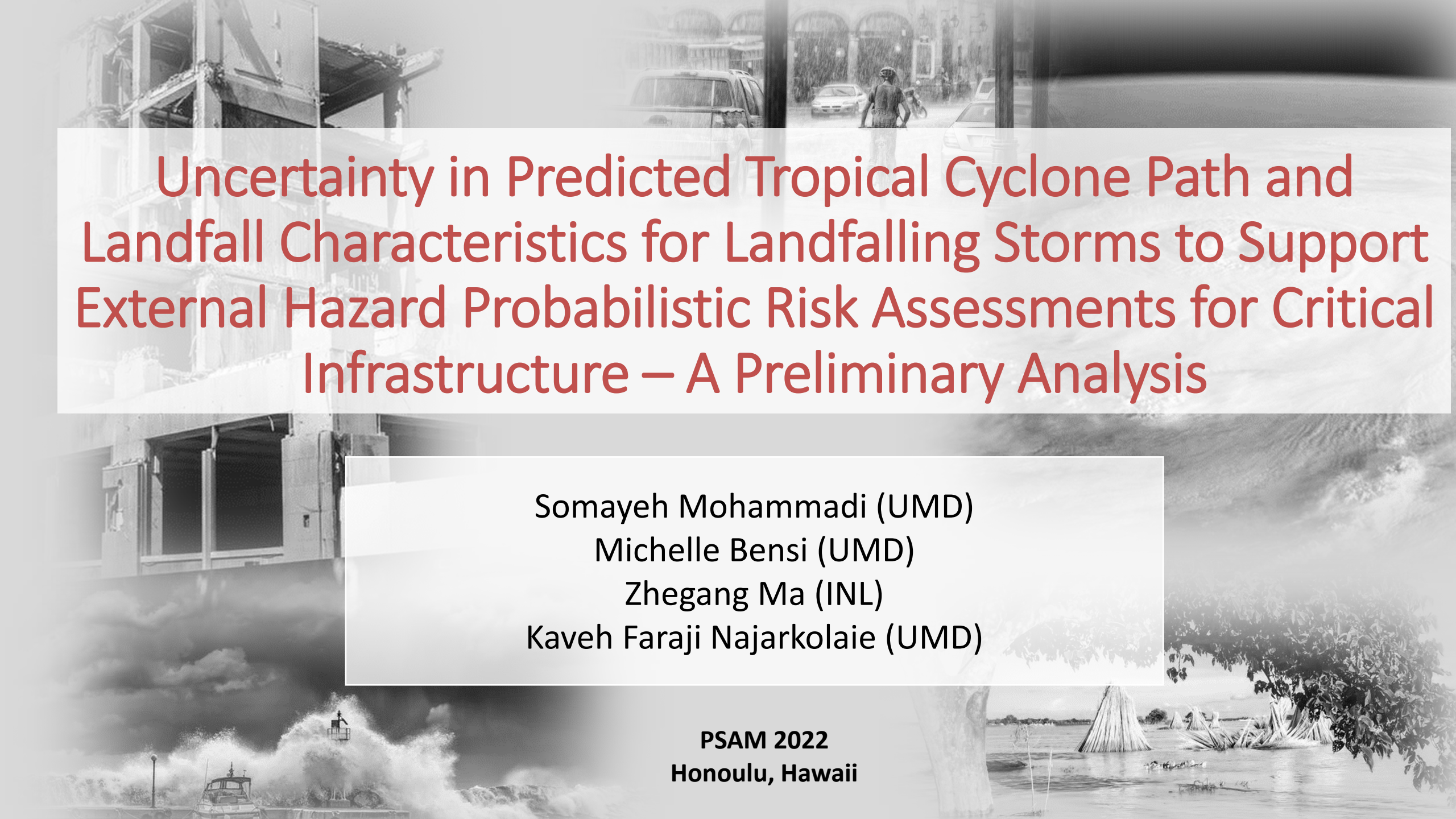

Uncertainty in Predicted Tropical Cyclone Path and Landfall Characteristics for Landfalling Storms to Support External Hazard Probabilistic Risk Assessments for Critical Infrastructure – A Preliminary Analysis

Somayeh Mohammadi (UMD)
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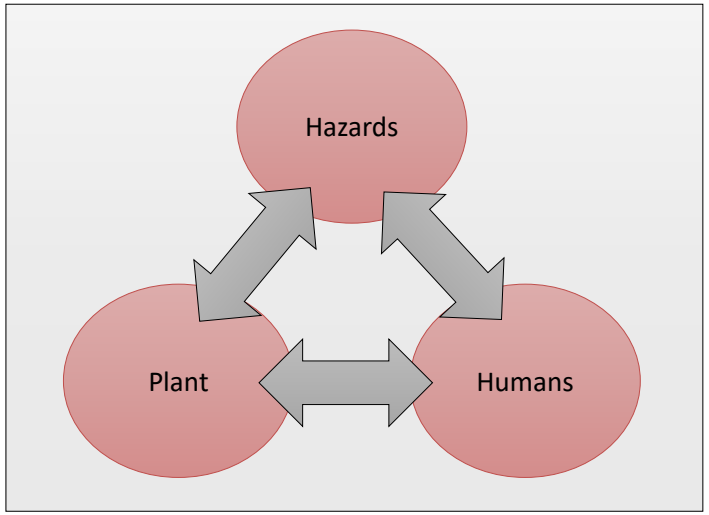
PSAM 2022
Honoulu, Hawaii

Identifying and Prioritizing Sources of Uncertainty in External Hazard Probabilistic Risk Assessment



Project Goals

Identify significant sources of uncertainty in XHPRA, with particular emphasis on how they relate to the frequency, severity and temporal evolution of hazard events

Isolate and assess the effects of key sources of uncertainty from the perspective of hazard severity, temporal evolution, physical event impacts, event progression, and interplay between human response and physical event impacts

Integrate insights related to key sources of uncertainty to develop a risk-informed process for prioritizing measures to reduce uncertainty

Research Execution

Research Thrust 1

Task 1: Stakeholder Outreach and Development of Uncertainty Taxonomy

Research Thrust 2

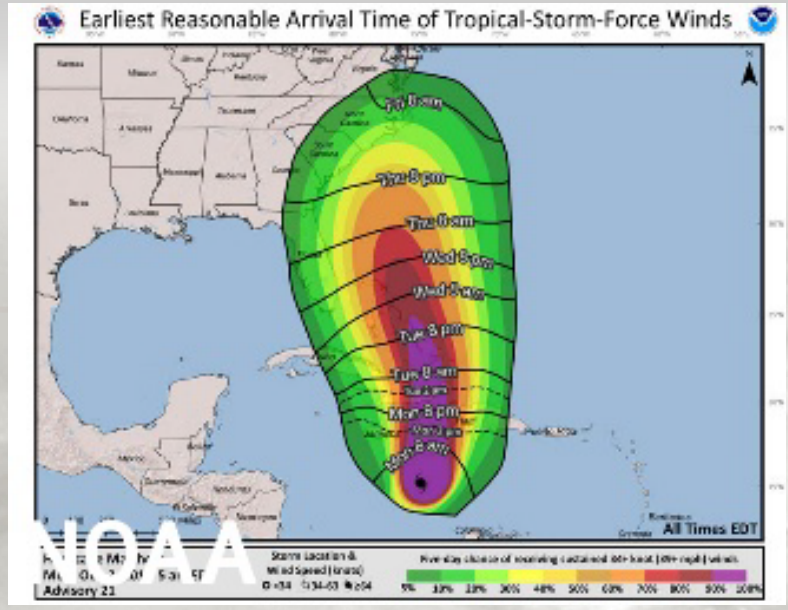
Task 2: Hazard Uncertainty Characterization and Data Analysis

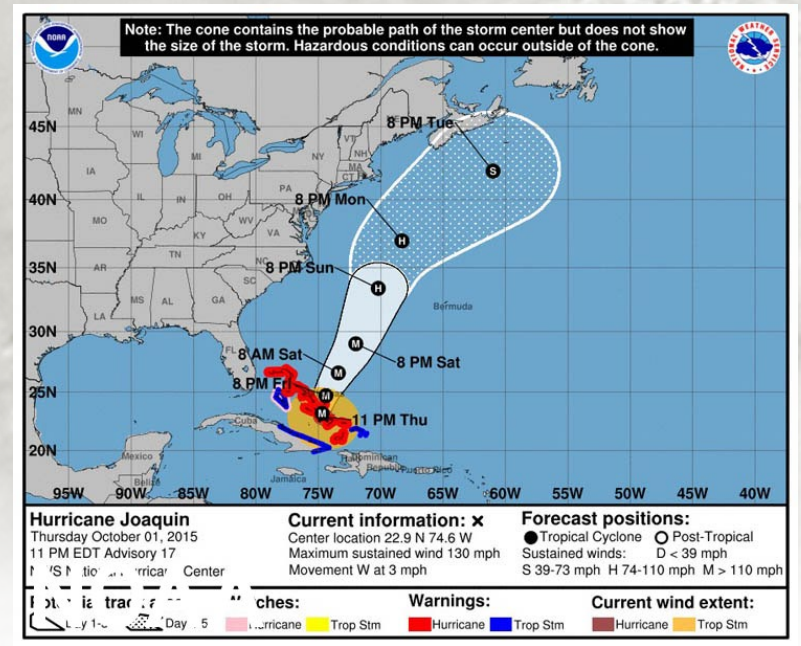
Task 3: Assessment of Uncertainty in Scenario Development

Task 4: Characterization of Uncertainty in Human Response Under Physical Effects

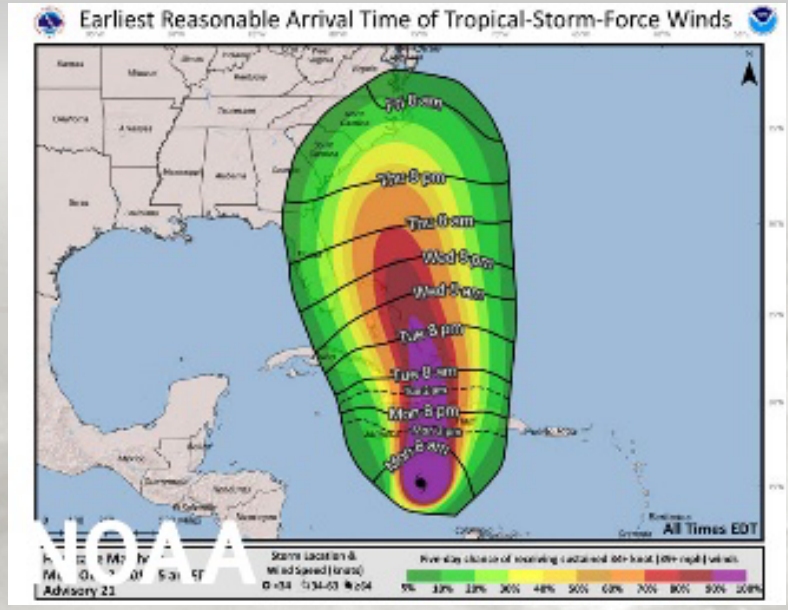
Research Thrust 3

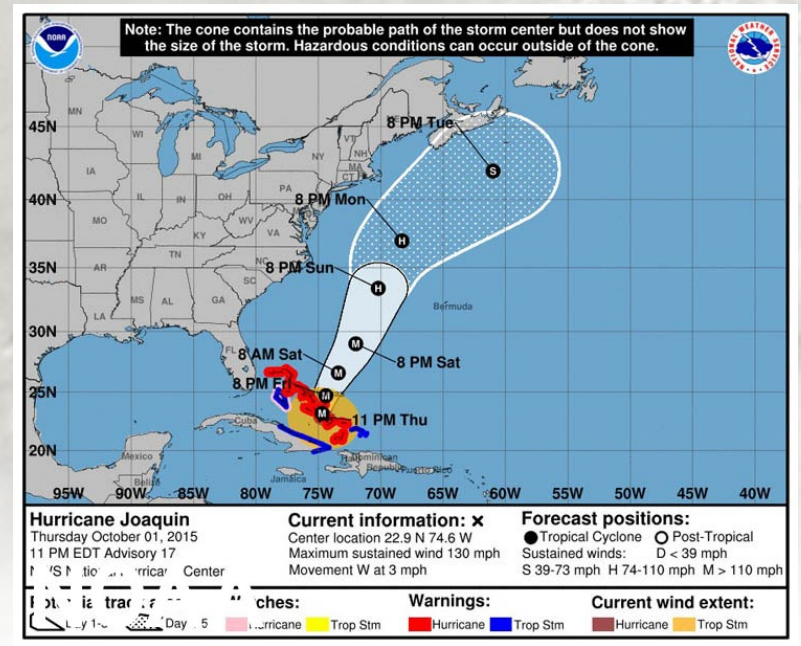
Task 5: Integration & Development of Method for Prioritization of XHPRA Uncertainties





Source: https://www.noaa.gov/news/what-s-new-in-hurricane-forecasting





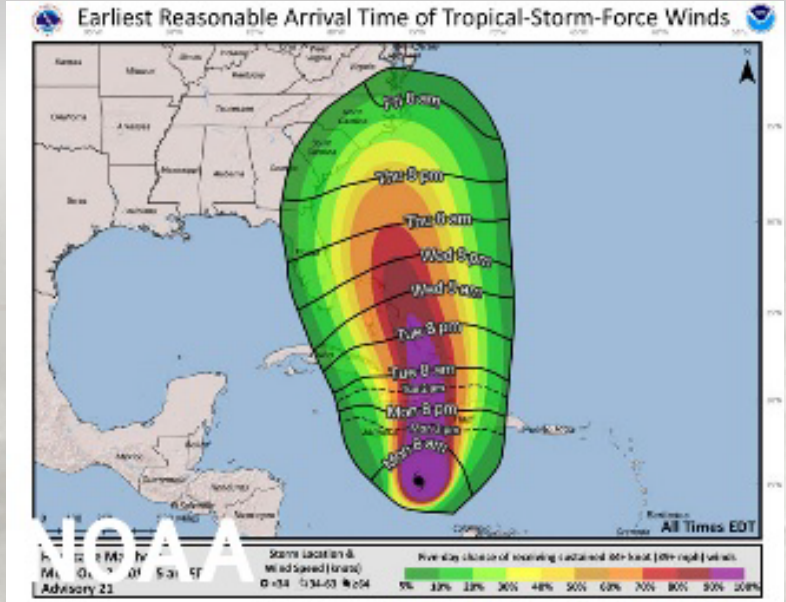
Storm Forecast

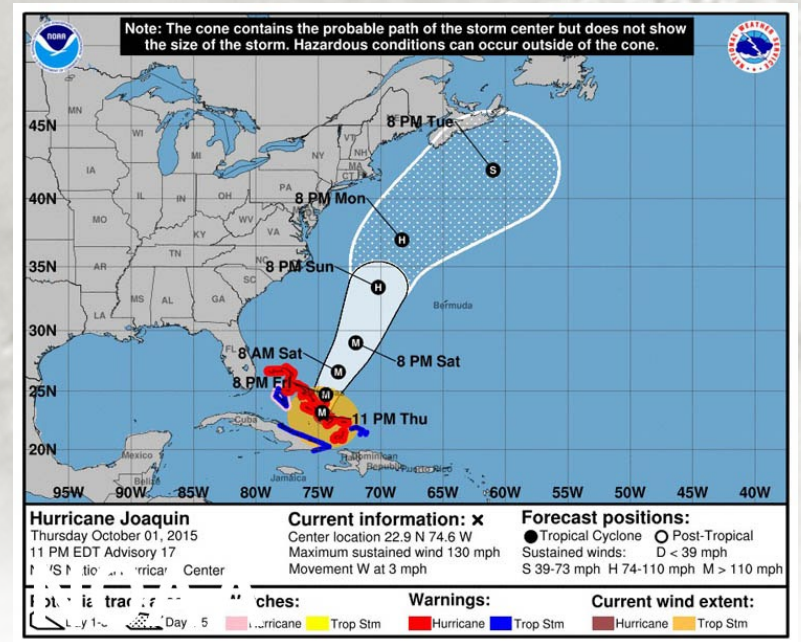
Uncertainty associated with the time available to implement actions

Decisions to Implement Actions

Execution of Actions

Source: https://www.noaa.gov/news/what-s-new-in-hurricane-forecasting





Storm Forecast

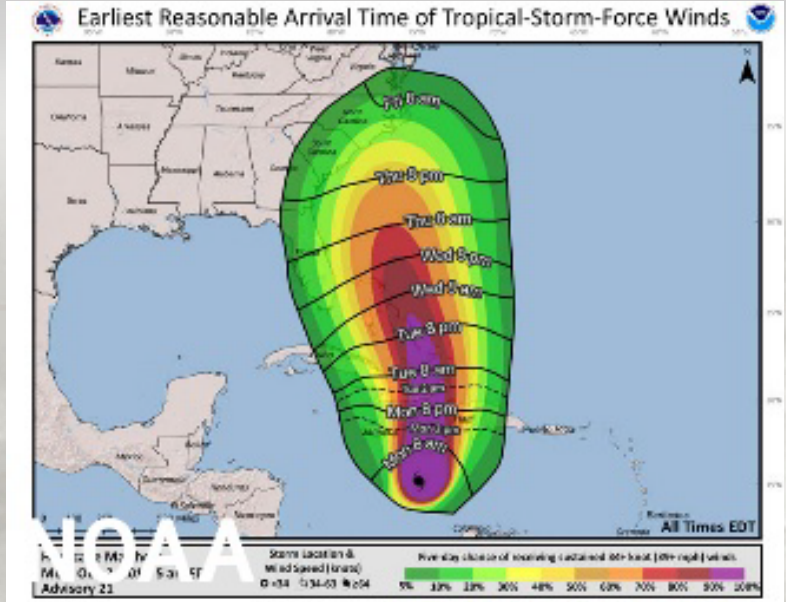
Uncertainty associated with the time available to implement actions

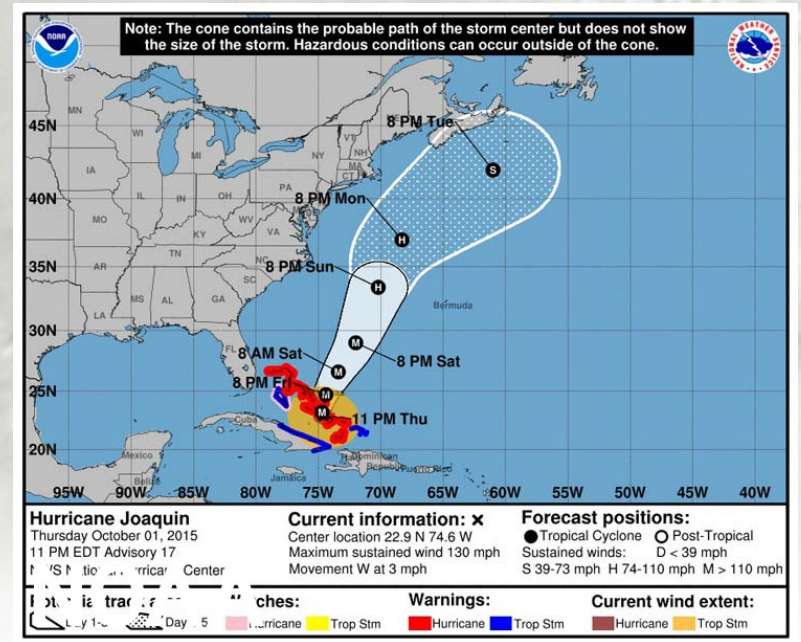
Decisions to Implement Actions

Execution of Actions

Seek to understand difference between assumed time available and actual time available

Source: https://www.noaa.gov/news/what-s-new-in-hurricane-forecasting





Storm Forecast

Uncertainty associated with the time available to implement actions

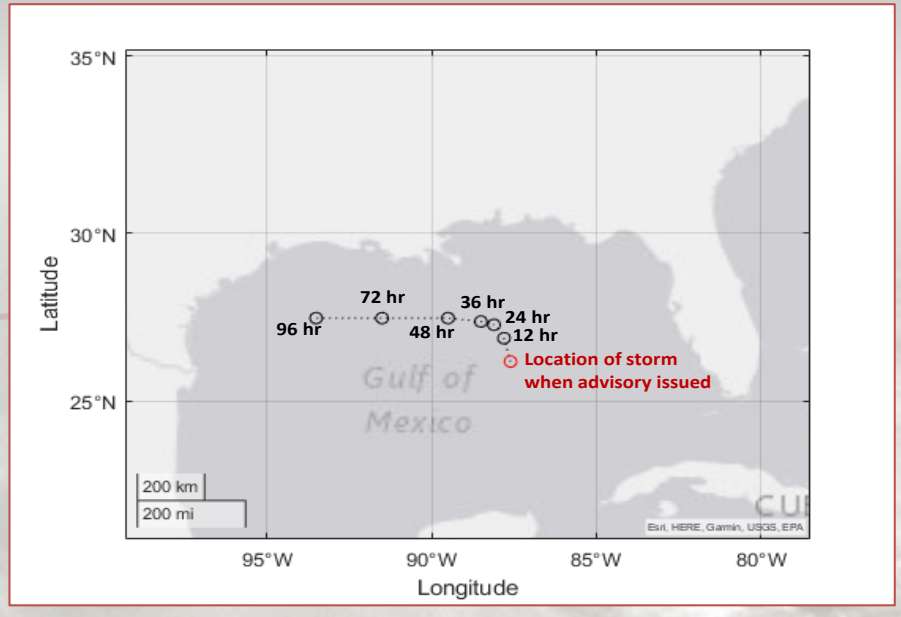
Decisions to Implement Actions

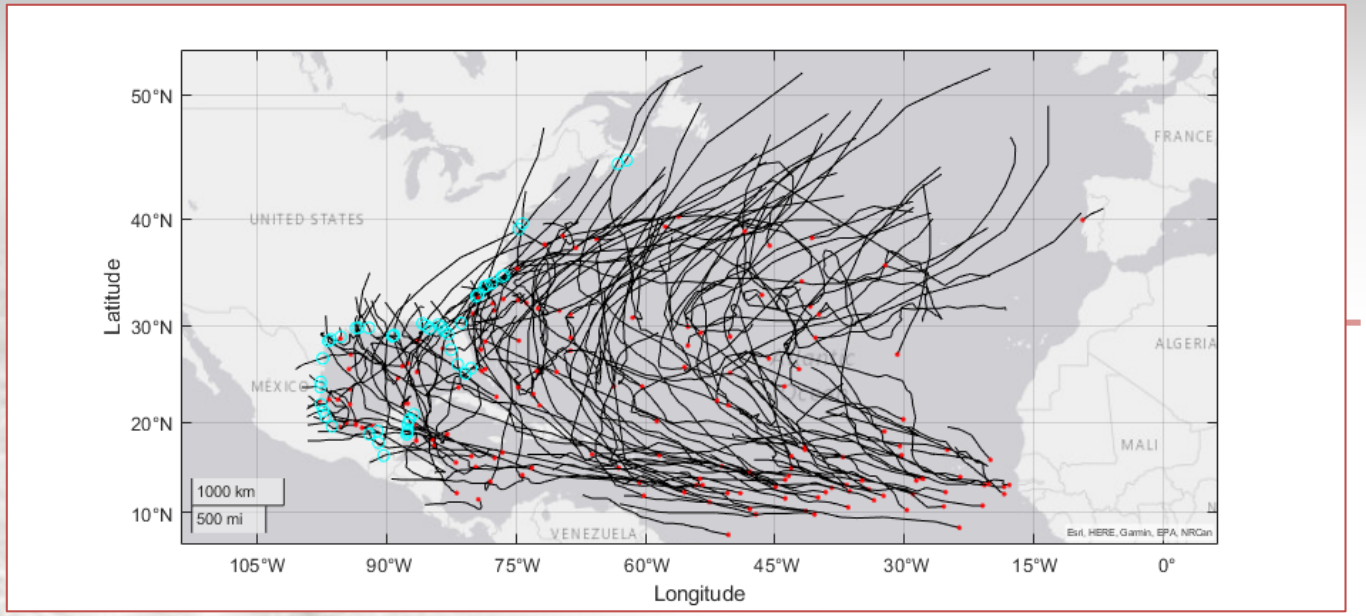
Execution of Actions

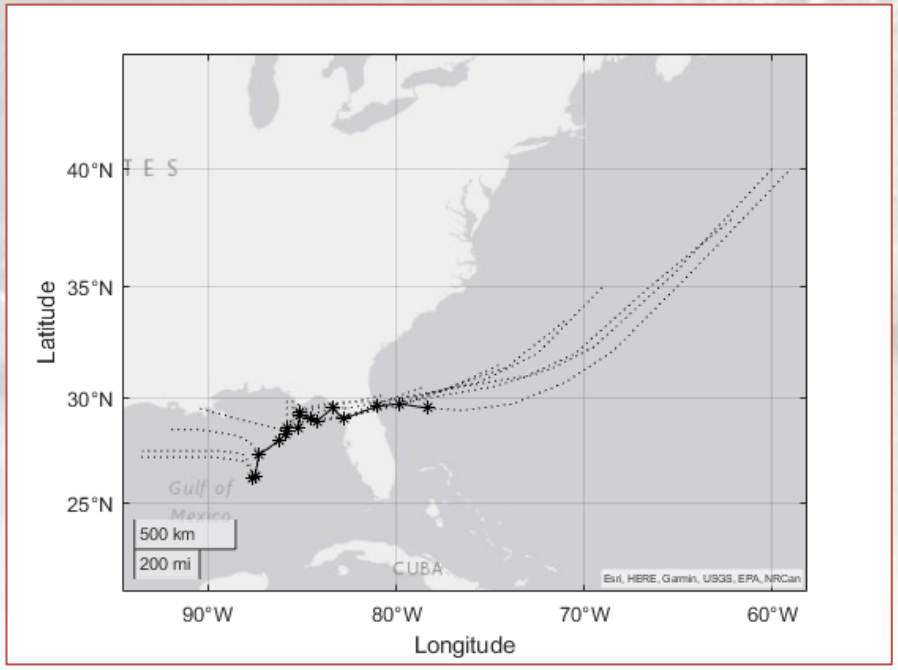
Seek to understand difference between assumed time available and actual time available

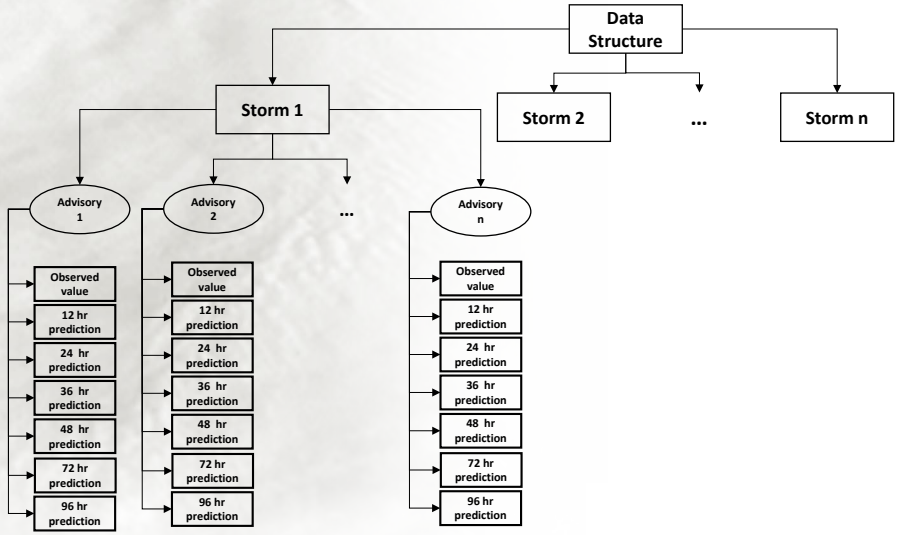
There have not been systematic assessments of uncertainties associated with TC forecasts in a manner amenable to characterizing uncertainties required for an XHPRA for NPPs.

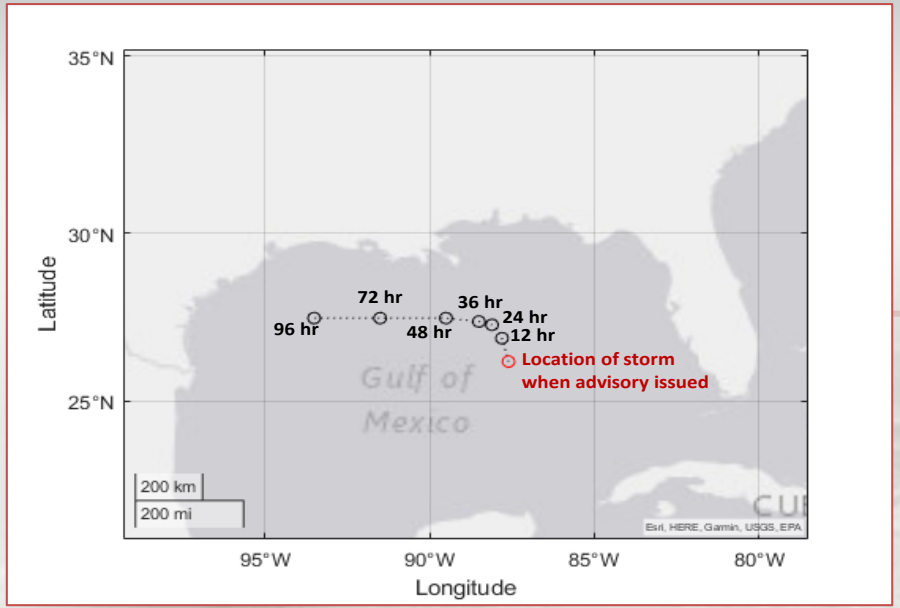
Source: https://www.noaa.gov/news/what-s-new-in-hurricane-forecasting

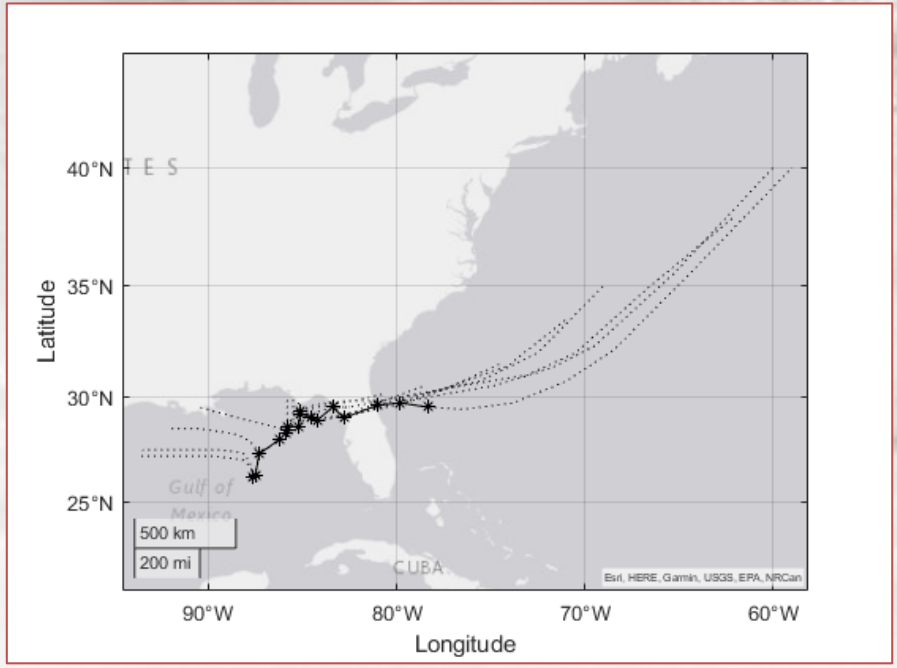

35°N
30°N
25°N
Latitude
72 hr
36 hr
96 hr
48 hr
24 hr
12 hr
Location of storm
when advisory issued
Gulf of
Mexico
200 km
200 mi
Esri, HERE, Garmin, USGS, EPA
95°W
90°W
85°W
80°W
Longitude


50°N
40°N
30°N
20°N
10°N
Latitude
UNITED STATES
MÉXICO
VENEZUELA
FRANCE
ALGERIA
MALI
1000 km
500 mi
Esri, HERE, Garmin, EPA, NRCan
105°W
90°W
75°W
60°W
45°W
30°W
15°W
0°
Longitude


40°N
35°N
30°N
25°N
Latitude
Gulf of
Mexico
CUBA
500 km
200 mi
Esri, HERE, Garmin, USGS, EPA, NRCan
90°W
80°W
70°W
60°W
Longitude


Data Structure
Storm 1
Storm 2
...
Storm n
Advisory 1
Advisory 2
...
Advisory n
Observed value
12 hr prediction
24 hr prediction
36 hr prediction
48 hr prediction
72 hr prediction
96 hr prediction



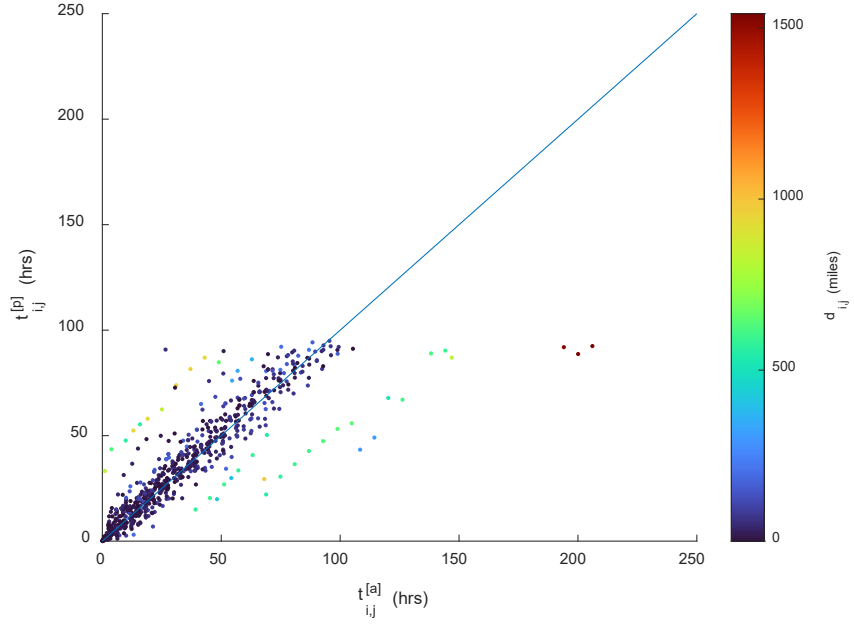


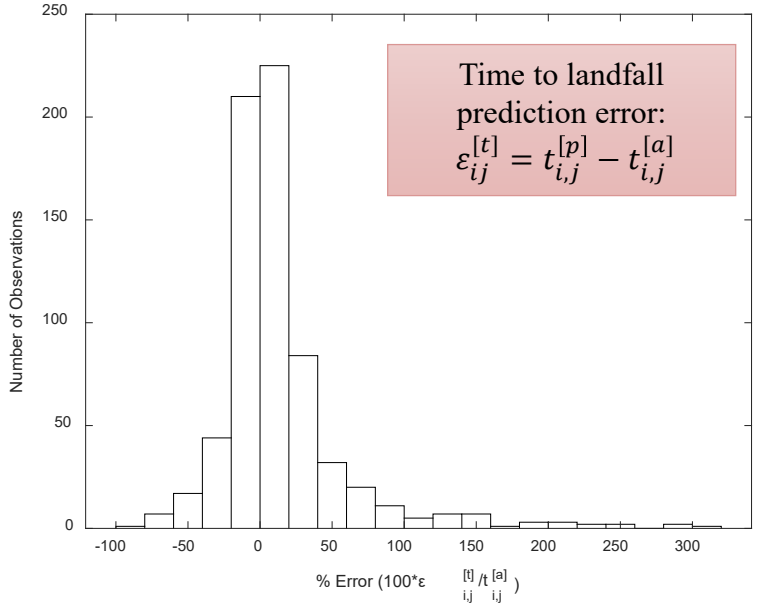
For each landfalling storm i and each associated storm advisory

- $t_{i,j}^{[a]}$ =the time elapsed between the issuance of advisory j for storm i and the interpolated observed landfall time of storm i (hours)
- $t_{i,j}^{[p]}$ =the time elapsed between the issuance of advisory j for storm i and the interpolated time of landfall (based on the predicted storm track) for storm i and advisory j (hours)
- $w_i^{[a]}$ = interpolated observed wind speed at landfall for storm i (mph)
- $w_{i,j}^{[p]}$ = interpolated predicted wind speed at landfall from advisory j for storm i (mph)
- $d_{i,j}$ = distance between the interpolated observed landfall location of storm i and the interpolated predicted landfall location of storm i from advisory j for storm i (miles)

Time to landfall prediction error: $\varepsilon_{ij}^{[t]} = t_{i,j}^{[p]} - t_{i,j}^{[a]}$

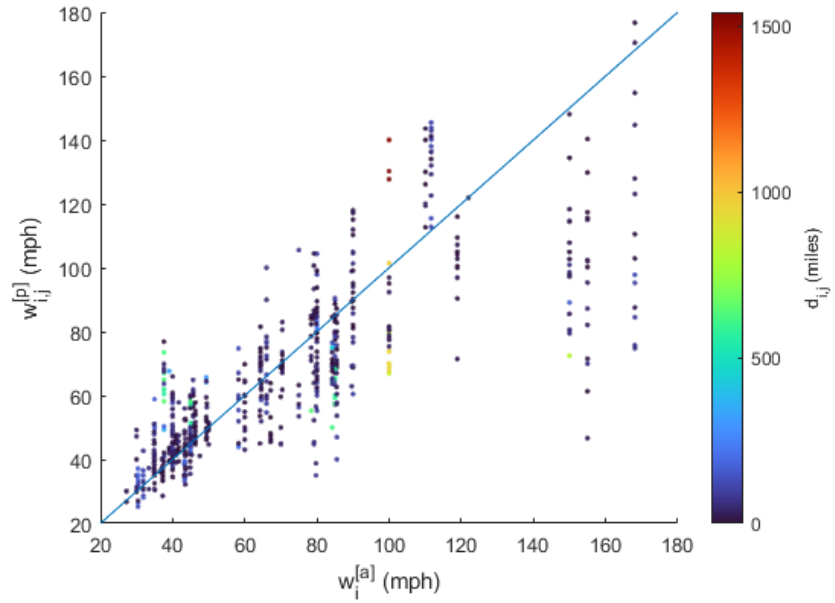
Landfall wind speed prediction error: $\varepsilon_{ij}^{[w]} = w_{i,j}^{[p]} - w_i^{[a]}$

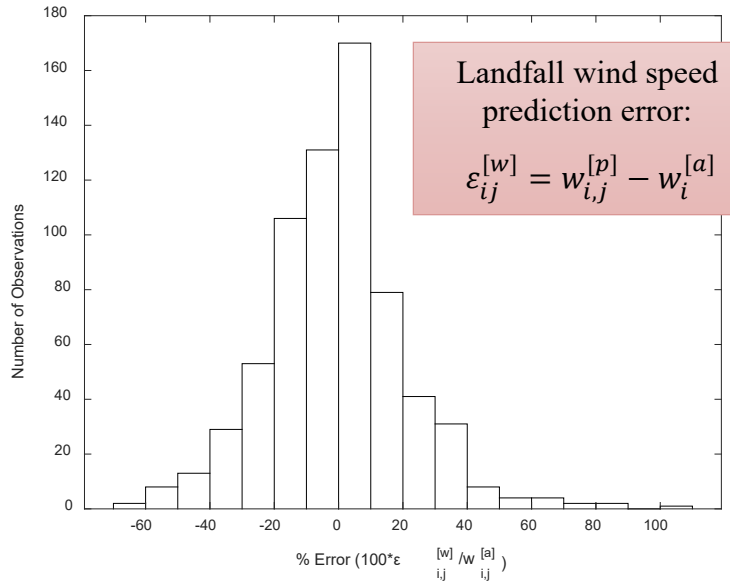




Time to landfall prediction error:

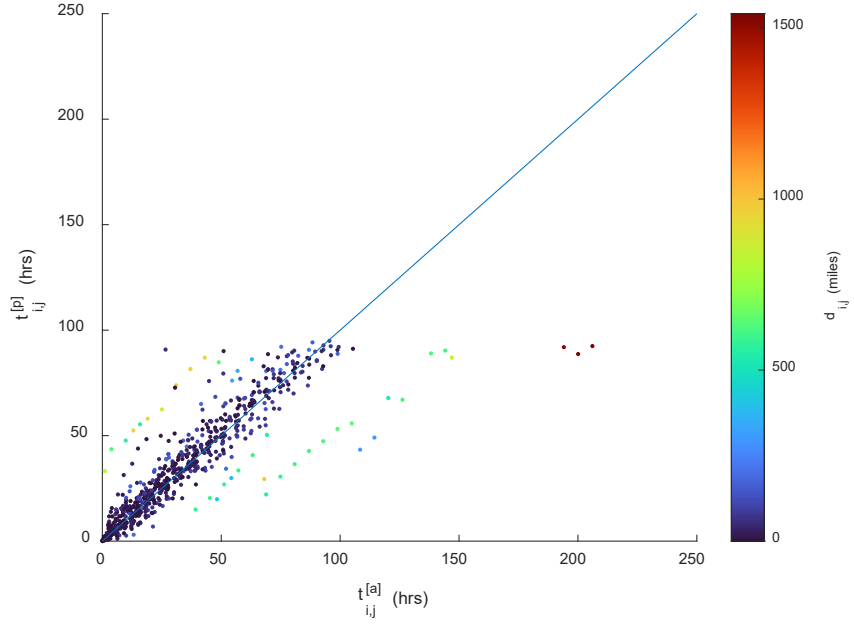
$$\varepsilon_{ij}^{[t]} = t_{i,j}^{[p]} - t_{i,j}^{[a]}$$

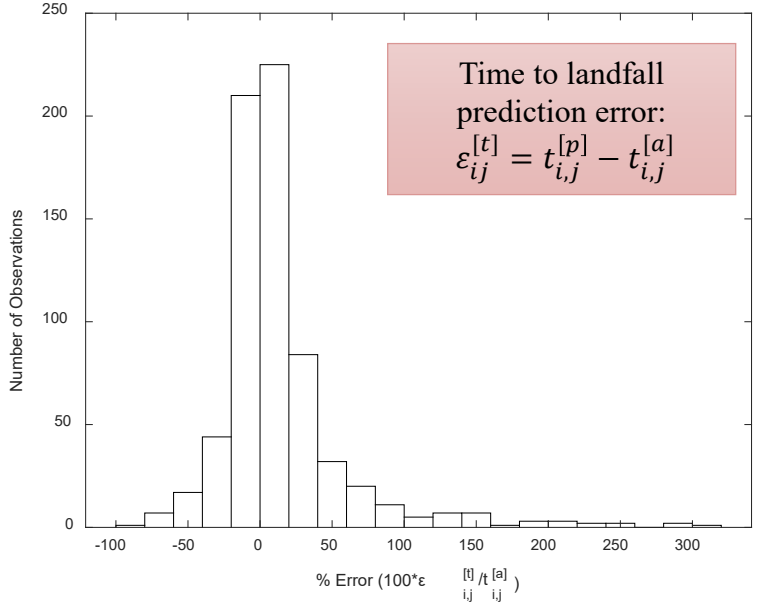


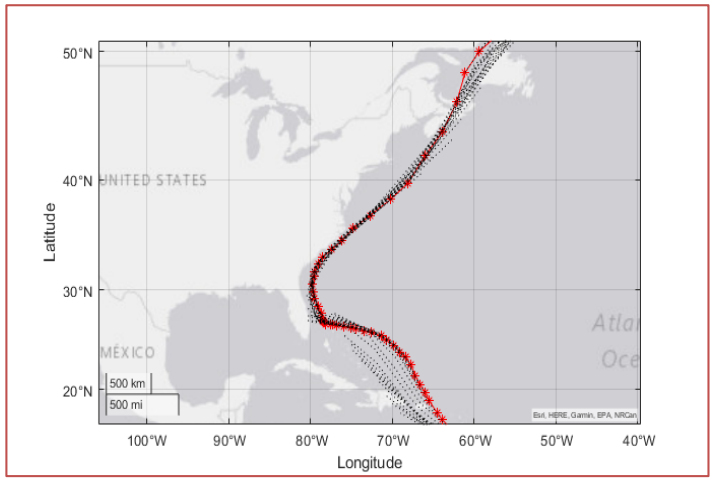


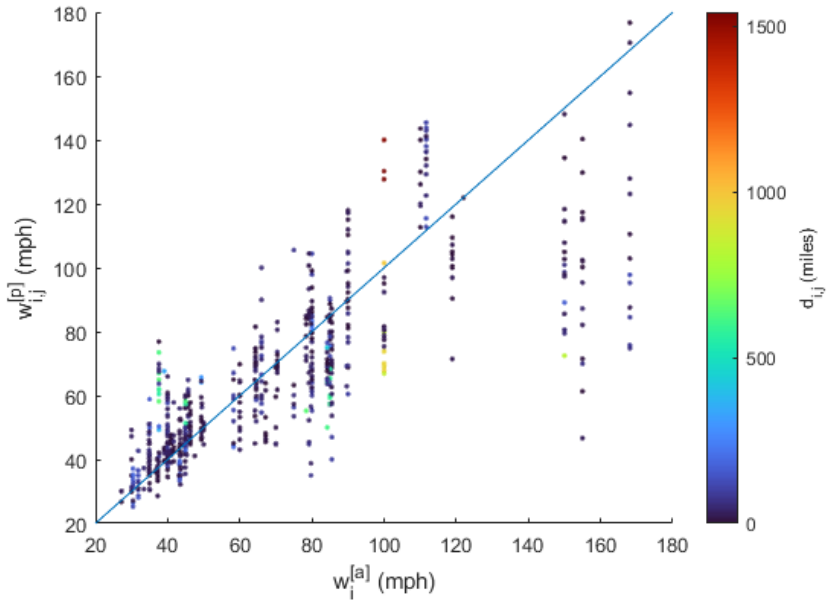
Landfall wind speed prediction error:

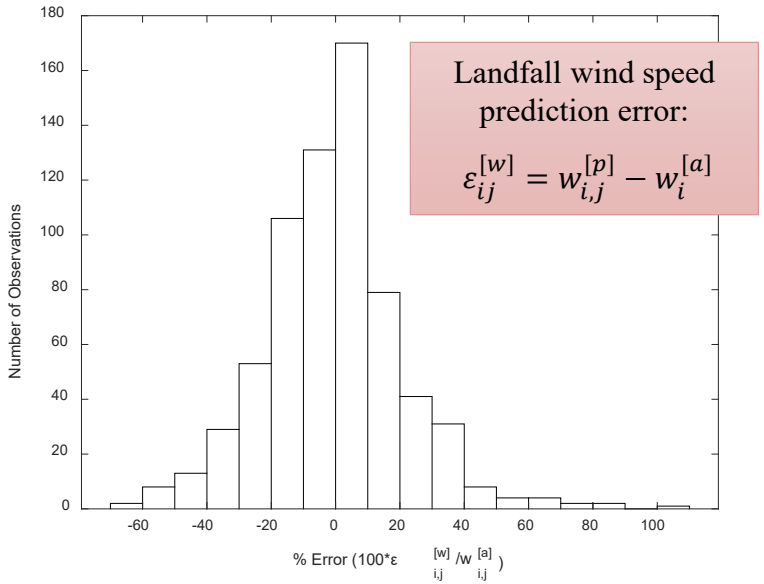
$$\varepsilon_{ij}^{[w]} = w_{i,j}^{[p]} - w_{i}^{[a]}$$

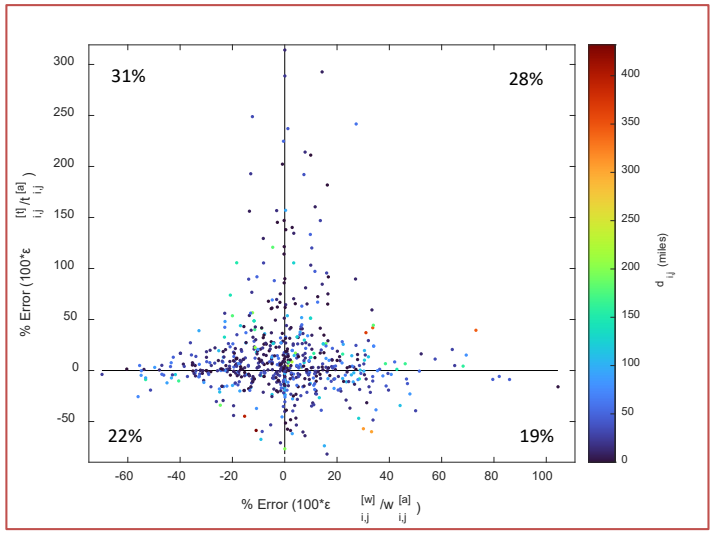

250
200
150
100
50
0
0
50
100
150
200
250
1500
1000
500
0
t [p] i,j (hrs)
t [a] i,j (hrs)
d i,j (miles)

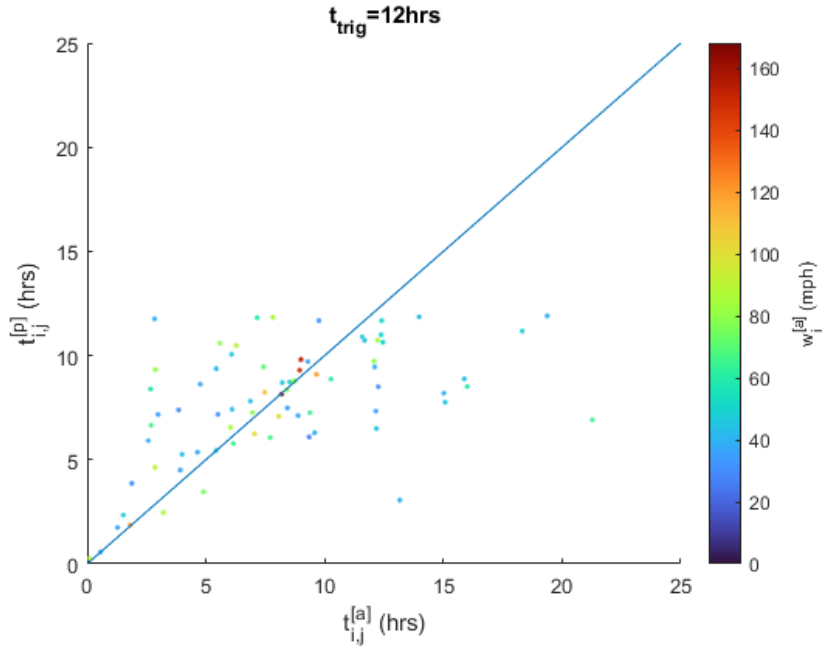

Time to landfall prediction error:
$\varepsilon_{ij}^{[t]} = t_{i,j}^{[p]} - t_{i,j}^{[a]}$
Number of Observations
% Error (100*ε [t] i,j /t [a] i,j)

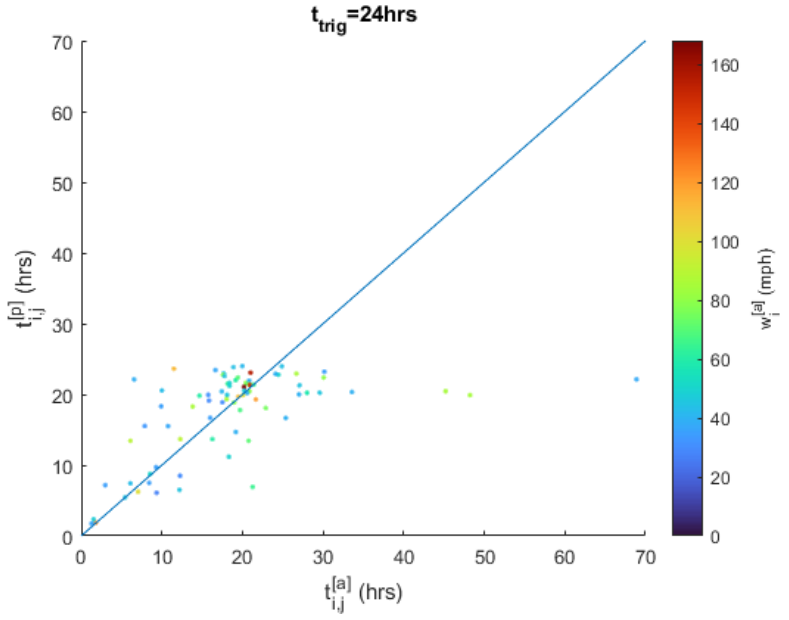

50°N
40°N
30°N
20°N
UNITED STATES
MÉXICO
500 km
500 mi
100°W
90°W
80°W
70°W
60°W
50°W
40°W
Latitude
Longitude

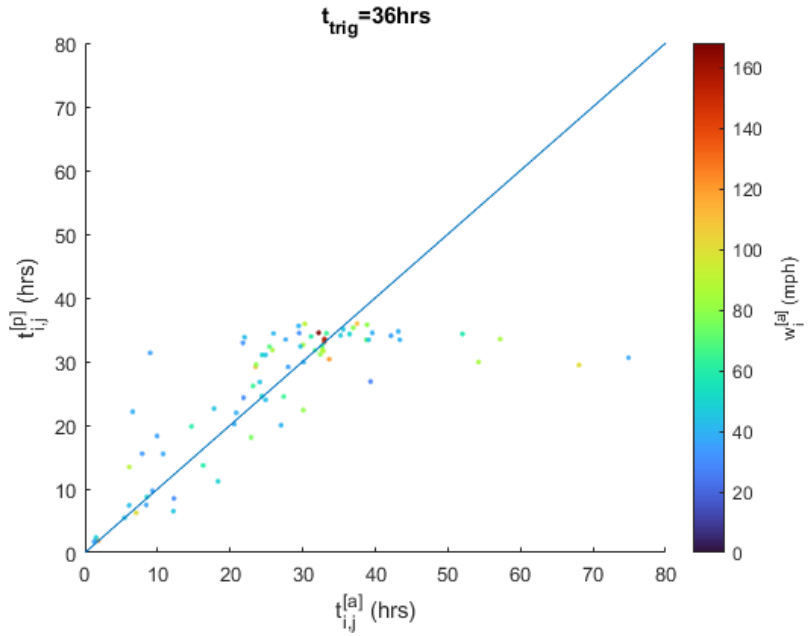

180
160
140
120
100
80
60
40
20
20
40
60
80
100
120
140
160
180
1500
1000
500
0
w [p] i,j (mph)
w [a] i (mph)
d i,j (miles)

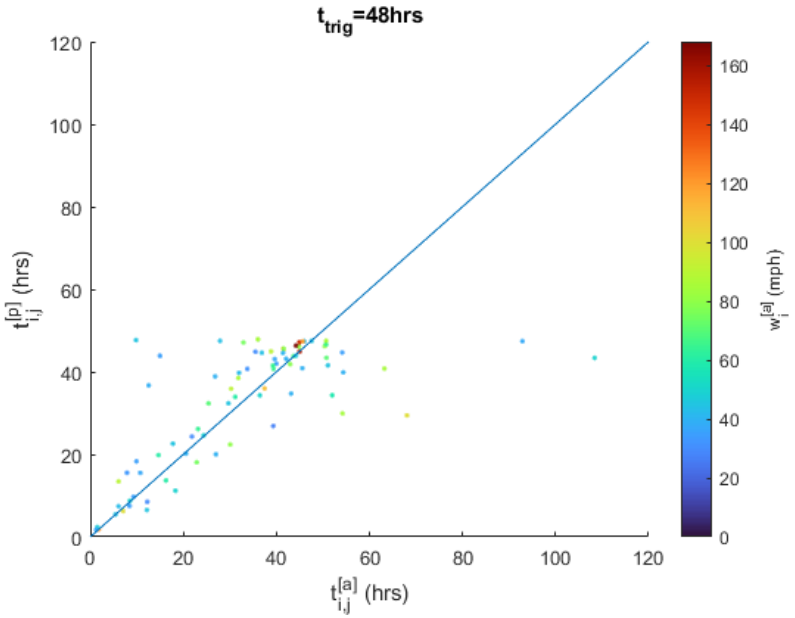

Landfall wind speed prediction error:
$\varepsilon_{ij}^{[w]} = w_{i,j}^{[p]} - w_i^{[a]}$
Number of Observations
% Error (100*ε [w] i,j /w [a] i,j)

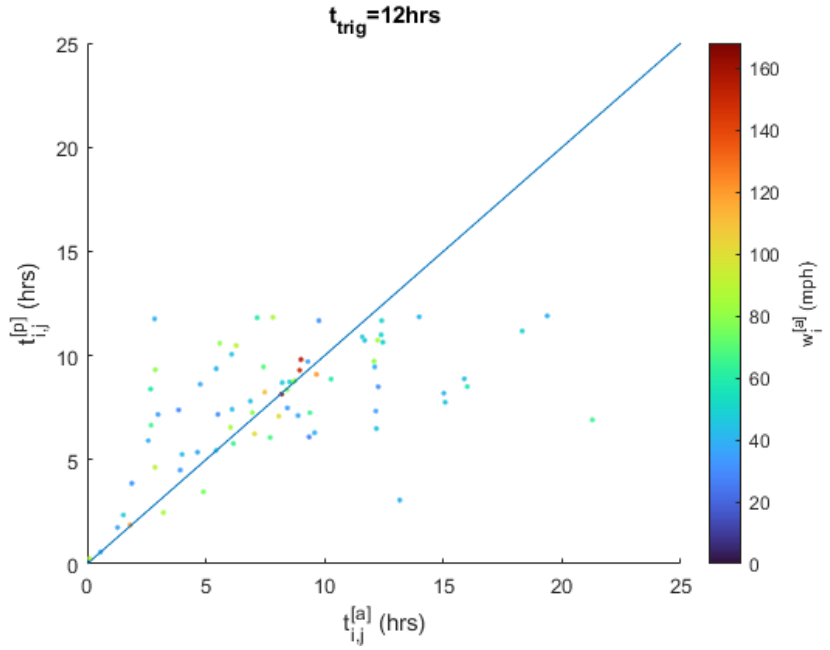

31%
28%
22%
19%
% Error (100*ε [t] i,j /t [a] i,j)
% Error (100*ε [w] i,j /w [a] i,j)
d i,j (miles)

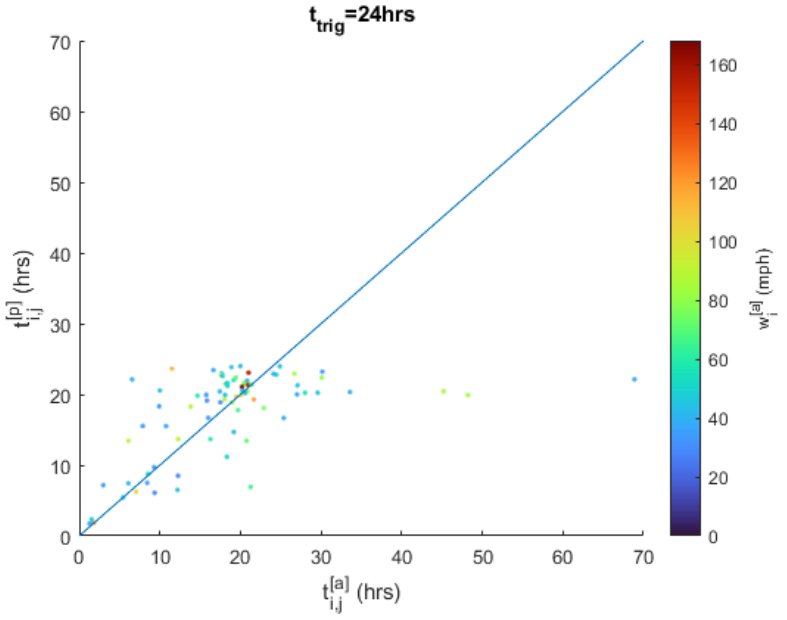

t_{trig}=12hrs
$t_{i,j}^{[p]}$ (hrs)
$t_{i,j}^{[a]}$ (hrs)
$w_i^{[a]}$ (mph)

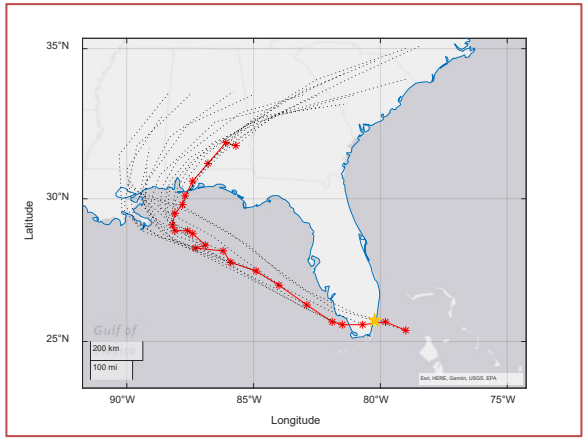

t_{trig}=24hrs
$t_{i,j}^{[p]}$ (hrs)
$t_{i,j}^{[a]}$ (hrs)
$w_i^{[a]}$ (mph)

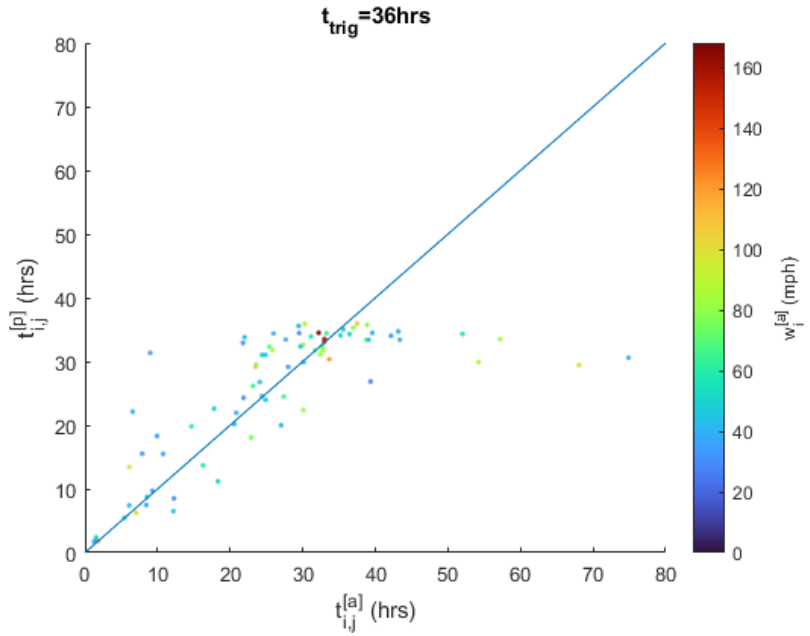

t_{trig}=36hrs
$t_{i,j}^{[p]}$ (hrs)
$t_{i,j}^{[a]}$ (hrs)
$w_i^{[a]}$ (mph)

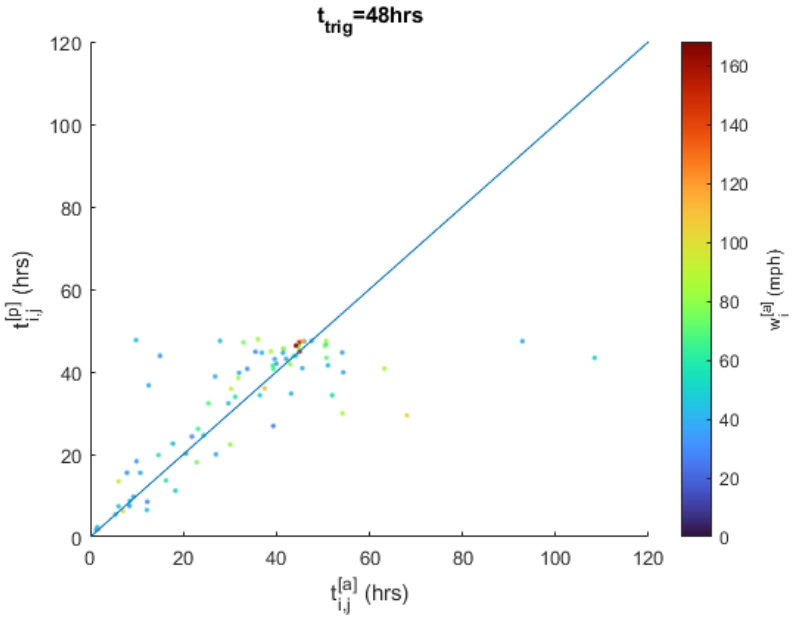

t_{trig}=48hrs
$t_{i,j}^{[p]}$ (hrs)
$t_{i,j}^{[a]}$ (hrs)
$w_i^{[a]}$ (mph)

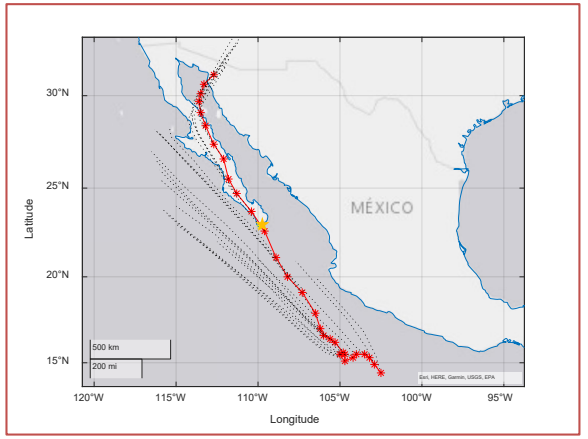

t_{trig}=12hrs
$t_{i,j}^{[p]}$ (hrs)
$t_{i,j}^{[a]}$ (hrs)
$w_i^{[a]}$ (mph)

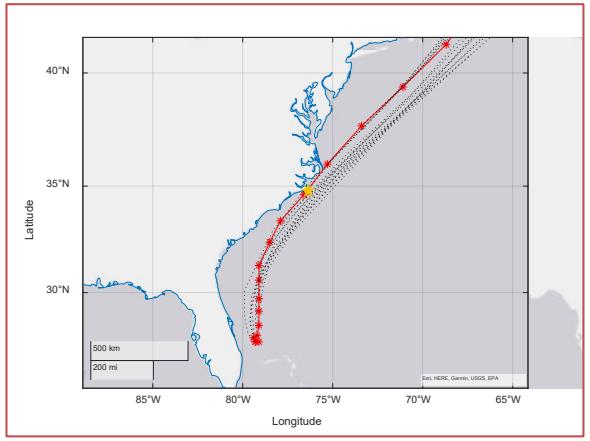

t_{trig}=24hrs
$t_{i,j}^{[p]}$ (hrs)
$t_{i,j}^{[a]}$ (hrs)
$w_i^{[a]}$ (mph)


Latitude
Longitude
Gulf of

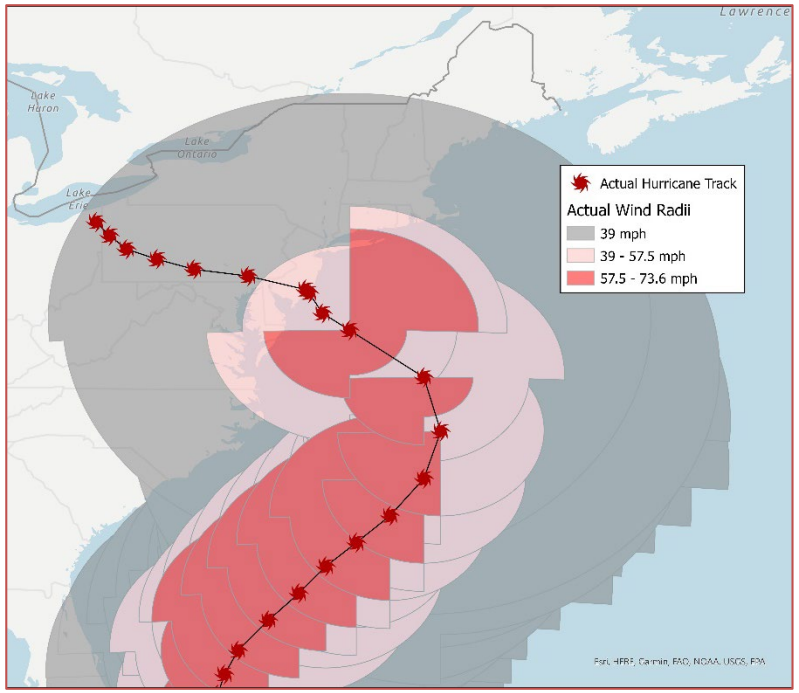

t_{trig}=36hrs
$t_{i,j}^{[p]}$ (hrs)
$t_{i,j}^{[a]}$ (hrs)
$w_i^{[a]}$ (mph)

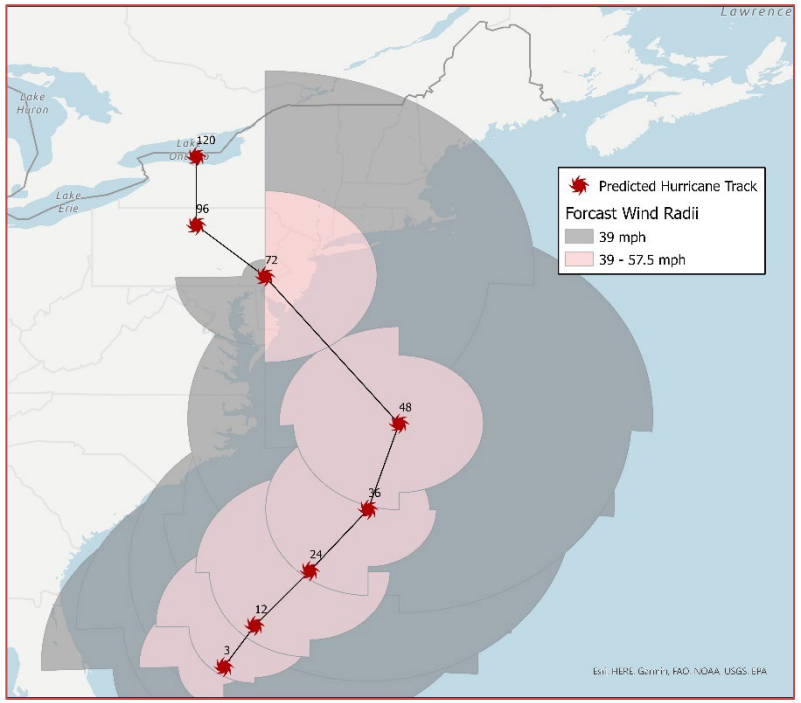

t_{trig}=48hrs
$t_{i,j}^{[p]}$ (hrs)
$t_{i,j}^{[a]}$ (hrs)
$w_i^{[a]}$ (mph)

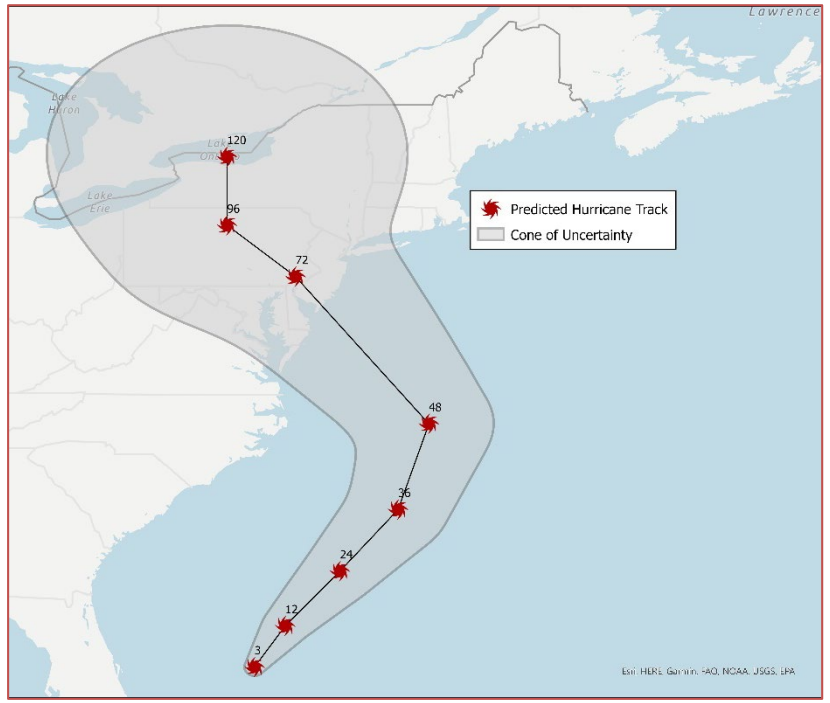

Latitude
Longitude
MÉXICO


Latitude
Longitude

Next Steps


Lawrence
Lake Huron
Lake Ontario
Lake Erie
Actual Hurricane Track
Actual Wind Radii
39 mph
39 - 57.5 mph
57.5 - 73.6 mph


Lawrence
Lake Huron
Lake Erie
120
96
72
48
36
24
12
3
Predicted Hurricane Track
Forcast Wind Radii
39 mph
39 - 57.5 mph


Lawrence
Lake Huron
Lake Erie
120
96
72
48
36
24
12
3
Predicted Hurricane Track
Cone of Uncertainty

Contributors:
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Michelle Bensi (UMD)
Zhegang Ma (INL)
Kaveh Faraji Najarkolaie (UMD)

Questions?

This research is supported by a research grant from the **Department of Energy's Nuclear Energy University Program (NEUP)** under grant/cooperative agreement DE-NE0008974.