Modeling to Support an Appeal of FEMA Preliminary Flood Insurance Rate Maps

Wind and Pressure Field Grid Corrections (Deliverable 3.2)
Task Order #1778-05

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Revision	Date	Status	Comments	Prepared	Reviewed	Approved
A	2021-04-16	Draft		TH	GT	TH

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1. Task Overview

During a Review and Evaluation of the Federal Emergency Management Agency's (FEMA) Coastal Flood Risk Study (Task Order No. 1778-01), Baird identified several issues related to the accuracy of the modeling that was conducted by FEMA in support of the preparation of preliminary Florida Insurance Study (FIS) reports and Flood Insurance Rate Maps (FIRMs) for eastern Palm Beach County (County). These modeling issues may have resulted in erroneous 1-percent annual chance water surface elevations [i.e., Base Flood Elevations (BFE)] and/or FEMA assigning an incorrect flood hazard flood zone to properties.

For Task 3 of Task Order 1778-05, Modeling to Support an Appeal of FEMA Preliminary Flood Insurance Rate Maps, Baird's specific objective was to further investigate how the coarse wind and pressure grid used impact the result of the Flood Insurance Rate Maps.

2. Wind and Pressure Grid Review and Analysis

According to FEMA, "The production run phase of the South Florida Storm Surge Study (SFLSSS) applies the SWAN+ADCIRC (ADCIRC version 52.30 with SWAN version 41.01) (Booij, et al., 1999; Luettich and Westerink, 2005; Dietrich, et al., 2011) coupled approach to simulate the time-dependent surge in response to time-varying wind, barometric pressure, and wave forces." (FEMA 2018). The wind and barometric pressure variables are applied to the model and based on one of two gridded data sets which were provided to FEMA from Ocean Weather, Inc. (OWI). According to reporting provided by FEMA, "Ocean Weather, Inc. (OWI) provided multiple sets of time-dependent atmospheric pressure and wind files for each synthetic storm simulation. A file with the extension ".pre" contained atmospheric pressure fields, and a file with extension ".win" contained wind velocity fields. One set of files with relatively coarse resolution, referred to as a basin scale, covered the entire model mesh, including the western North Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. A second set of files covered a smaller area, referred to as regional scale, and provided more detailed pressure and wind inputs along the general vicinity of the storm track" (FEMA 2018). However, the detailed pressure and wind inputs did not cover the majority of Palm Beach County.

These files are provided in grided format and can be visualized as shown in **Figure 1** which shows the location of coarse and fine grids covering the County. The wind and atmospheric pressure field files used by FEMA do not cover Palm Beach County north of Boynton Inlet. Therefore, the storm surge and the wave model were forced using the coarser basin scale grid as compared to the rest of the SFL study area.

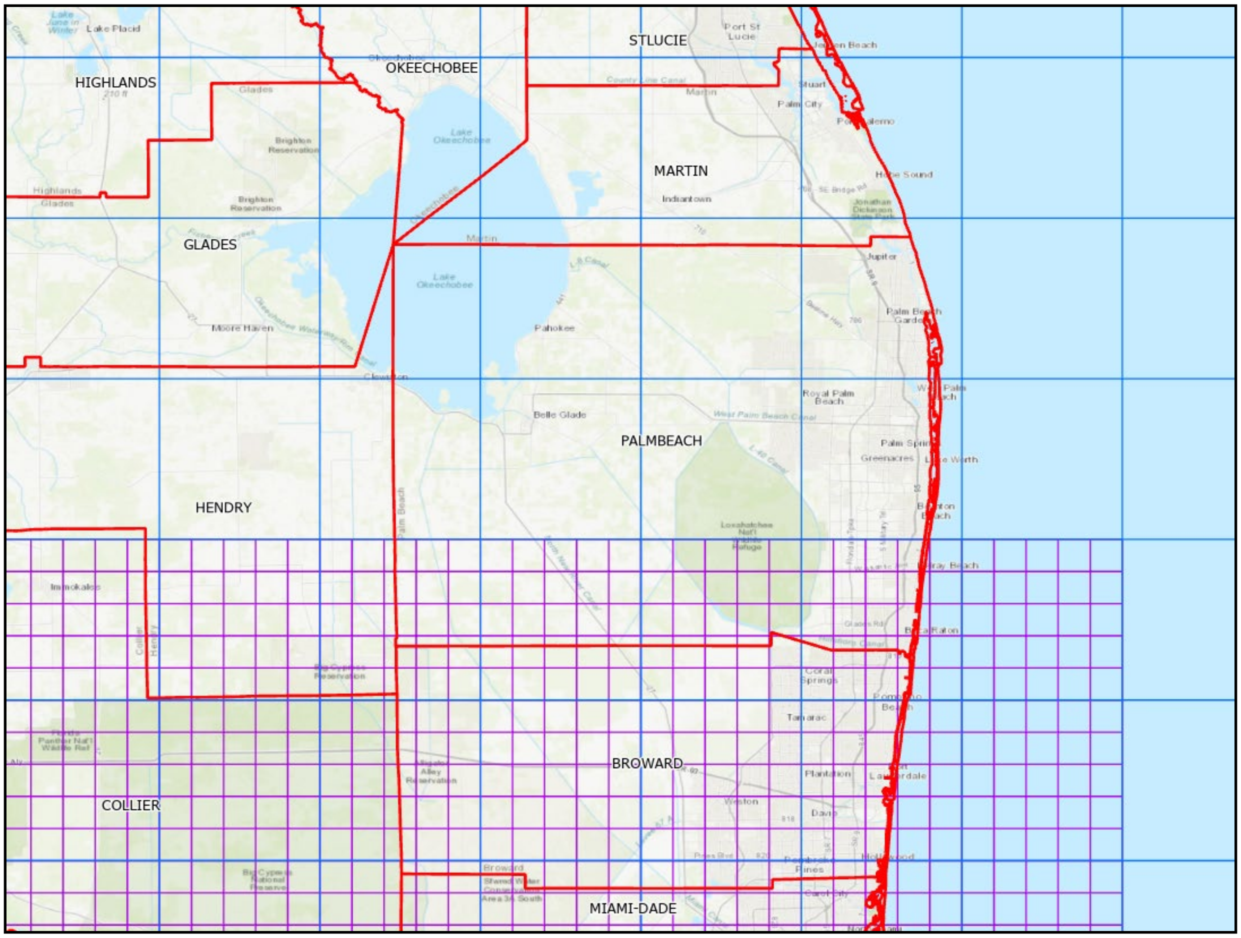

Figure 1. Wind and Pressure Field Grid Coverage for Palm Beach and Nearby Counties

Why FEMA's Data, Methods and/or Assumptions are Incorrect

FEMA's coarse (basin) grid was 5 times coarser than its finer (regional) grid that were used to define storm wind and pressure fields for the model. FEMA's basin grid for simulating storm wind and pressure fields covers the entire model domain (**Figure 2**) at a resolution of 0.25 degrees (approximately 15 nautical miles (nm) x 15 nm). Within the SFL study area, FEMA used a fine (regional) grid to resolve the distributions of the wind and pressure fields at a resolution of 0.05 degrees (approximately 3 nm x 3 nm) (**Figure 3**). The northern boundary of FEMA's regional grid was located approximately 12 miles north of the Palm Beach / Broward county line; thus, the northern 32 miles of Palm Beach County was not included in the finer regional grid and was modeled with the coarser basin grid. Therefore, in Palm Beach County, the storm surge and the wave model were forced using the coarser basin scale grid as compared to the rest of the SFL study area.

The coarser model grid resolution limits the SWAN+ADCIRC model's ability to represent the storm forcing parameters, and to accurately simulate storm surges for storms making landfall north of and near the boundary of the regional grid.

The highest 1% still water elevations (SWEL) reported by FEMA in Palm Beach County were found to occur within the southern portion of the Lake Worth Lagoon near Boynton Inlet. Review of FEMA's modeling data for the synthetic storms indicated that Storm 21 produced the highest modeled water surface elevations (WSE) within this portion of the lagoon. Storm 21 was an "east" coast storm making landfall to the north near Palm

Beach Inlet with a storm track from southeast to northwest as shown by the blue line in **Figure 2** and **Figure 3**. The track was located north outside of the regional grid. The modeled wind field at landfall for Storm 21, extracted from FEMA's modeling data, is shown in **Figure 4** to highlight the difference in model resolution between the basin (blue arrows) and regional (red arrows) grids. The insufficient wind and pressure fields grid resolution over most of Palm Beach County limits the SWAN+ADCIRC model's ability to accurately simulate storm surges for storms making landfall north of and near the boundary of the regional grid.

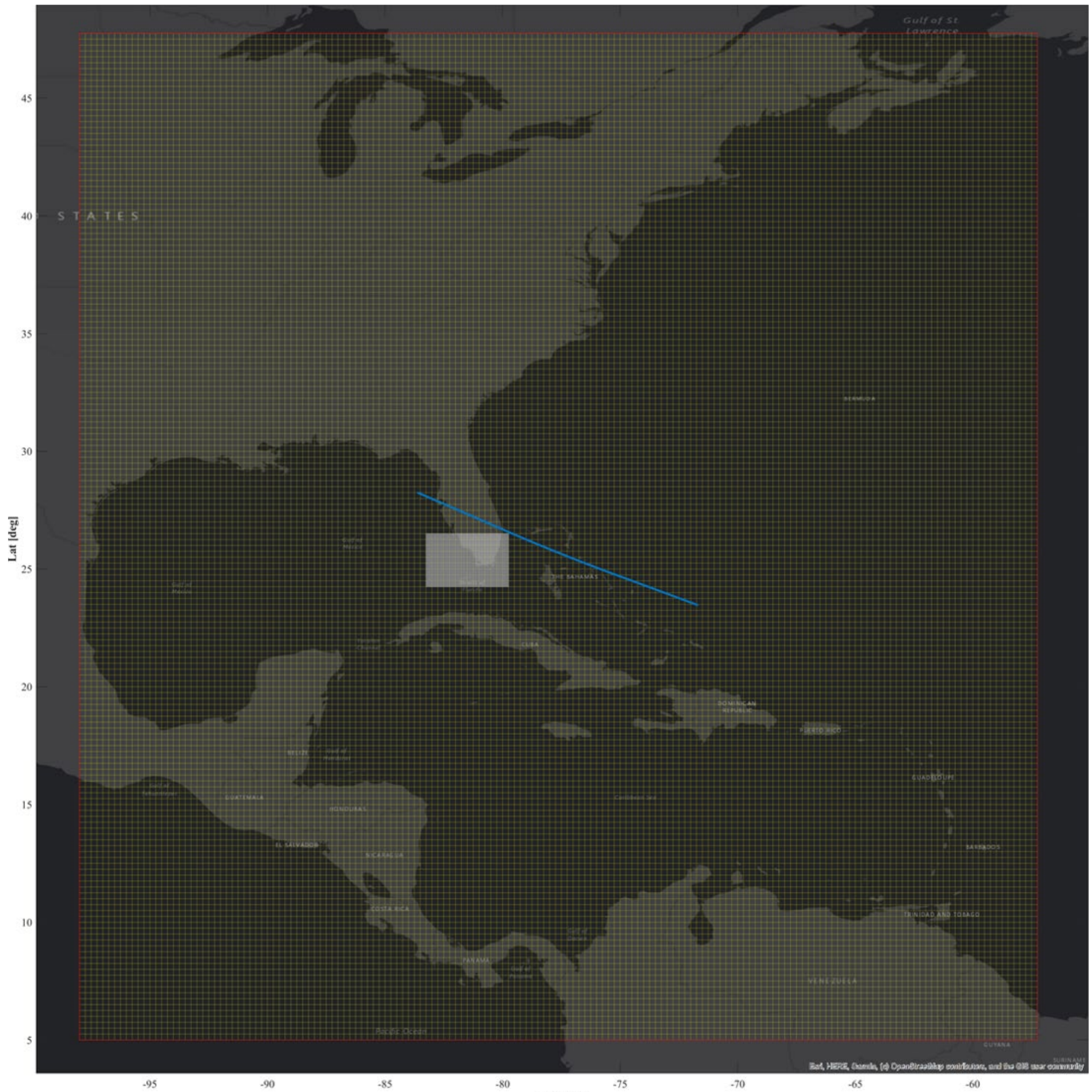

Figure 2. Wind and Pressure Field Grids Model Domain (Basin Grid is yellow and regional grid is white)

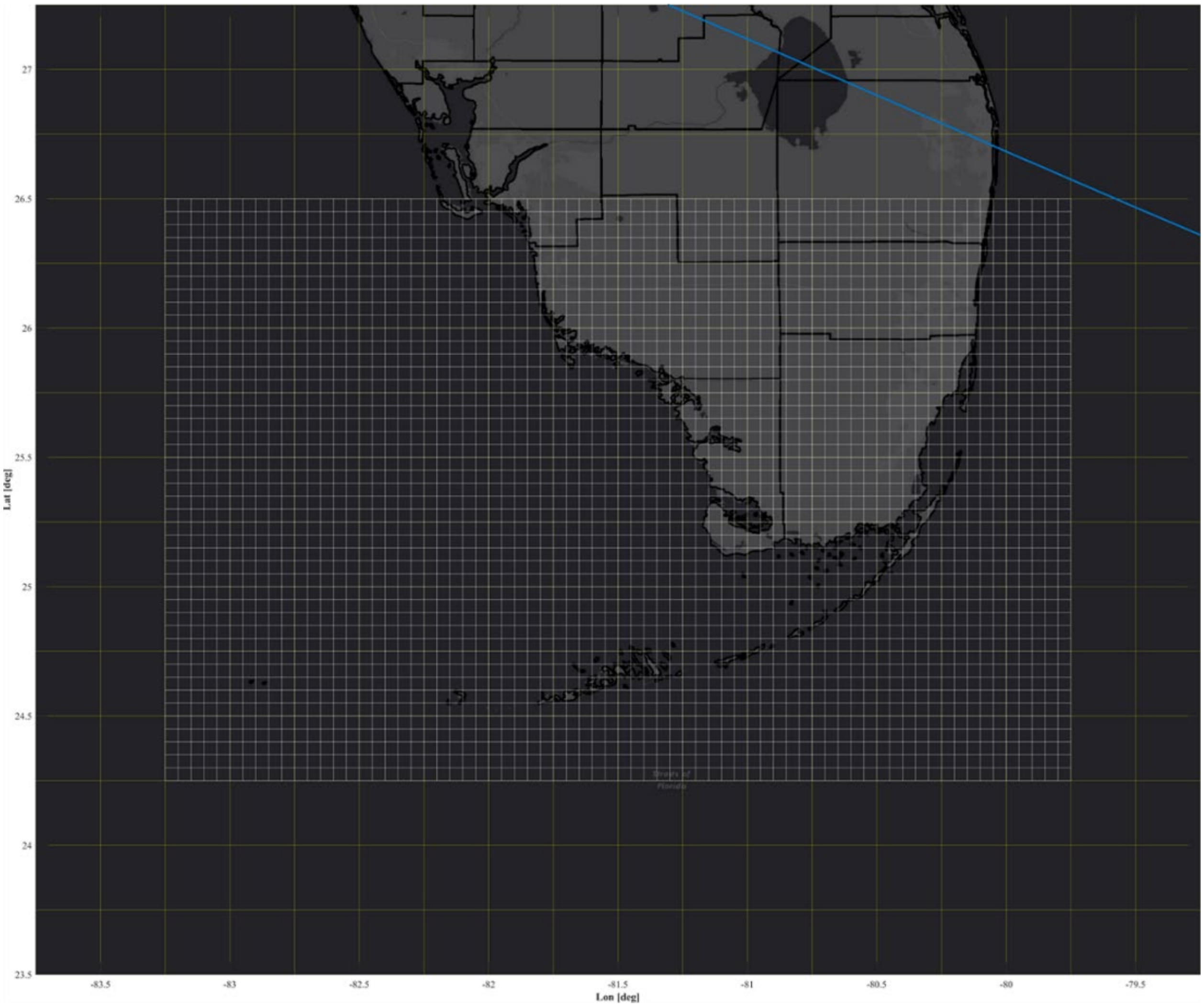

Figure 3. Wind and Pressure Field Regional Grids (basin grid is yellow and regional grid is white)

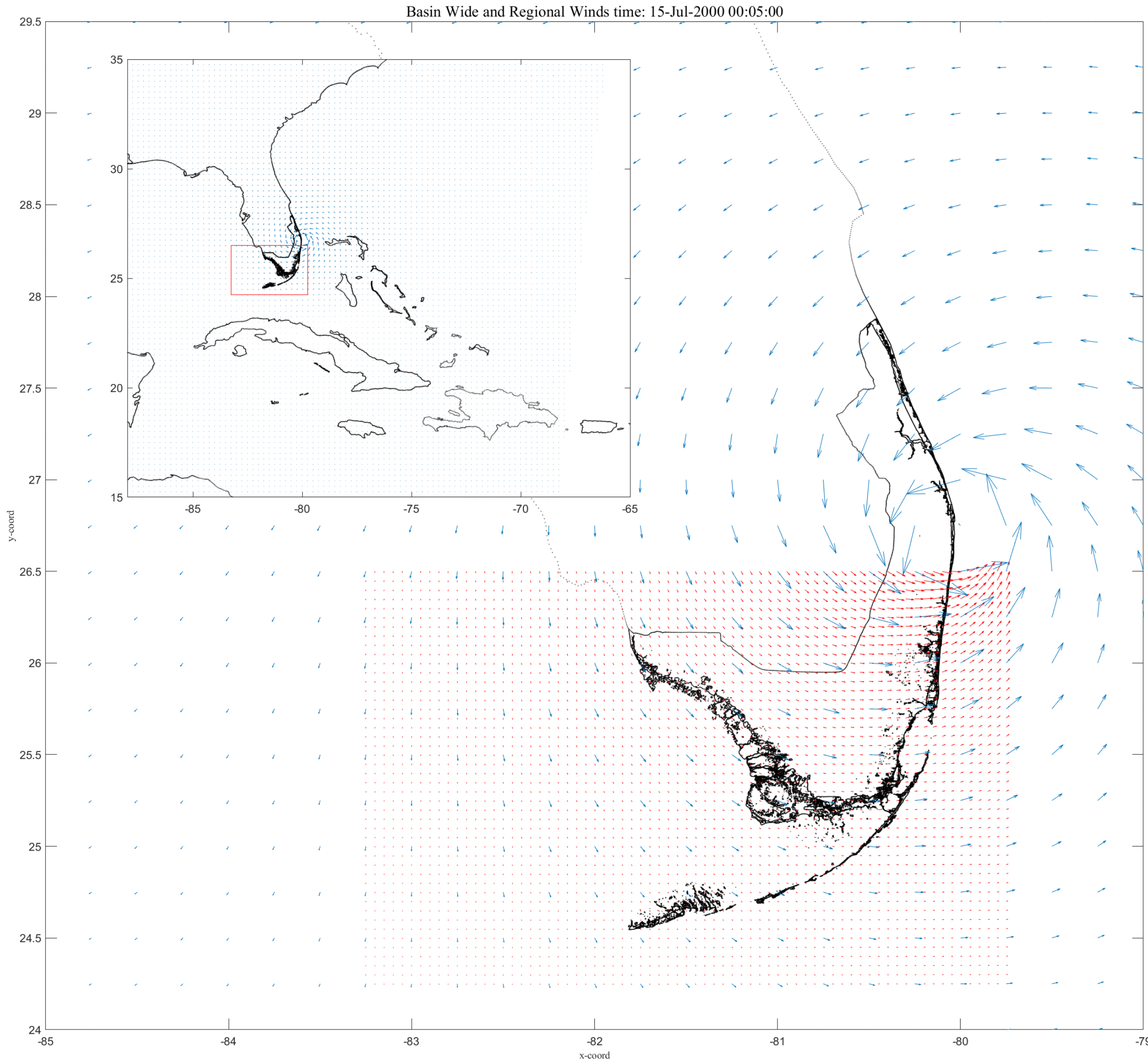

Figure 4. Wind Field Grids for Synthetic Storm 21 (basin grid vectors are blue and regional grid vectors are red)

Storm 21, which produced the highest modeled WSE, was among 60 synthetic storms (out of FEMA's 392 total) that made landfall outside the wind and pressure fields regional grid. **Figure 5** shows landfall locations for each of FEMA's 392 synthetic storms. Red dots indicate storms with landfall locations outside FEMA's regional grid; yellow dots indicate storms making landfall within the grid. Dots located offshore of land (e.g. northern Palm Beach County, south and west of Key West) indicate the closest point of the storms' tracks to the SFL Study area.

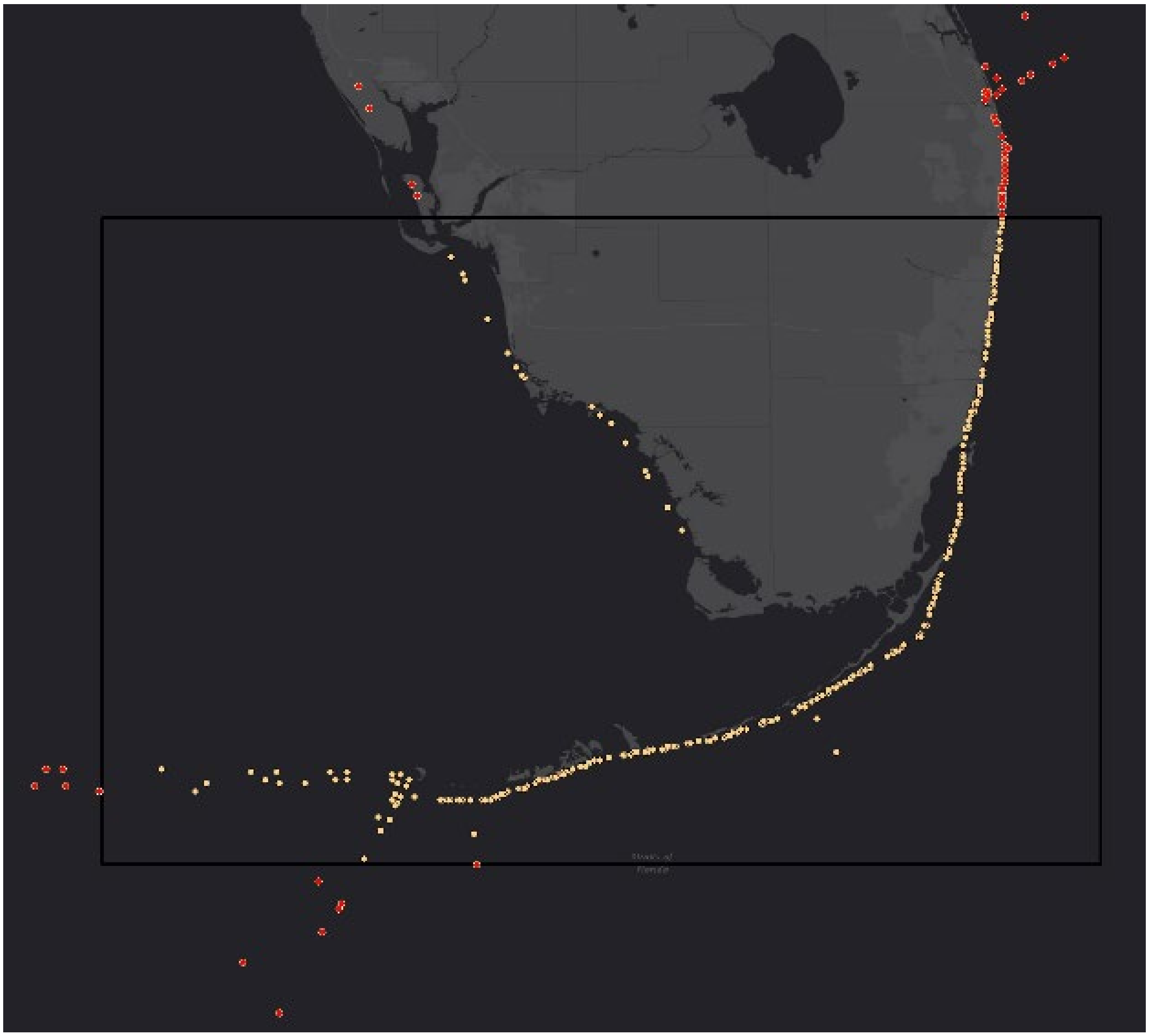

Figure 5. Wind and Pressure Field Regional Grid and Synthetic Storm Landfall Locations

Alternative Analysis Using More Correct Data and Methodologies

Since wind and pressure data was not produced at the finer resolution for the northern part of Palm Beach County, it was not possible to rerun the model with a finer grid. To show the impacts of the fine grid not covering the entire county, three storms were selected based on their return periods calculated in the Intracoastal Waterway (ICWW) near Boynton Inlet. **Figure 6** shows the tracks of the selected storms and the location where the return periods were calculated and **Figure 7** shows the return periods and WSE distribution using the results of all production runs from FEMA (Selected Storm 18, Storm 20 and Storm 21 marked as red) at this location.

All selected storms made landfall in northern Palm Beach County as shown in **Figure 6**. These events were chosen to bracket the potential impacts with particular focus to storms at the “tail” end (i.e., Storm 20, Storm 21) of the WSE/Return period distribution curve. By its nature, the distribution curve is very sensitive to the data points associated with higher return period events where the samples are scarce compared to lower return period events. For instance, the distribution curve presented in **Figure 7** has 352 data points with return periods below ~25 years (Storm 18). Only 40 points form the rest of the distribution curve.

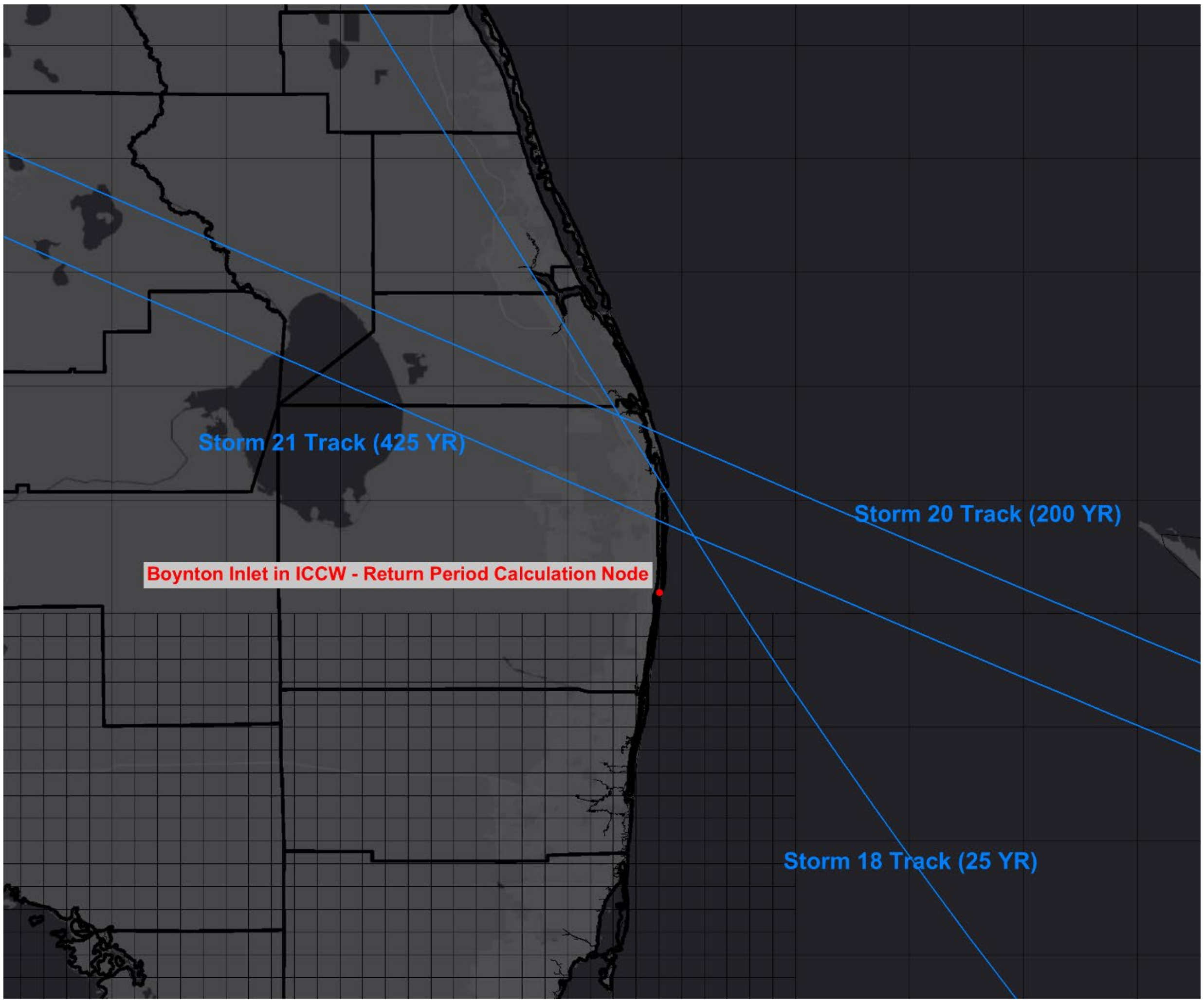

Figure 6. Storms tracks of events that were reanalyzed using only coarse wind and pressure grid.

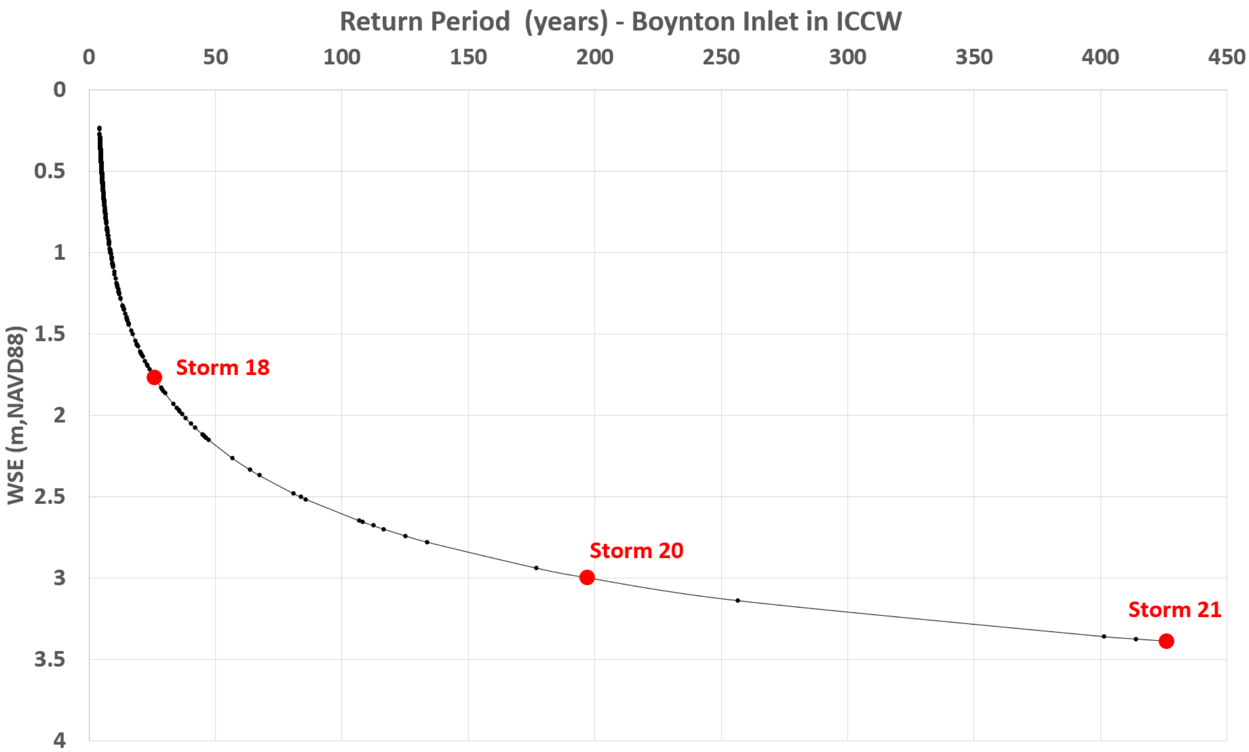

Figure 7. Return periods of reanalyzed storms.

The selected storms were run using the original setup files provided by FEMA. Additionally, reruns were completed using the same source codes for ADCIRC/SWAN (v52.30) as reported by FEMA.

Once re-simulations were complete, regional (fine) scale wind and atmospheric pressure inputs were removed leaving only the basin (coarse) scale wind and atmospheric pressure forcing as inputs to the model. No other changes were applied to FEMA's original setup files.

The impacts on the maximum WSE in Palm Beach County recorded during these simulations are presented in **Figure 8**, **Figure 10**, and **Figure 12** for Storm 18, Storm 20 and Storm 21 respectively. **Figure 9**, **Figure 11**, and **Figure 13** show the results over the entire fine grid area.

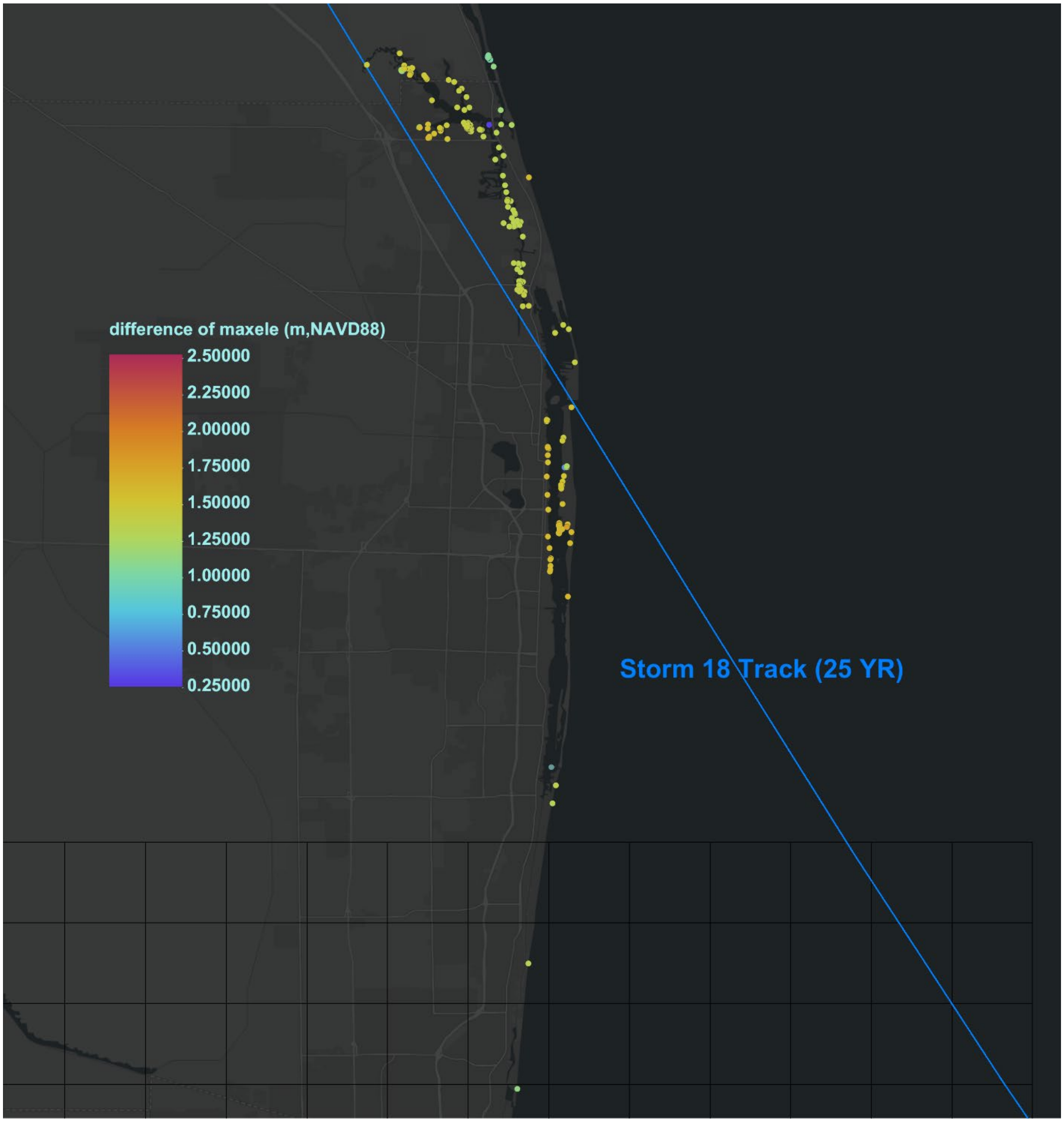

Figure 8. Maximum Water Surface Elevation Difference (meters) between fine and coarse wind and pressure grid for Storm 18 – Fine grid footprint shown for reference

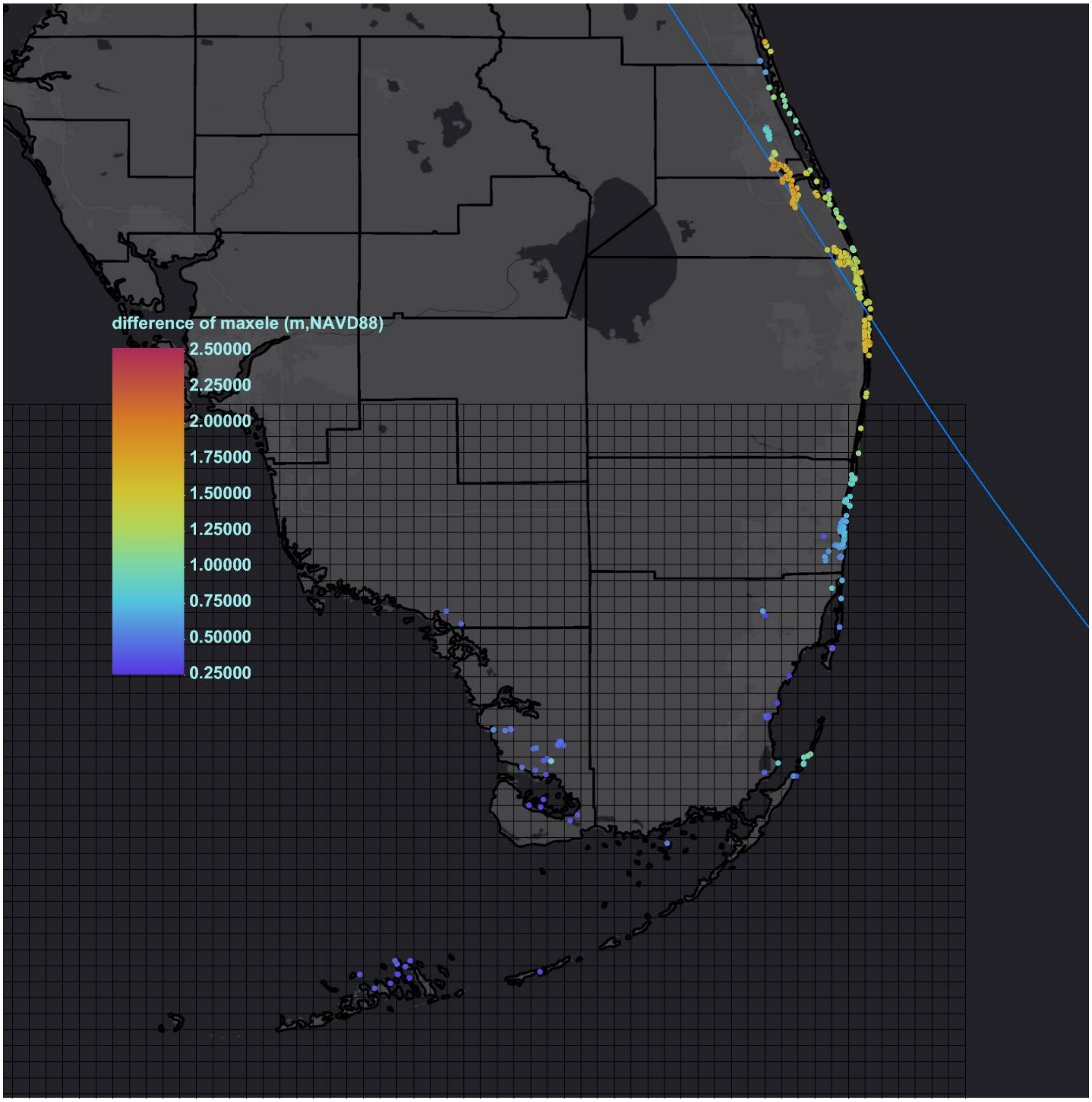

Figure 9. Maximum Water Surface Elevation Difference (meters) between fine and coarse wind and pressure grid for Storm 18 – Fine grid footprint shown for reference

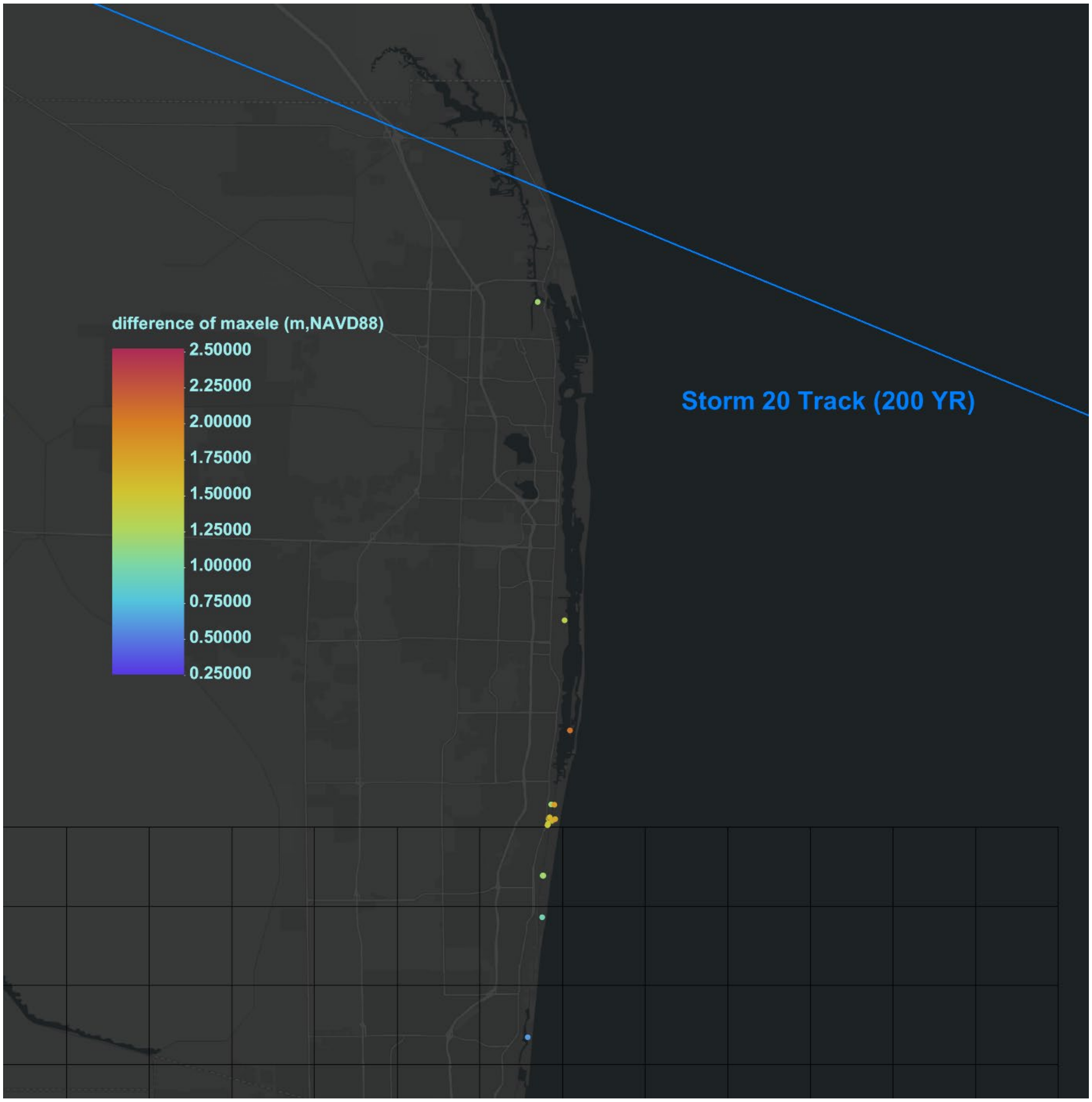

Figure 10. Maximum Water Surface Elevation Difference (meters) between fine and coarse wind and pressure grid for Storm 20 – Fine grid footprint shown for reference

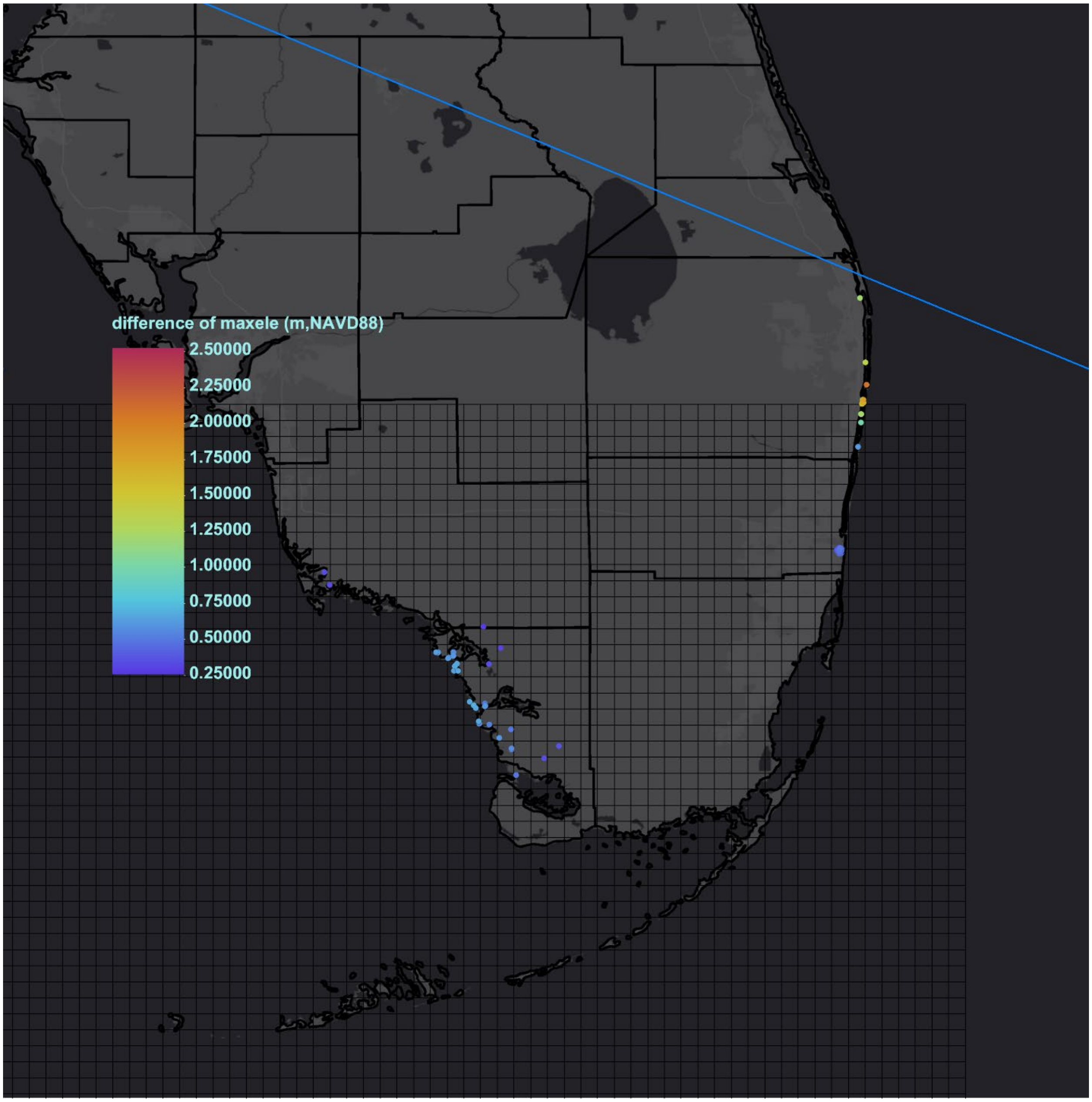

Figure 11. Maximum Water Surface Elevation Difference (meters) between fine and coarse wind and pressure grid for Storm 20 – Fine grid footprint shown for reference

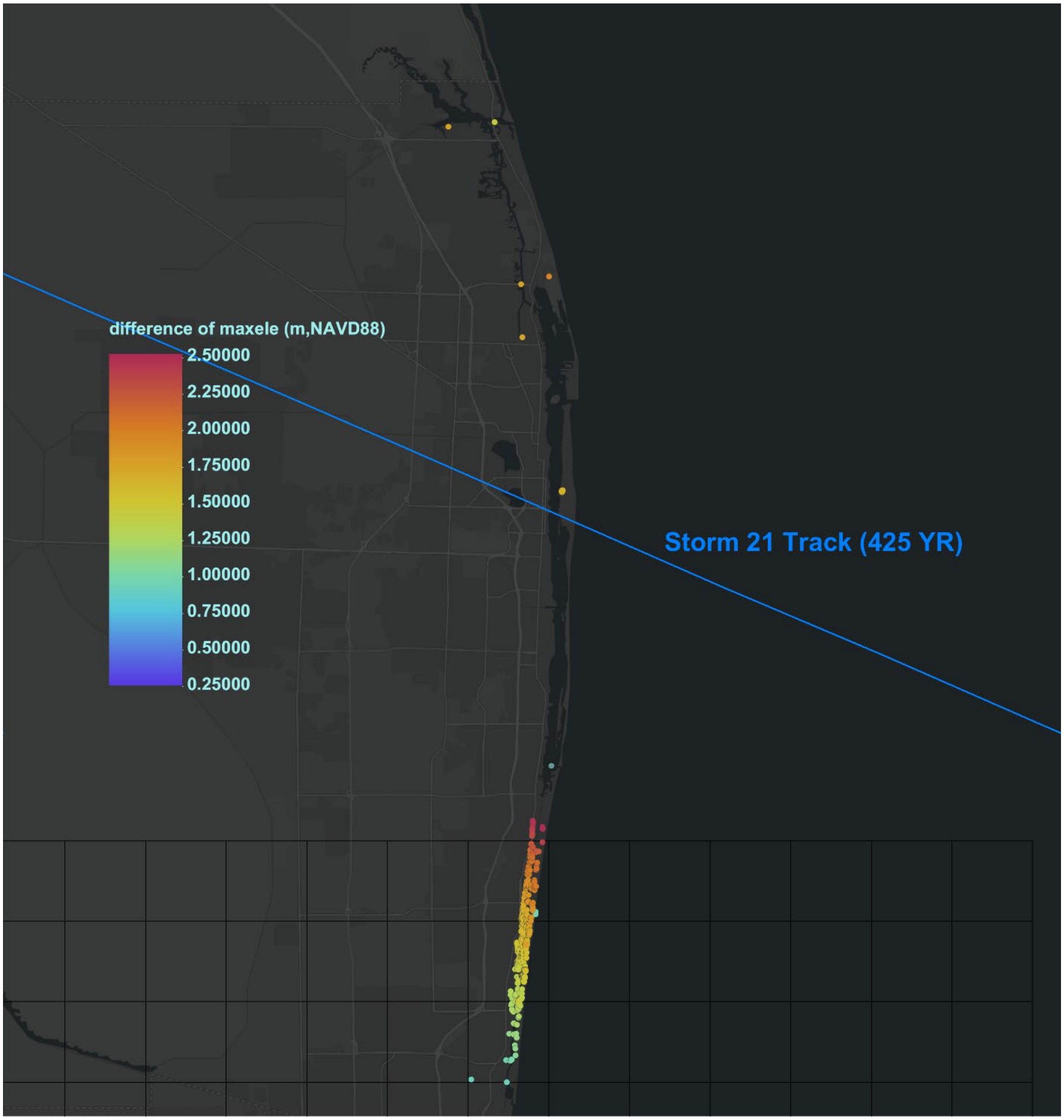

Figure 12. Maximum Water Surface Elevation Difference (meters) between fine and coarse wind and pressure grid for Storm 21 – Fine grid footprint shown for reference

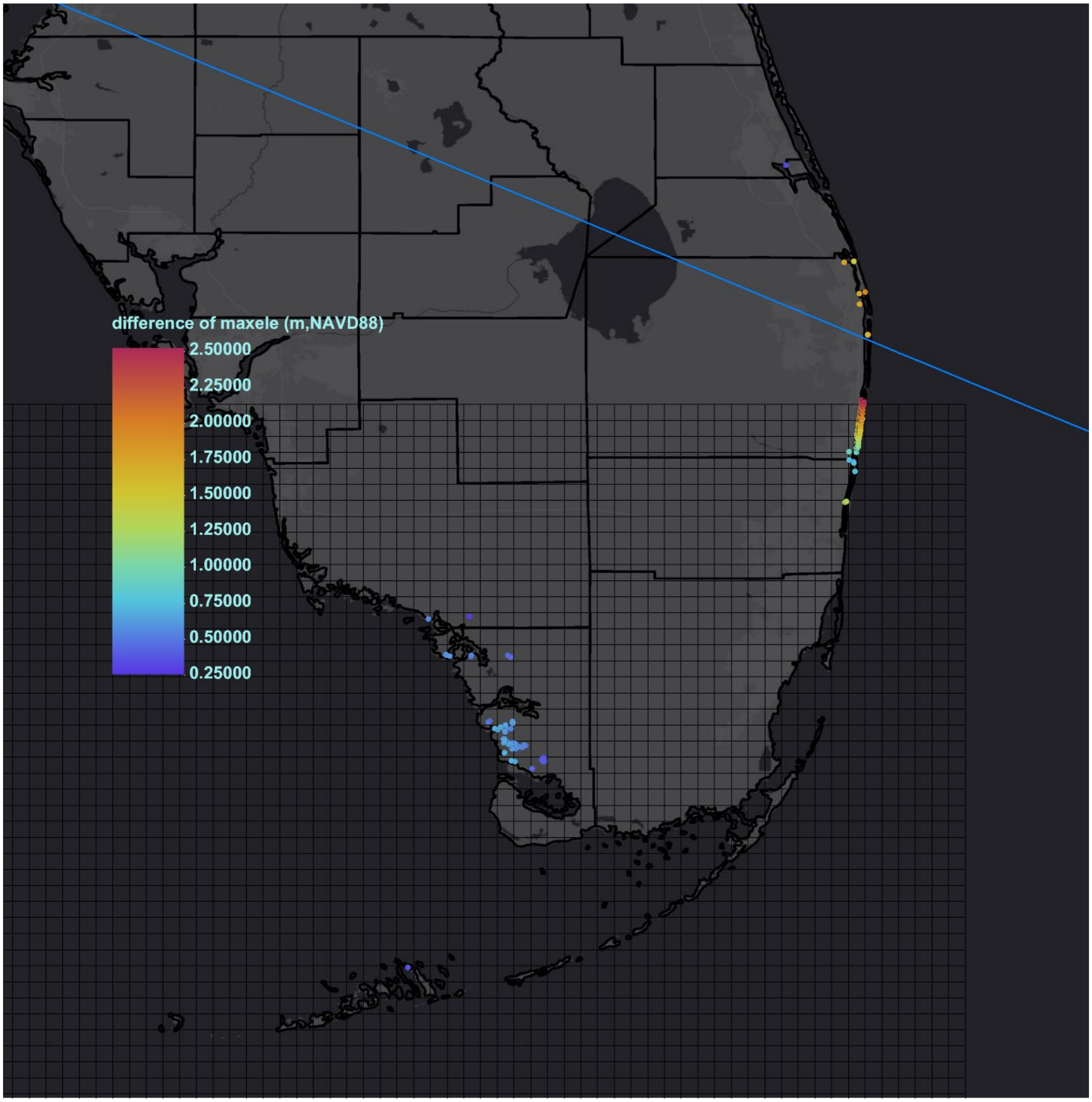

Figure 13. Maximum Water Surface Elevation Difference (meters) between fine and coarse wind and pressure grid for Storm 21 – Fine grid footprint shown for reference

The use of a coarse wind and pressure grid results in differences up to 2.5 meters (over 8 feet) for Storm 21. As expected, the differences are the greatest in the area where the finer grid was used by FEMA. To quantify the impact to the 100-year Stillwater Elevation (SWE), all production events would have to be re-run and statistics recomputed. This was not possible during the 90-day appeal period, but the analyses presented here are sufficient to show that the lack of a detailed wind and pressure grid has a significant impact on model results.

The modeling completed by Baird shows that wind and pressure modeled using inadequate resolution results in differences in WSE of up to 8-feet when compared to results with a finer gird. Based on these results, it is imperative that FEMA obtain wind and pressure data at the finer resolution used for the rest of the SFL Study for the northern portion of Palm Beach County and rerun the analysis.

A review of a several recent available studies completed by FEMA shows that a fine wind a pressure grid covering the entire study area was used. **Table 1** summarizes the studies and the grid sizes used.

Table 1. Wind and Pressure Grid Resolution of Recent FEMA Studies

Study	Basin Grid Resolution	Regional Grid Resolution
FEMA Region 2 NY	0.25 ° (degrees)	0.025 °
FEMA Region 6 LA	0.05 °	0.05 °
FEMA Region 6 TX	0.2 °	0.08/0.02 °
FEMA Region 4 FL, ECCFL	0.25 °	0.05 ° (*)
FEMA Region 4 FL, SFL	0.25 °	0.05 ° (*)

(*) Brevard County (ECCFL) is partially covered, Palm Beach County (SFL) is partially covered

3. Summary

The use of a coarse wind and pressure grid results in differences up to 2.5 meters (over 8 feet) for Storm 21. As expected, the differences are the greatest in the area where the finer grid was used by FEMA. To quantify the impact to the 100-year Stillwater Elevation (SWE), all production events would have to be re-run and statistics recomputed. This was not possible during the 90-day appeal period, but the analyses presented here are sufficient to show that the lack of a detailed wind and pressure grid has a significant impact on model results.

4. References

FEMA 2018. Production Runs IDS3: Section 1 Task Order 99: South Florida Flood Insurance Study Version 3.0 June 2018: Final Report Including Appendices Digital File Name: SFL_IDS3_Sect1_Prod_Rept_IncAppendecies_Final_June2018.pdf, June 2018

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