Region II Storm Surge Project – Production Runs

September 2014

Federal Emergency Management Agency
Department of Homeland Security
500 C Street, SW
Washington DC, 20472

Contract: HSFEHQ-09-D-0369
Task Order: HSFE02-09-J-0001

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Figures

Tables

Appendices

Acronyms and Abbreviations

ADCIRC	ADvanced CIRCulation Model for Oceanic, Coastal and Estuarine Waters
cm	centimeter
FEMA	Federal Emergency Management Agency
JPM-OS	Joint Probability Method-Optimum Sampling
m	meter
OWI	Oceanweather, Inc.
QA/QC	Quality Assurance/Quality Control
RAMPP	Risk Assessment, Mapping, and Planning Partners
SWEL	Stillwater Elevation
UnSWAN	Unstructured version of Simulating WAves Nearshore model

SECTION ONE INTRODUCTION

This document describes the production phase of the Region II Storm Surge Project. This phase is responsible for conducting the coupled ADvanced CIRCulation (ADCIRC) and Unstructured Simulating WAves Nearshore (UnSWAN) model simulations for each of the 159 hurricanes and 60 extratropical storms (30 unique storms simulated at two randomly-selected tidal phases) that were developed as part of the Joint Probability Method-Optimum Sampling (JPM-OS) approach.

Before beginning the production phase, a model grid was generated with approximately 604,790 nodes. This grid was validated to seven historic storms — four tropical storms and three extratropical storms — using historic measured high-water marks and wave heights to assist with the model validation. The ADCIRC model simulates the time-dependent surge in response to time varying wind and pressure fields and wave forces. The UnSWAN model simulates wave generation and propagation using the same wind fields. The coupling consists of providing the ADCRIC model-generated surface elevations to the UnSWAN model, and the UnSWAN-generated wave forcing to the ADCIRC model. Each model simulation is used to provide the maximum elevation of the storm surge and wave characteristics for the associated storm at each model grid node. These production phase outputs were then analyzed to develop surge elevations associated with discrete return intervals.

This report documents the work completed to facilitate, implement and ensure the quality assurance/quality control (QA/QC) of the 219 production runs. When storm surge simulations use a large mesh with the coupled ADCIRC-UnSWAN model, massive computing capacity is typically required to provide efficient simulation times. For this project, the model was implemented on a 256-node, parallel processor operated by the Risk Assessment, Mapping and Planning Partners (RAMPP) subcontractor, Worldwinds, Inc. Despite this computational power, typical storm simulations required 6 to 16 hours to execute (6 hours for the tropical storms and 16 hours for the extratropical storms). Thus, for 219 storms, the basic computational time was estimated to be approximately 80 days. This estimate does not include "down" time for scheduled maintenance, power failures, and other unscheduled events. Therefore, any steps to reduce the computational time for each individual storm could have a significant impact on the production run schedule. Consequently, the first part of the production run phase focused on identifying time-saving options in the production run program.

SECTION TWO STORM SIMULATION PROCEDURE

The general process for completing each of the production run simulations is depicted in the flow diagram shown in Figure 1. The process contains three basic parts:

1) loading input files and launching the run,

2) post-processing the files and conducting a local QA/QC, and

3) downloading the output files, conducting a detailed QA/QC and archiving the input and output files.

The final post-processing step comprises the statistical analysis used to generate the frequency of occurrence surfaces and is discussed in detail in subsequent reports (RAMPP, 2014b)

The input wind and pressure fields were developed by RAMPP’s subcontractor, Oceanweather, Inc. (OWI). A description of the detailed file staging associated with Part 1 is shown in Figure 2. The full set of input and output files is shown in Figure 3.

The final validated model including the topographic-bathymetric mesh and model input parameters were used for the production simulations.

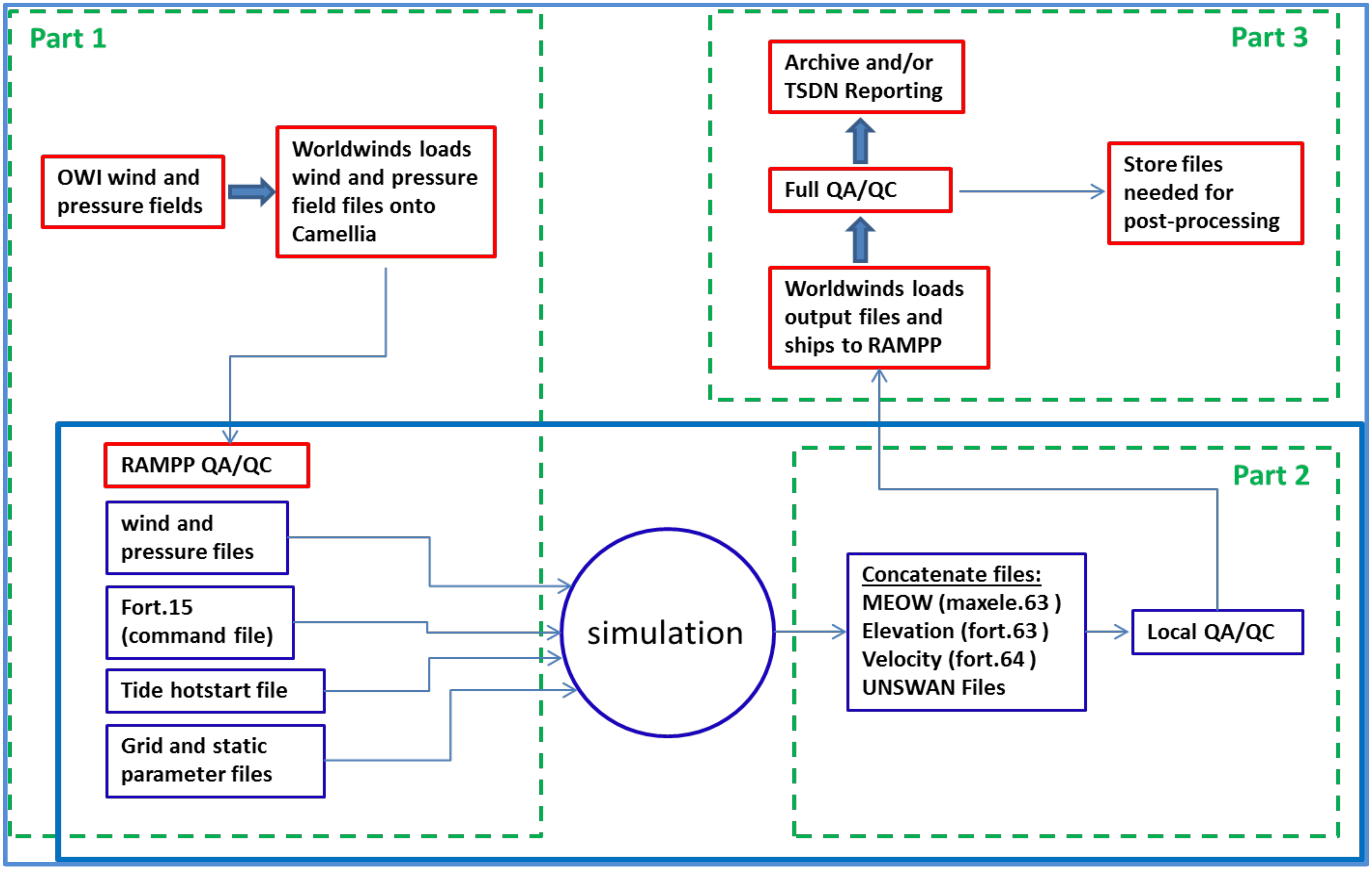


Figure 1. Flow diagram showing steps in completing a storm simulation.

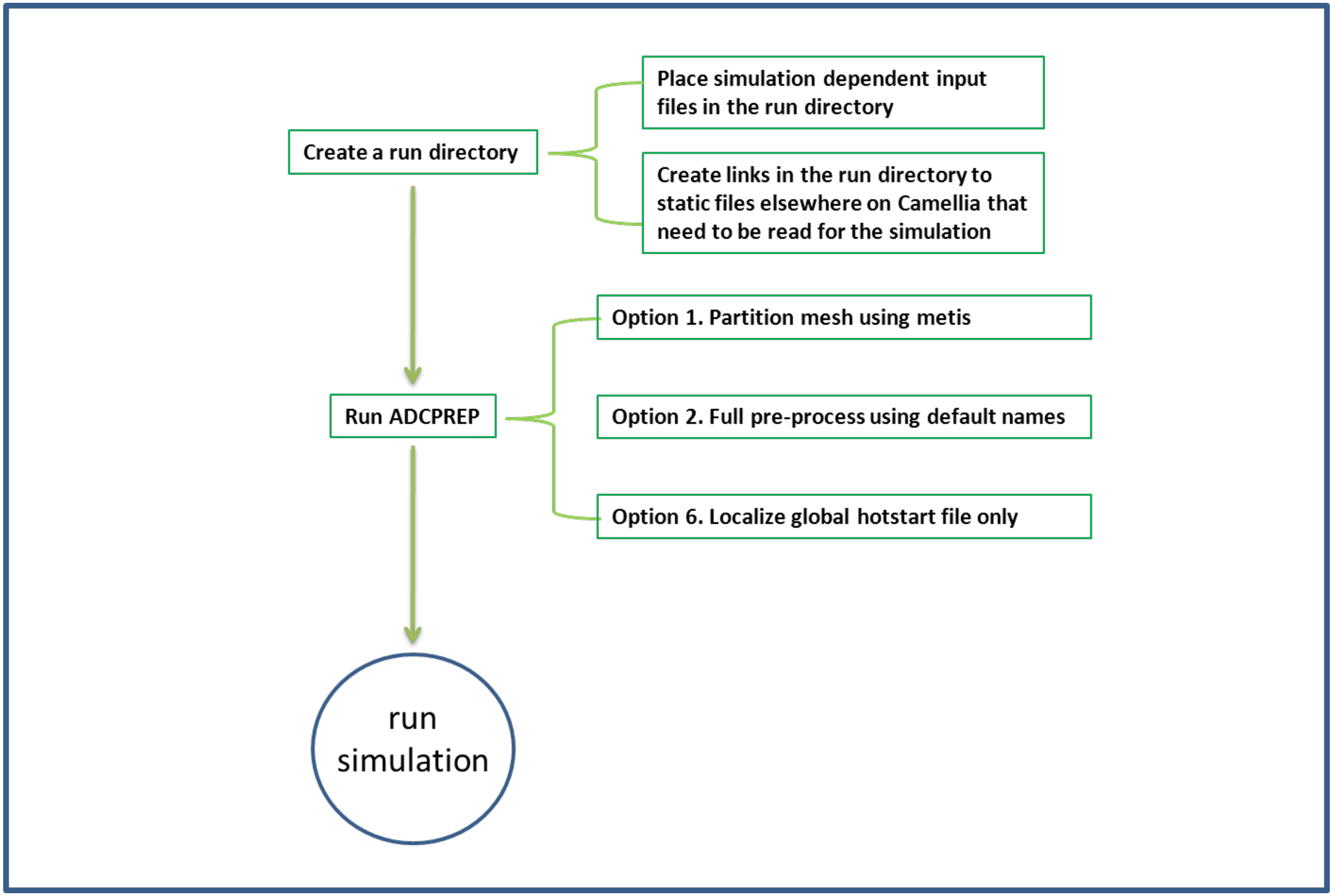
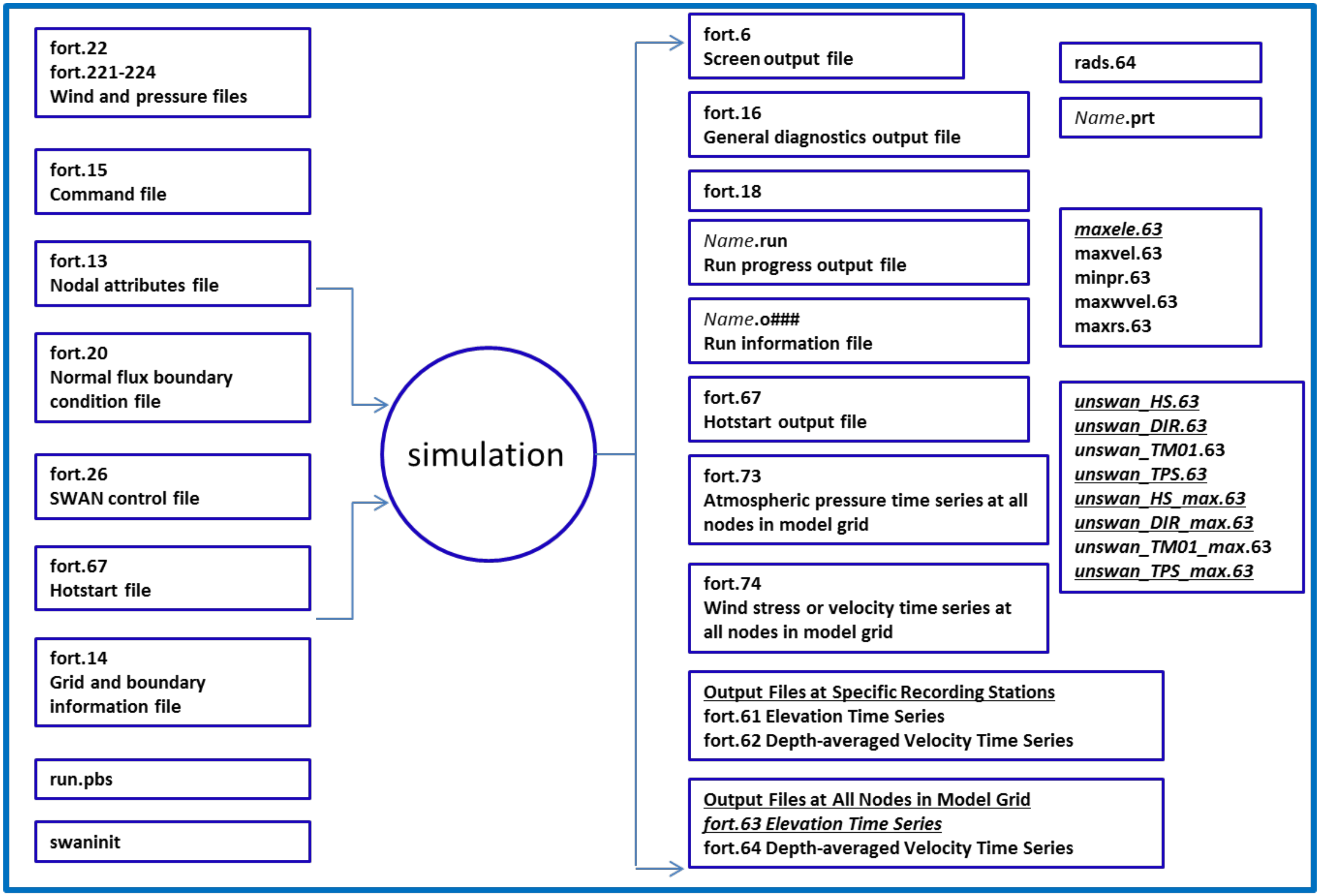


Figure 2. Flow diagram showing steps for launching a storm simulation.



"Name" is the name given to the simulation in the run.pbs file

Figure 3. Flow diagram showing flow of input and output files for a storm simulation.

SECTION THREE FILE MANAGEMENT

The input and output files for a single storm event are listed in Figure 3. All input files were required for each simulation. A continuous ADCIRC tide-only simulation was created and used as the hotstart, or initial condition for each production simulation.

All output files listed in Figure 3 were created during each simulation, but only those indicated with italicized and underlined text were archived. The other files were either created automatically by ADCIRC-UnSWAN, or they were created for the purpose of problem resolution in the event that any instability occurred in the simulation.

RAMPP's subcontractor, Worldwinds, Inc., provided downloading and shipping services during the production runs. As a batch of runs was completed, the designated output files were downloaded from the cluster onto an external hard drive and shipped to RAMPP for detailed QA/QC and archiving.

SECTION FOUR STORM RUN TIME ESTIMATES

An estimate of the actual time for the simulations was made based on the validation simulations and was approximately 2 hours per simulated day. The simulated time necessary to properly represent an extratropical storm event was approximately 8 days. This yields a total of 16 hours of actual time for each of the 60 extratropical storms.

In the interest of scheduling, computational efficiency, and related practical considerations, a brief sensitivity study was completed to determine the optimal simulation time and numerical parameters for the 159 tropical storm simulations. The two parameters studied were the number of days simulated and the UnSWAN time step.

For the number of days simulated, both 3- and 5-day simulations were investigated. The wind and pressure fields were defined so that each storm would make landfall 24 hours before the end of the simulation, leaving 2 and 4 days prior to landfall, respectively.

Four storms from the 159 production run tropical storm set were selected for testing the 3- and 5-day simulations. They were selected to provide a range of storm conditions based first on speed and then on strength, with one storm for each combination. The storm strength was determined based on the central pressure and radius to maximum winds. The selected storms and their designated names are shown in Table 1. The storm parameter values characterizing each selected storm are shown in Table 2.

Table 1. Selected storms and naming convention.

	JPM-OS1 name		**Name Assigned for Testing**	
	Fast	Slow	Fast	Slow
Powerful	NJA_0017_007	NJA_0016_005	FP	SP
Weak	LI_0030_006	LI_0009_006	FW	SW

Each of the four chosen storms was simulated for the 5 days, as well as for a shorter 3-day run. The naming convention used to refer to the simulations in this study is Strength+Speed+Runday (e.g., a 3-day run of the Fast Powerful storm, NJA_0017_007, is called FP3).

During the storm selection process, the data used to generate the storm wind and pressure input fields were also used to evaluate forward speed and pressure. The overall storm strength was determined from both the storm generation data and storm summary information provided by OWI, which contains graphical information on storm size and wind speed. The summary page for each of the selected storms is provided for reference in Appendix A.

Table 2. Central pressure and forward speed at landfall and averaged over the storm track for selected storms.

	Pressure at Landfall (mb)	Forward Speed and Landfall (m/s)	Average Pressure (mb)	Average Forward Speed (m/s)	Radius to Maximum Winds (km)
FP	926	29.5	937	20.1	37
SP	926	15.2	937	10.3	78
FW	964	9.2	968	6.7	46
SW	937	16.3	945	11.1	65

Storms were simulated with tidal forcing turned off in order to simplify the run procedure, as careful matching of timing relative to tides would be required otherwise. Although it can be argued that this affected the results, especially in terms of comparing fast and slow storms, storm speed did not appear to be a major factor in the differing results, suggesting that any effect introduced by tides would be minimal.

Results from the 3- and 5-day simulations compared well for powerful storms, with maximum differences of less than 5 centimeters (cm). However, differences in the maximum surge for the weak storms were larger than 5 cm in some areas, as shown in Figure 4.

Further analysis of the results indicated that oscillation from the initial and sudden application of the wind forcing was causing differences in the 3-day and 5-day simulation results. The sudden application of non-zero forcing is analogous to applying an impulsive load to the system, which naturally yields large oscillations throughout the domain. For the 5-day simulations, the run length ensures that these oscillations are dampened before the peak surge arrives. However, for the shorter 3-day simulations the oscillations were not dampened and caused the differences in the simulation results. To minimize the spurious oscillations induced by the sudden application of wind and pressure in the model, a 0.5-day ramping function was applied to these terms for 3- and 5-day simulations and results were compared. Run names for these storms with the 0.5-day ramp period are prefixed with "oDRAMP0p5." Comparisons were done for maximum water elevation, maximum significant wave height, and water elevation time series at selected locations. The selected locations are shown in Figure 5.

The time series of water elevation at a few of the locations are shown in Figure 6. It is evident that the oscillations for the 3-day ramped runs were less than 5 cm in amplitude at the time of peak surge. A comparison of the maximum surge elevation is shown in Figure 7. There were no differences in the results in the New York City area, which is not shown in Figure 7. The results indicate that differences between the 3-day and 5-day (both with 0.5-day ramp) simulations are within a few centimeters at the peak surge. The differences are typically less than 5 cm.

The extratropical storms developed more slowly than the tropical storms and the initial oscillations were not considered a problem in those simulations. However, because the extratropical storms had a much longer simulation period, on the order of 8 days, a 1.5 day ramp was applied to all extratropical storm simulations.

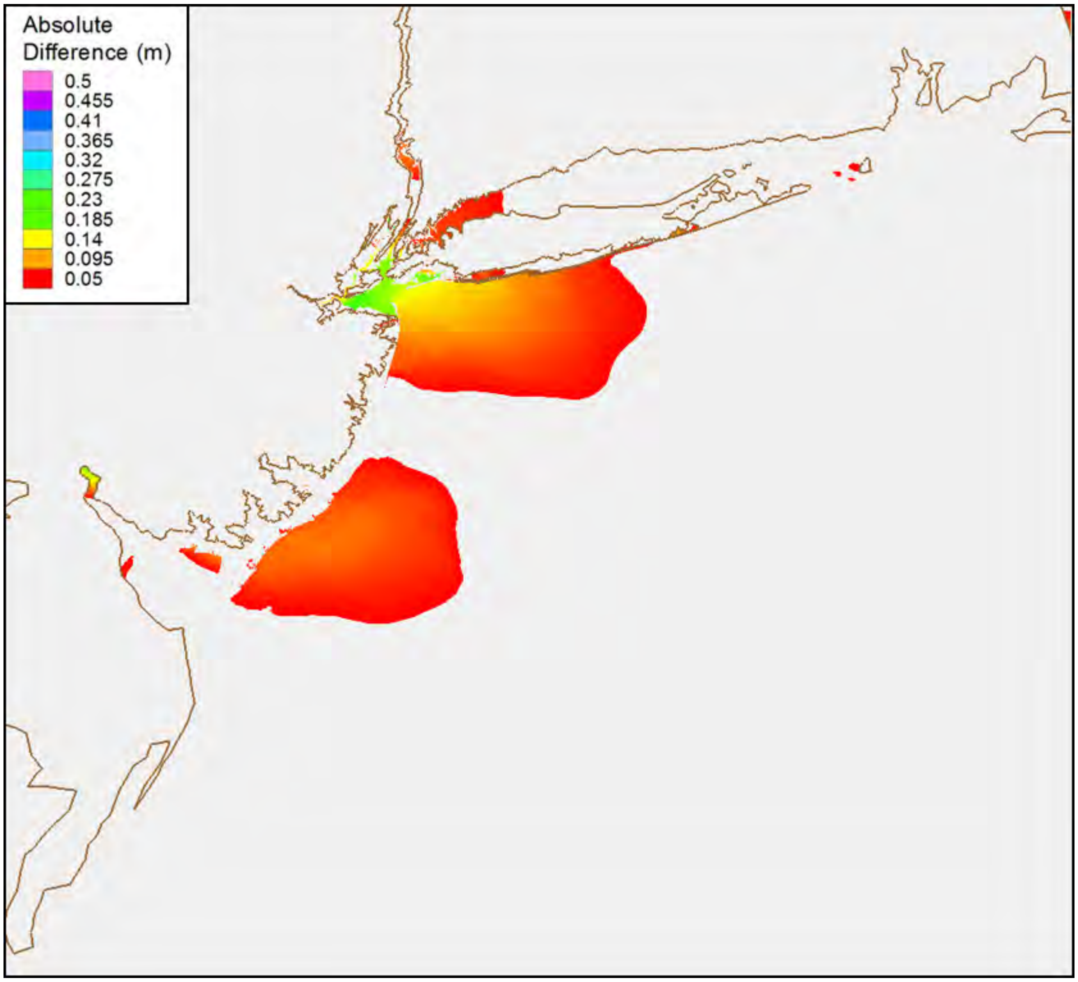


Figure 4. Absolute differences between FW5 and FW3 maximum water elevation.

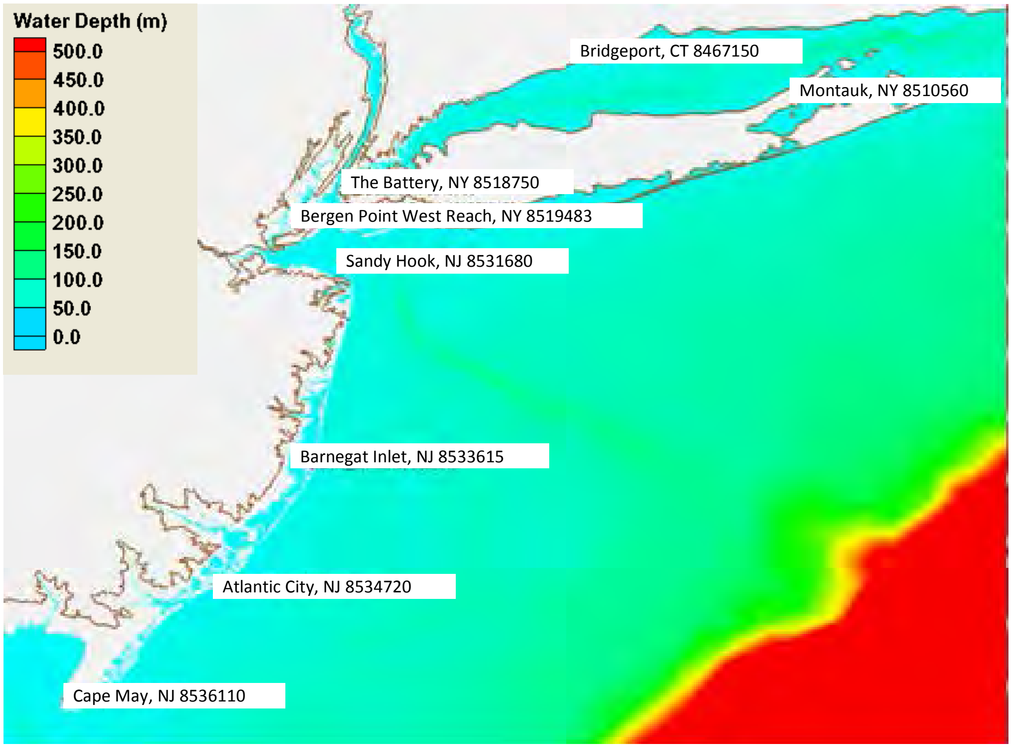


Figure 5. Water elevation stations overlaid on bathymetry mesh; grey color denotes land, brown line indicates the limit of the mesh.

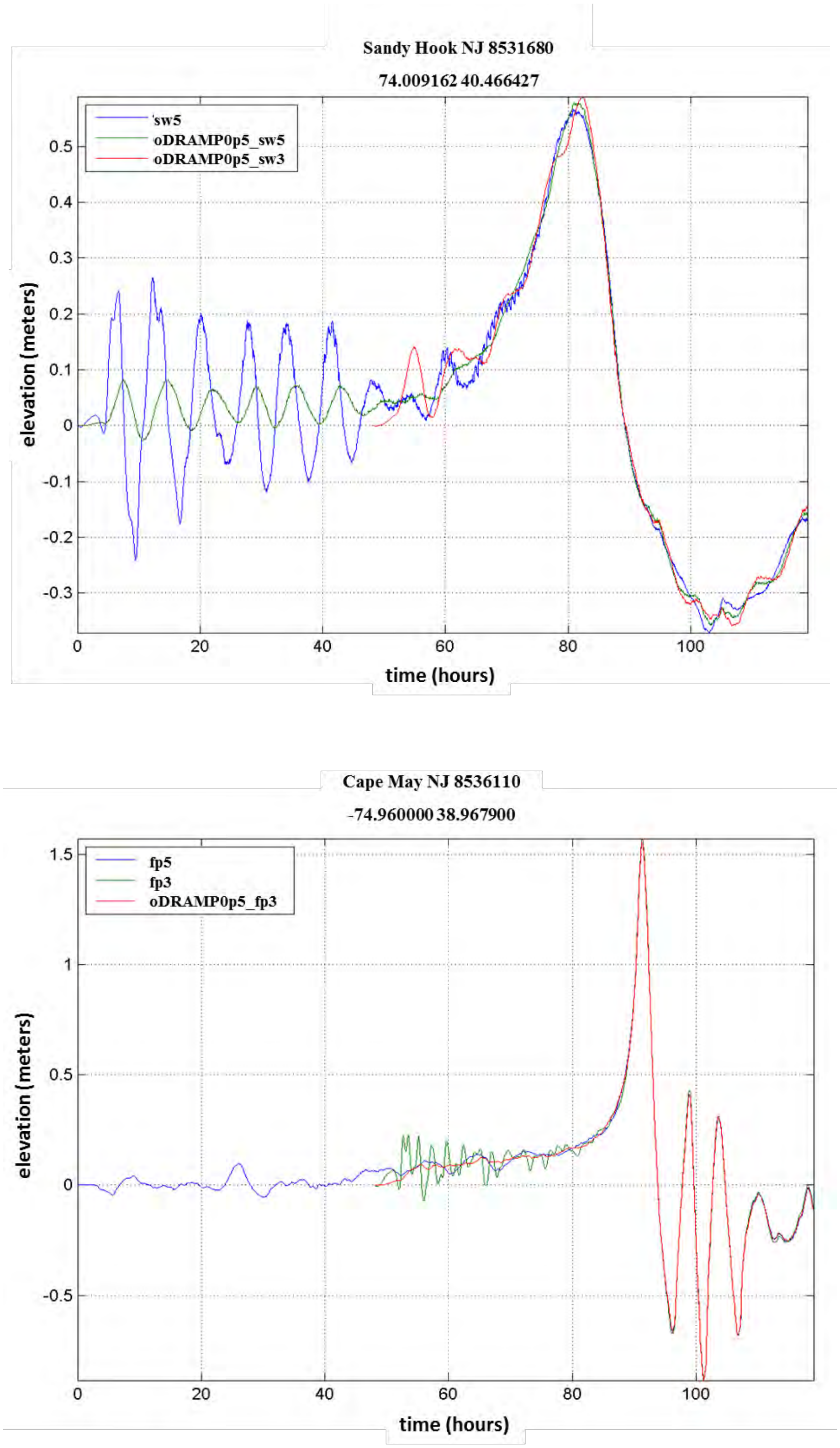
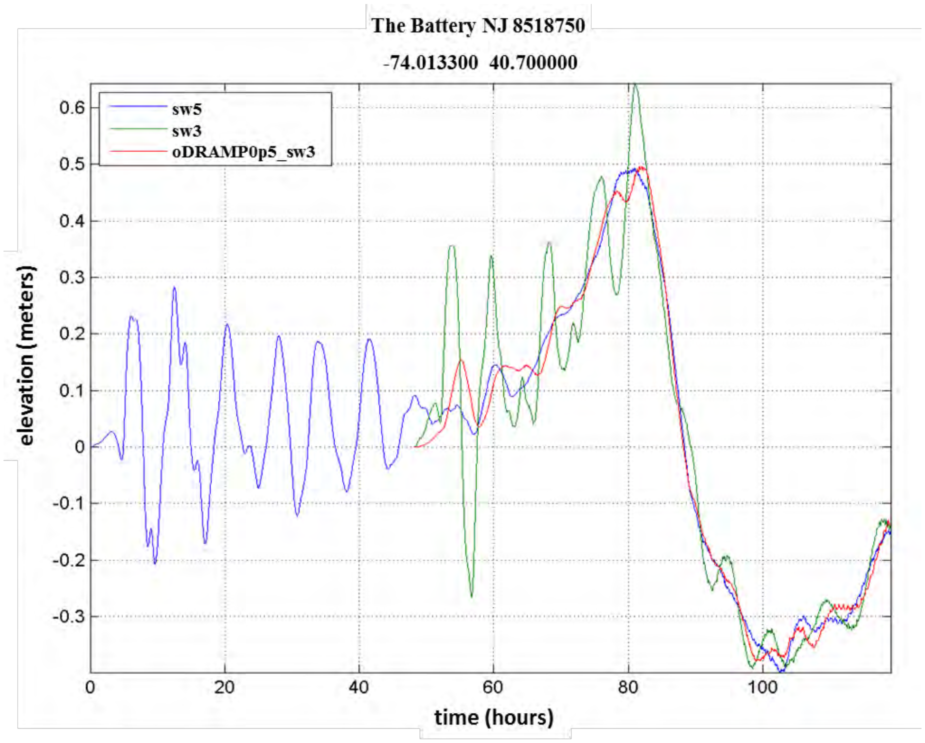


Figure 6. Water elevation time series comparing ramped and non-ramped simulations; note that gage location and simulations shown vary for each plot.



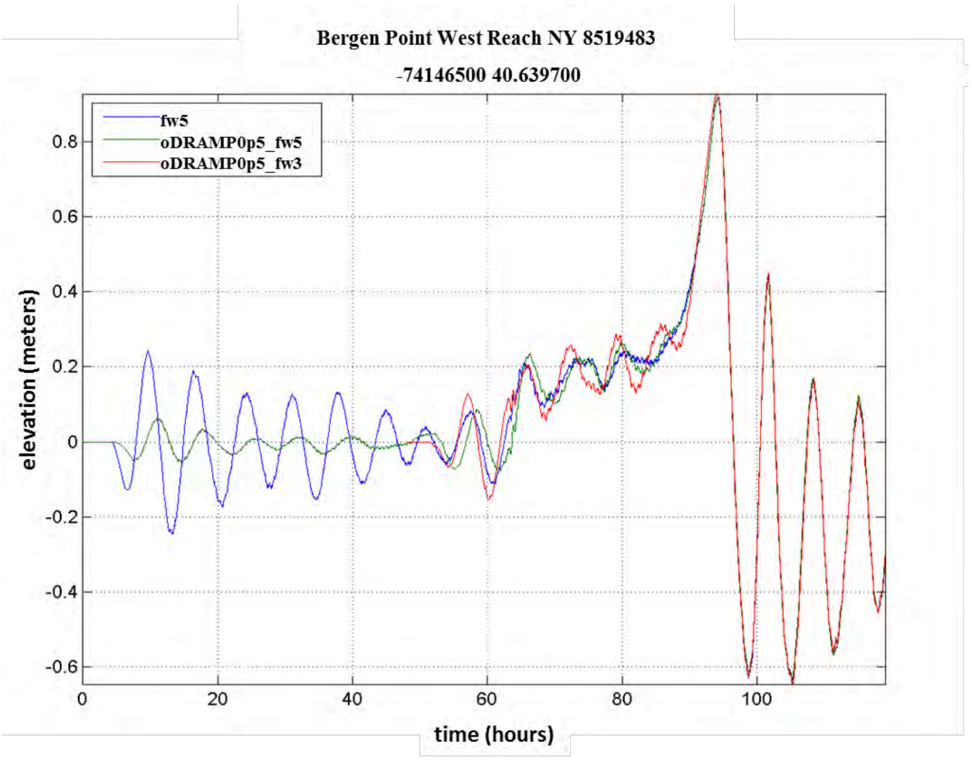


Figure 7 (cont). Water elevation time series comparing ramped and non-ramped simulations; note that gage location and simulations shown vary for each plot.

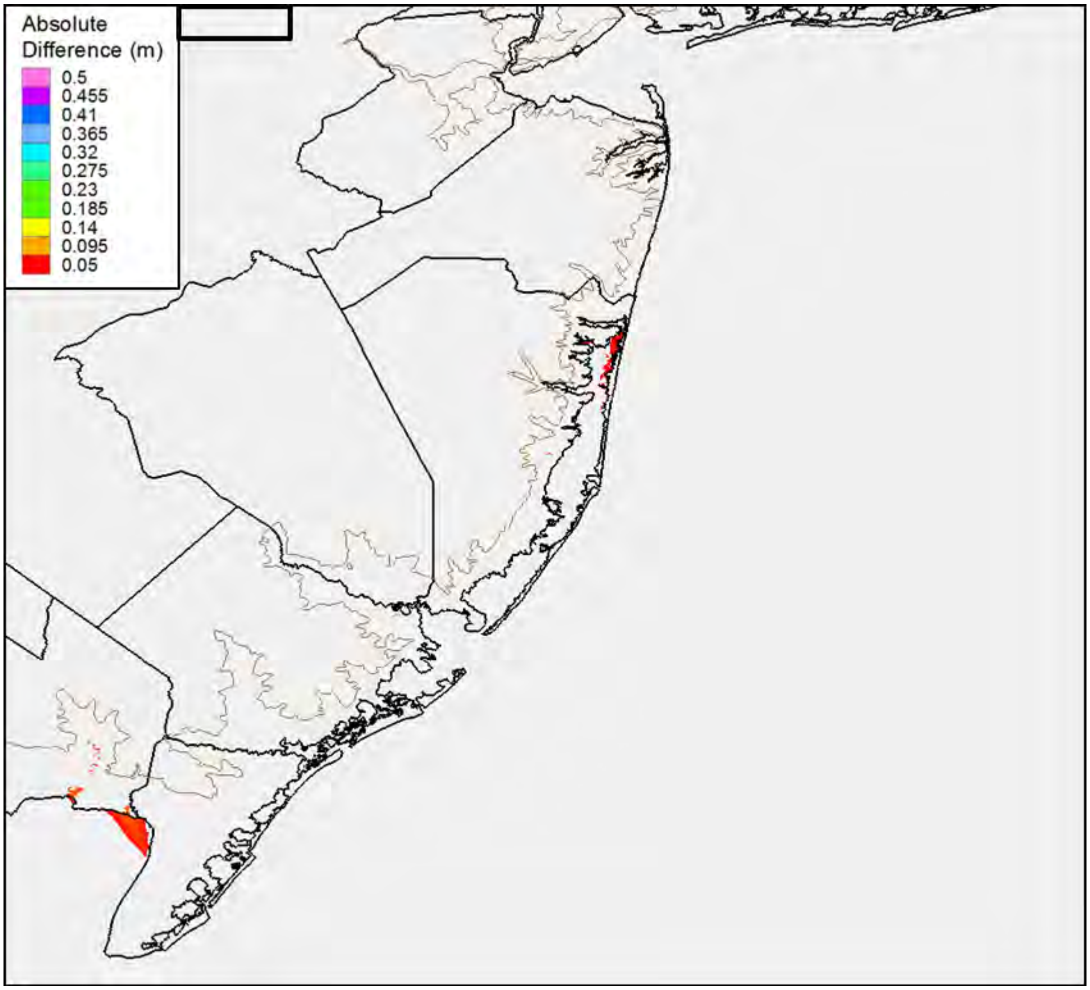


Figure 8. Absolute difference between ramped SW5 and SW3 maximum water elevation; differences less than 5 cm are not shown.

The impact of the 3- and 5-day simulations on the maximum significant wave heights for each simulation caused larger, more pervasive differences, presumably due to the propagation of distant storm waves. However, because of depth limiting, the differences along the open coast do not reach the shoreline (Figure 8). Storm FW showed the largest variations between 3- and 5-day simulations, with a 5-cm difference in peak significant wave height starting at ~200 meters (m) offshore, and 10 cm at ~400 m offshore. All other storms showed less than a 5-cm difference within 20 kilometers of the coast.

In summary, it was found that the initial shorter 3-day simulation period produced unacceptable changes in both the wave heights and surge elevations in the region of interest relative to the longer 5-day simulations. However, when a ramping period of 0.5 day was included, the results for the 3-day simulation compared well to the 5-day simulation. For this reason, 3-day simulation duration (with storm forcing being ramped during the first 12 hours of the 72-hour simulation) was selected for the tropical production runs.

The UnSWAN simulation time step is another parameter that can significantly affect the simulation duration. For each time step, the UnSWAN algorithms apply an iterative solution technique. Typically, as the time step is increased, the number of iterations required to obtain a converged solution for each time step increases. However, the relationship is not necessarily linear. Therefore, it is possible that an optimal combination of time steps and number of iterations exists that yields the most efficient solution.

An iteration test for the UnSWAN model was completed to determine the most efficient parameter setting for the UnSWAN time step and the maximum iteration count for each time step. The concept was to use the least number of iterations and largest time step possible, while ensuring that the solution would converge with each time step. This approach would reduce the simulation times and help maintain the project schedule without compromising the integrity of the results.

During these tests, the UnSWAN wave simulation did not appear to be converging for some nodes in each simulation. Attempts to decrease the time step and increase the maximum iteration did not have an apparent impact. Sporadic differences in wave height were also observed inland of the open coast behind New Jersey's barrier islands; however, these were not consistent between trials. The application of the 0.5-day ramp-up period did not affect the UnSWAN convergence issues. The behavior appeared to occur at a very limited set of nodes (albeit different in each simulation) and the problematic data was filtered out in the post-processing analysis while still providing abundant spatial coverage.

With the exclusion of the nodes with spurious data, RAMPP adopted an UnSWAN time step of 20 minutes and a maximum iteration count of 20. Note that during the QA/QC process an issue with the peak period was identified that required additional post-processing. It is likely that the spurious wave heights were related to the peak period issue. This issue is summarized in the next section and discussed in more detail in the report entitled *Recurrence Interval Analysis of Coastal Storm Surge Levels and Wave Characteristics* (RAMPP, 2014b).

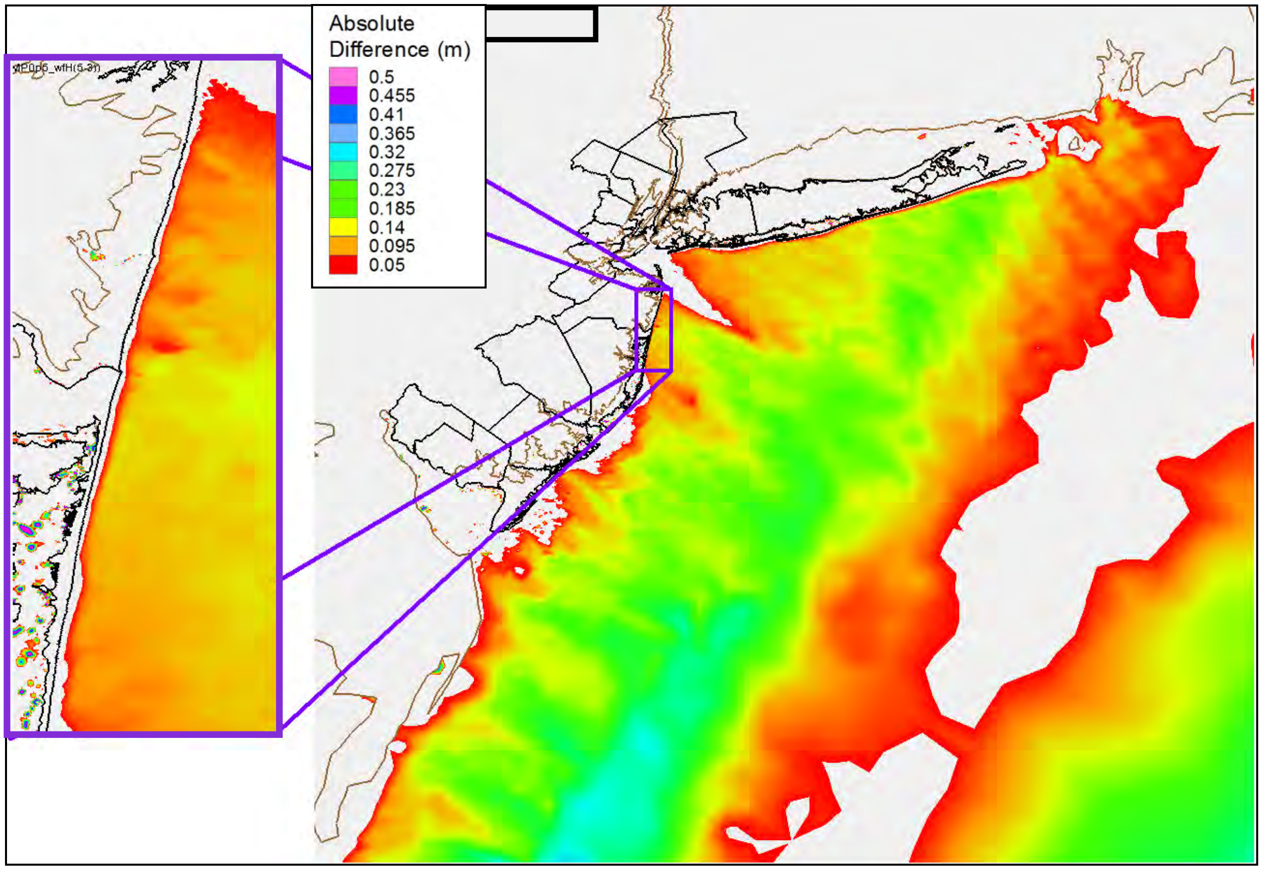


Figure 9. Absolute difference between ramped FW5 and FW3 maximum significant wave height; purple box and lines demarcate zoomed region at left.

SECTION FIVE QA/QC PROCEDURES

The ADCIRC-UnSWAN production run phase included an extensive QA/QC process. The basic QA/QC process involved checking all model input files for accuracy and consistency, and then assessing all model output files for stability and anomalies. The output checking was done in two phases. The initial check was done immediately after the simulation and was applied to the files on the cluster. The level of checking was intermediate and was intended to quickly assess that the simulation ran properly and the output was within typical ranges. It also included map view snapshots of maximum surge levels and wave heights to quickly screen for anomalies. The second, more thorough phase was conducted after the files were retrieved from the cluster. This phase included reviewing the time series of spatial plots of surge and waves, higher frequency output at specific nodes, and screening of intermediate files. This two-phase approach (local and detailed) allowed the team to quickly identify any major issues before successive simulations were executed.

The RAMPP study team developed QA/QC forms to standardize the methods for determining and reporting QA/QC events. After completing the review, the reviewer filled out the appropriate form and submitted it to the data originator for issue resolution. The issues were investigated by the file originator and resolved. The issues were rechecked to confirm the resolution. Details of the production run QA/QC process are described in the following sections. The three QA/QC forms are shown in Figures 9, 10 and 11.

During the production run task, a problem was identified with the surface directional effective roughness length input file, which contains nodal input attributes. The error existed in an open source preprocessing code used by several modeling groups to prepare one of the input files used in the ADCIRC storm surge simulations. The surface directional effective roughness length was developed using the ADCIRC utility program surface_roughness_calc_v14.f[1] with the New Jersey Land Use and Gap Analysis Program land use/land cover datasets. These are standard methodologies used in FEMA studies. The code is also one of several Fortran codes used for pre-processing input files for ADCIRC that are provided freely to the ADCIRC community by the model developers at the University of North Carolina at Chapel Hill. The error resulted in an incorrect ordering of the directional land roughness lengths contained in an ADCIRC input file (fort.13). When FEMA notified URS of the issue, the RAMPP study team immediately conducted a QA/QC review to determine its impact.

A corrected version of the fort.13 input file was promptly created and included the correct order of directional wind reduction lengths. The study team then began sensitivity testing to assess the impacts on the Region II storm surge model results. The sensitivity tests showed that for individual storms, when comparing the updated surge levels to the original levels, differences were less than ~3.0 cm (0.1 foot) for most of the study area. There were isolated differences of plus and minus 0.5 foot in back bay areas and rare instances when differences exceeded 30 cm (1 foot)

Overall, the 1-percent-annual-chance stillwater elevations (SWELs) for the Region II study area were shown to be rather insensitive to the adjustments made to the directional wind roughness lengths when using the corrected fort.13 ADCIRC input file. While there were more significant differences seen in individual storm comparisons (~15 to 30 cm, or 0.5 to 1.0 feet)), the recurrence interval analysis resulted in differences in the 1-percent-annual-chance SWELs of less than 3 cm (0.1 foot) for most of the study area. Locations where differences in the 1-percent-annual-chance SWELs were greater than ~3 cm (0.1 foot) were closely examined and it was determined that these differences would not affect the Base Flood Elevation or the extent of the flood hazard area.

These rather small differences in the 1-percent-annual-chance SWELs are also within the expected uncertainty of the predicted surge elevations given the overall context and complexity of the storm surge modeling effort. The sensitivity testing results provided technical justification for moving forward with the original study results as significant impacts were not observed. The RAMPP sensitivity analysis was replicated for other FEMA map projects in process. The sensitivity analysis results for the other studies were similar to those obtained by RAMPP. The surface directional effective roughness length nodal attribute is not used in the UnSWAN model. Thus, there was no direct impact of the directional effective roughness issues on the UnSWAN simulations. The only impact was indirect. The ADCIRC simulated water elevations may have varied slightly due to the directional effective roughness issues. Because the water elevation is passed from ADCIRC to UnSWAN, the UnSWAN-simulated waves may have been influenced. However, since the impact to the ADCIRC-simulated water levels was generally less than ~3.0

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[1] An earlier version of the code, surface_roughness_calc_v13.f, was also used and it contained the same error discovered in surface_roughness_calc_v14.f

cm (0.1 foot), the indirect impact on the UnSWAN simulated wave heights is expected to be negligible. The study team's findings were presented to the Coastal Integrated Project Team, as well as the Technical Advisory Panel for the NYC/NJ Surge Study, and it was concluded that the impact of the original pre-processor code error was negligible and therefore did not require updating the affected production run simulations. A detailed description of the analysis of this issue is provided in the Spatially Varying Nodal Attribute Parameters Report (RAMPP, 2014a).

The QA/QC process also indicated that the peak wave period data that were obtained from the production run outputs contained spurious results that required special attention. The simulated peak period data are used to characterize the starting wave conditions for subsequent overland wave analysis and their integrity is critical to accurate overland wave modeling. The wave heights for each storm were reasonable, except for the occasional spurious values. However, for the peak period there were numerous distinct regions, referred to as clusters, where the peak periods were 32 seconds. Some of these clusters of spurious peak period values appear to occur in all simulations, and some clusters occurred only in one or a few simulations. Additionally, for the clusters that appear chronically, the extent of the affected area may vary from storm to storm. In all cases, it appears that for the peak period, the affected areas are defined by an abrupt change from reasonable wave period values to periods of 32 seconds.

RUN INFORMATION	
Run Name: (JPM_OS1_XXXX_XXX)	

INPUT FILE CHECK	
Reviewer:	
Organization:	Choose an item.
Date Checked:	
Tide ID	
Storm ID	
swaninit, *.pbs, fort.22, fort.26 files in storm folder?	Choose an item.
Symbolic link verified for: fort.13, fort.14, fort.221, fort.222, fort.223, fort.224	Choose an item.
Correct hotstart input file available (fort.67 or fort.68)	Choose an item.
PE0000 folder contains correct files (fort.13, fort.14, fort.15, fort.16, fort.18, fort.26, fort.67 or fort.68)	Choose an item.
Parameters in fort.15 file checked? (RUNID, IHOT, NWS, WTIMINC, RNDAY, NOUTE, NOUTGE, NOUTGM)	Choose an item.
Were the storm parameter summary plots reviewed?	Choose an item.

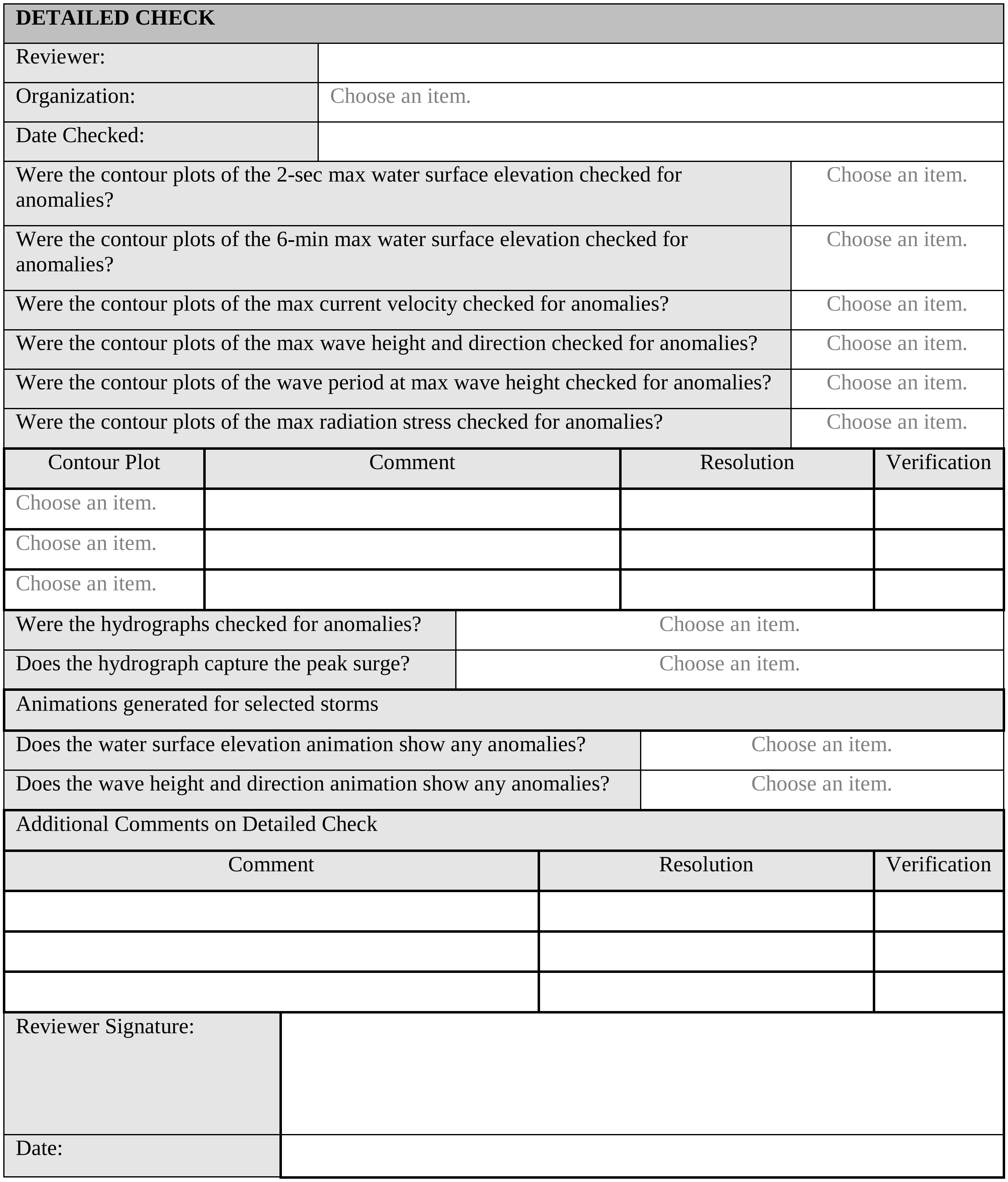
Additional Comments on Input Files

File	Comment	Resolution	Verification

Reviewer Signature:	
Date:	

Figure 10. QA/QC Form for launching a simulation.

OUTPUT FILE CHECK			
Reviewer:			
Organization:	Choose an item.		
Date Checked:			
Model ran to completion without large instabilities.			Choose an item.
Model created appropriate output files. (Check file size)			Choose an item.
Post-processing plots were created.			Choose an item.
Large scale WSE, Hs, Tp, Tm plots were reviewed for anomalies			Choose an item.
<u>Additional Comments on Output Files</u>			
File	Comment	Resolution	Verification
Reviewer Signature:			
Date:			



DETAILED CHECK	
Reviewer:	
Organization:	Choose an item.
Date Checked:	
Were the contour plots of the 2-sec max water surface elevation checked for anomalies?	Choose an item.
Were the contour plots of the 6-min max water surface elevation checked for anomalies?	Choose an item.
Were the contour plots of the max current velocity checked for anomalies?	Choose an item.
Were the contour plots of the max wave height and direction checked for anomalies?	Choose an item.
Were the contour plots of the wave period at max wave height checked for anomalies?	Choose an item.
Were the contour plots of the max radiation stress checked for anomalies?	Choose an item.

Contour Plot	Comment	Resolution	Verification
Choose an item.			
Choose an item.			
Choose an item.			

Were the hydrographs checked for anomalies?	Choose an item.
Does the hydrograph capture the peak surge?	Choose an item.
Animations generated for selected storms	
Does the water surface elevation animation show any anomalies?	Choose an item.
Does the wave height and direction animation show any anomalies?	Choose an item.
Additional Comments on Detailed Check	

Comment	Resolution	Verification

Reviewer Signature:	
Date:	

Figure 12. QA/QC Form for detailed check after output files have been downloaded.

The simulated mean wave period characteristics are much different than those of the peak period. In many regions where the peak period anomalies occurred, there was no obvious impact on the mean period. In some regions, there was an apparent impact, but the impact was limited to fewer nodes. Furthermore, in the area of the impacted mean periods, there was a transition rather than an abrupt change. A review of the wave height indicated that the impact of the peak period anomalies did not have a profound effect on the wave height. Figure 12 shows an example of the typical behavior for one storm simulation. The peak period anomalies encompass a large region, indicated in blue (i.e., periods of 32 seconds). The areas of mean period anomalies are much smaller and are contained in two relatively small areas in the upper right of the mean period contour plot. An inspection of the mean period contour plot indicates that the impacts to the wave height are limited to only those areas where the mean period is impacted.

The relatively large clusters of anomalous peak periods occurring throughout the grid prevented a straightforward processing of the simulated wave data for use in the subsequent overland wave modeling. This study is one of the first to use the directly coupled ADCIRC and UnSWAN models for the storm simulations. Subsequent to completing the production simulations, this issue with the peak and mean period was identified by ADCIRC-UnSWAN code authors and resolved (Dietrich et al., 2012), but the remedies were not available at the time of this study. Thus, the identification of the peak wave period issue and the subsequent uncertainty in the reliability of the peak period data dictated that the study team develop an alternate approach for generating the starting peak wave period data. One approach would be to remove the areas with the anomalous peak period because they are relatively easy to identify. However, removing these data would create large gaps in the spatial representation of the peak periods, and would reduce confidence in interpolating peak period data across the gaps from nodes on the perimeter.

An alternate approach, which was ultimately adopted, consists of processing the mean wave period results from the storm simulations instead of the peak wave period data. A review of the mean wave period data indicated that the affected areas were significantly smaller in extent, and consequently, the spatial extent of the gaps would be small if impacted nodes were removed. Therefore, interpolation of data across the gaps could be completed with confidence. The mean period data could then be transformed into a peak period using transformational relationships developed in those areas where both the mean and peak data were reliable.

Therefore, the production runs were not modified in response to the peak period issue. The peak period data were post-processed as part of the recurrence interval analysis and special QA/QC procedures were applied there. Details of the peak period issue and its resolution in terms of the recurrence interval analysis are documented in the Recurrence Interval Analysis of Coastal Storm Surge Levels and Wave Characteristics report (RAMPP, 2014b).

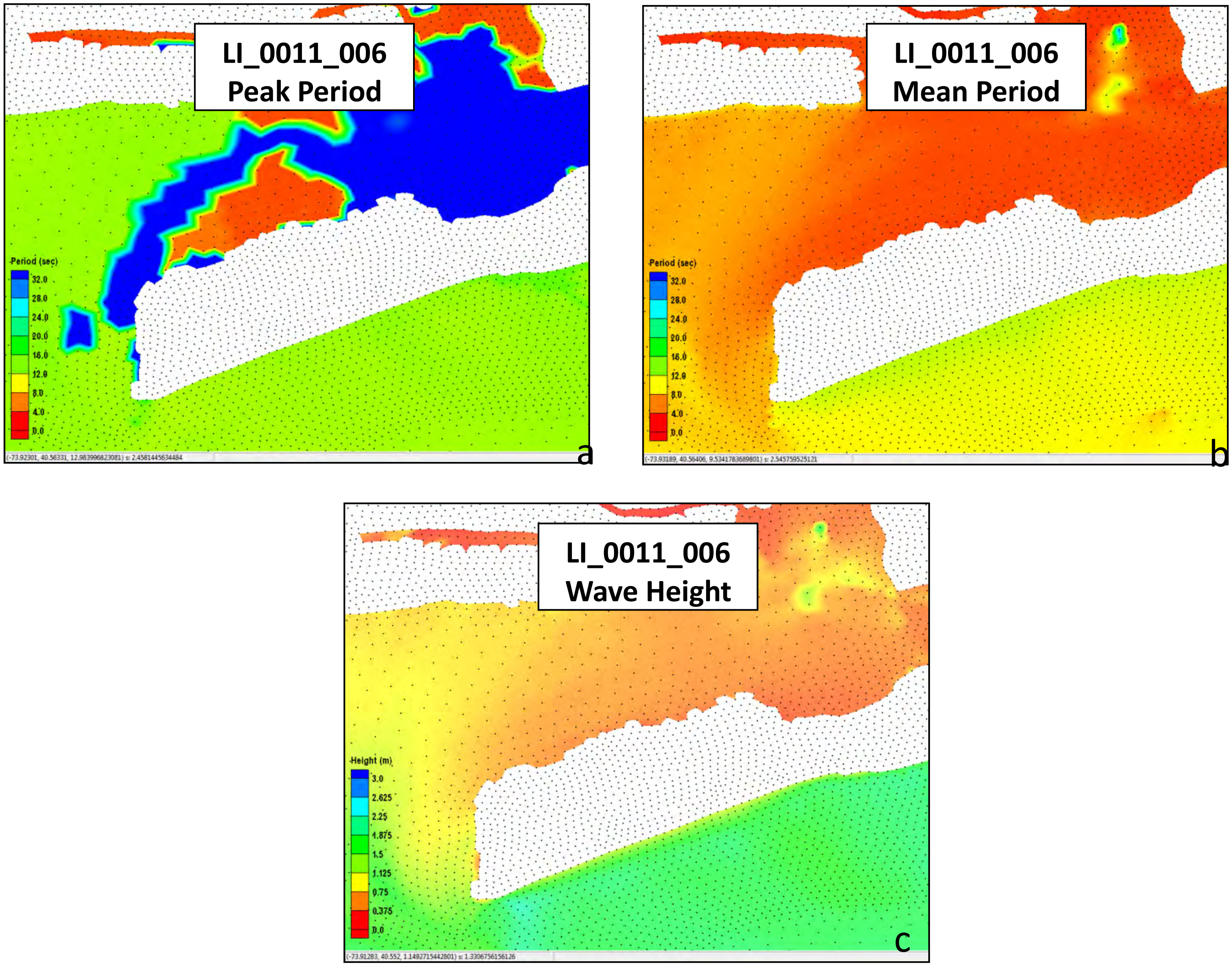


Figure 12: Example of peak period, mean period and wave height distribution for storm LI_0011_006 near Jamaica Bay.

SECTION SIX REFERENCES

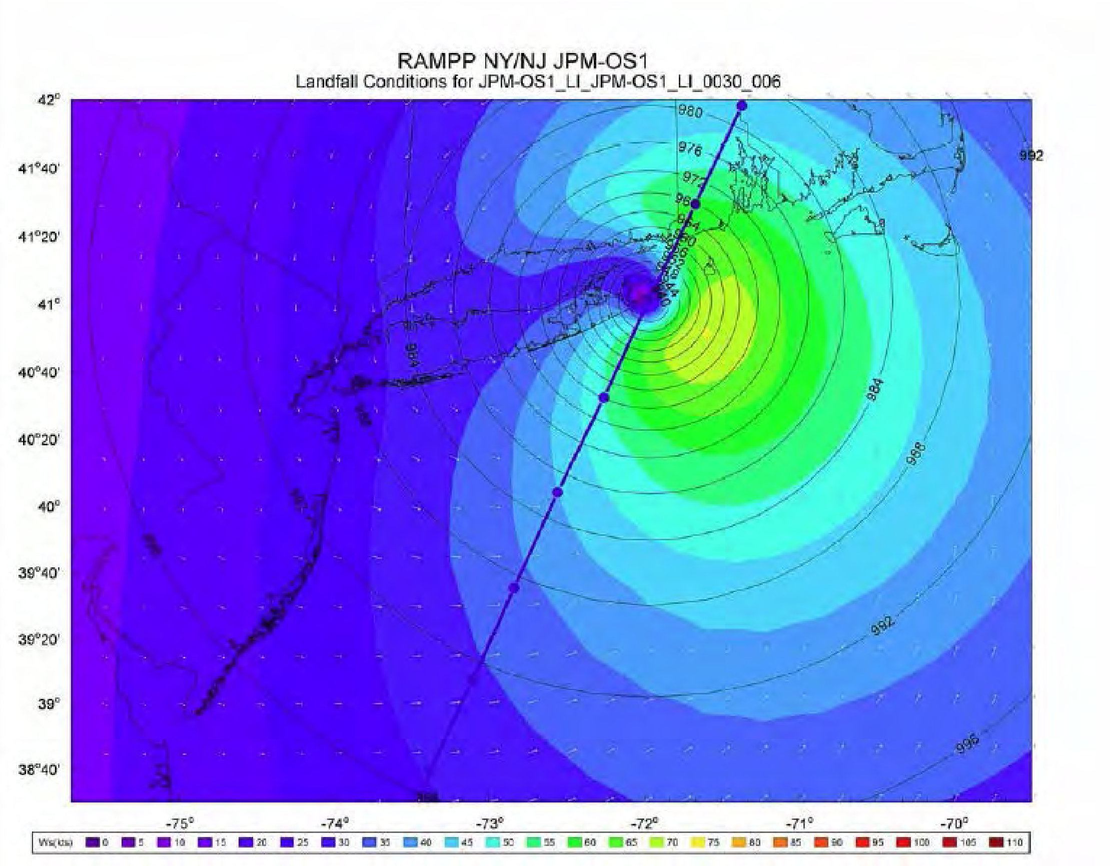
J.C. Dietrich, M Zijlema, P-E Allier, L.H. Holthuijsen, N. Booij, J.D. Meixner, J.K. Proft, C.N. Dawson, C.J. Bender, A. Naimaster, J.M. Smith, J.J. Westerink Limiters for Spectral Propagation Velocities in SWAN, Ocean Modelling, in press, DOI: 10.1016/j.ocemod.2012.11.005, 2012.

RAMPP, 2014a.Region II Storm Surge Project – Spatially Varying Nodal Attribute Parameters, FEMA TO HSFE02-09-J-001, 2014.

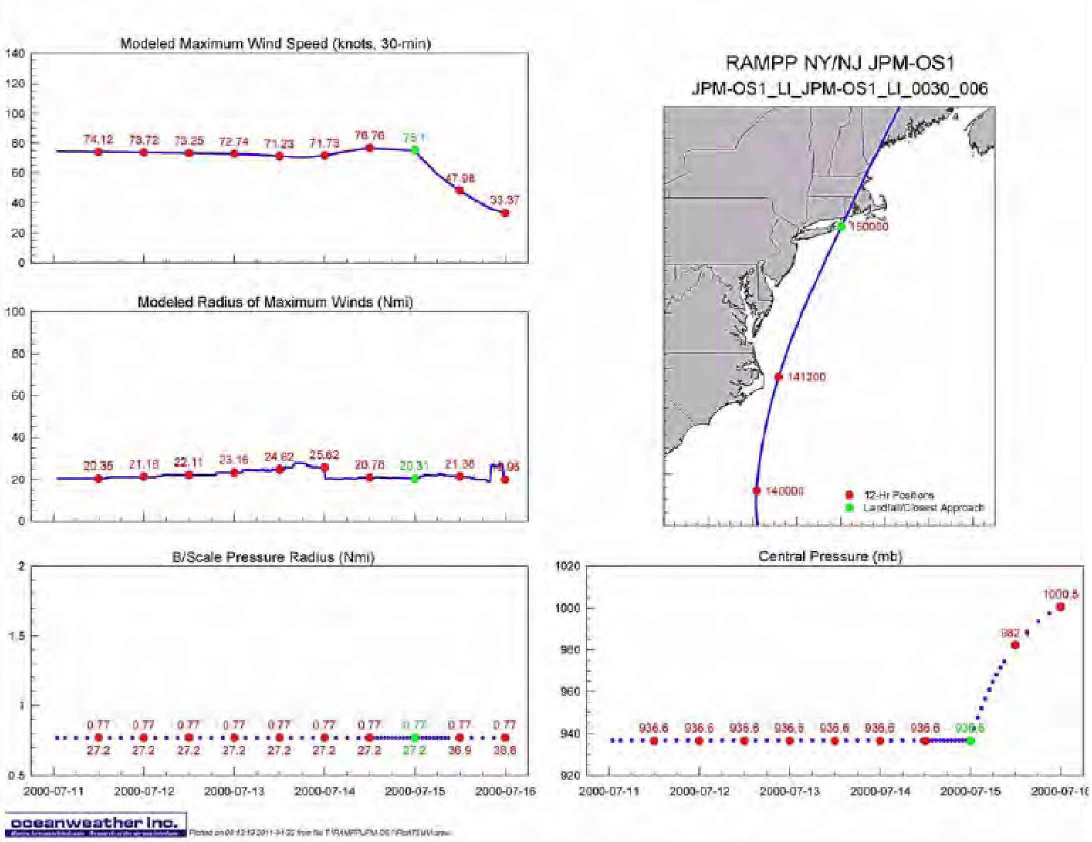
RAMPP, 2014b. Region II Storm Surge Project – Recurrence Interval Analysis of Coastal Storm Surge Levels and Wave Characteristics, FEMA TO HSFE02-09-J-001, 2014.

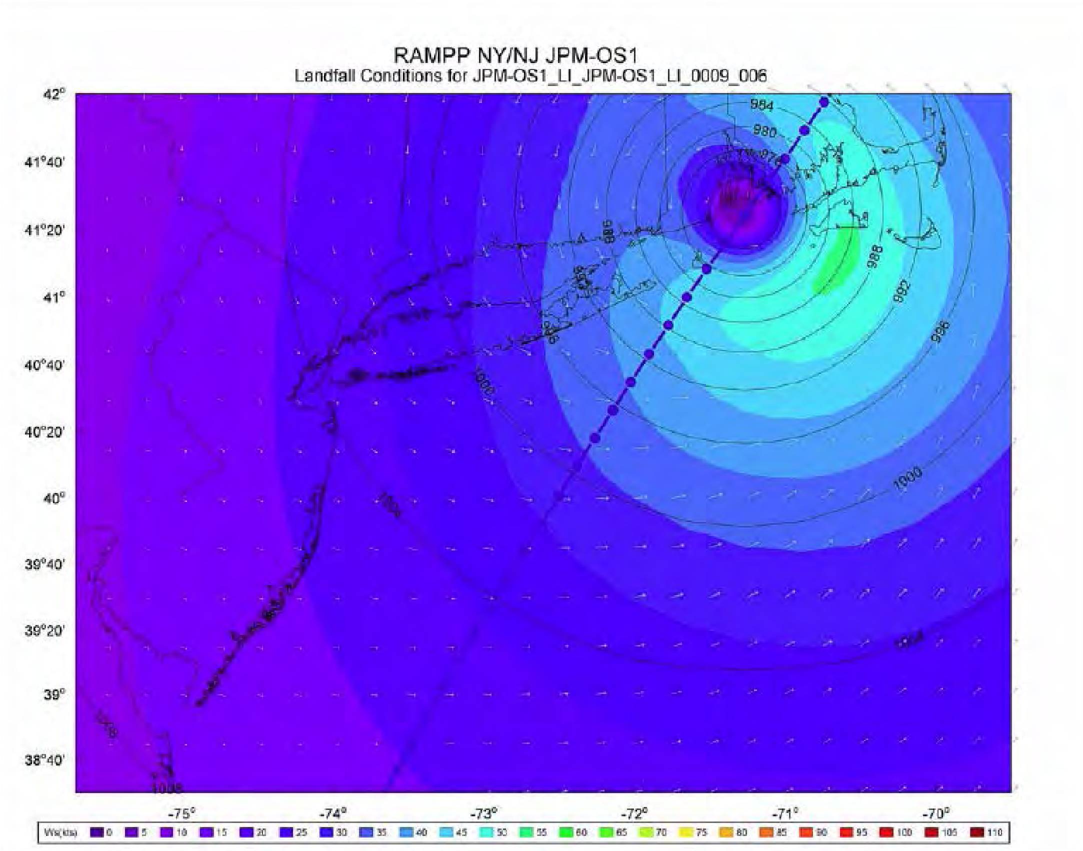
Appendix A

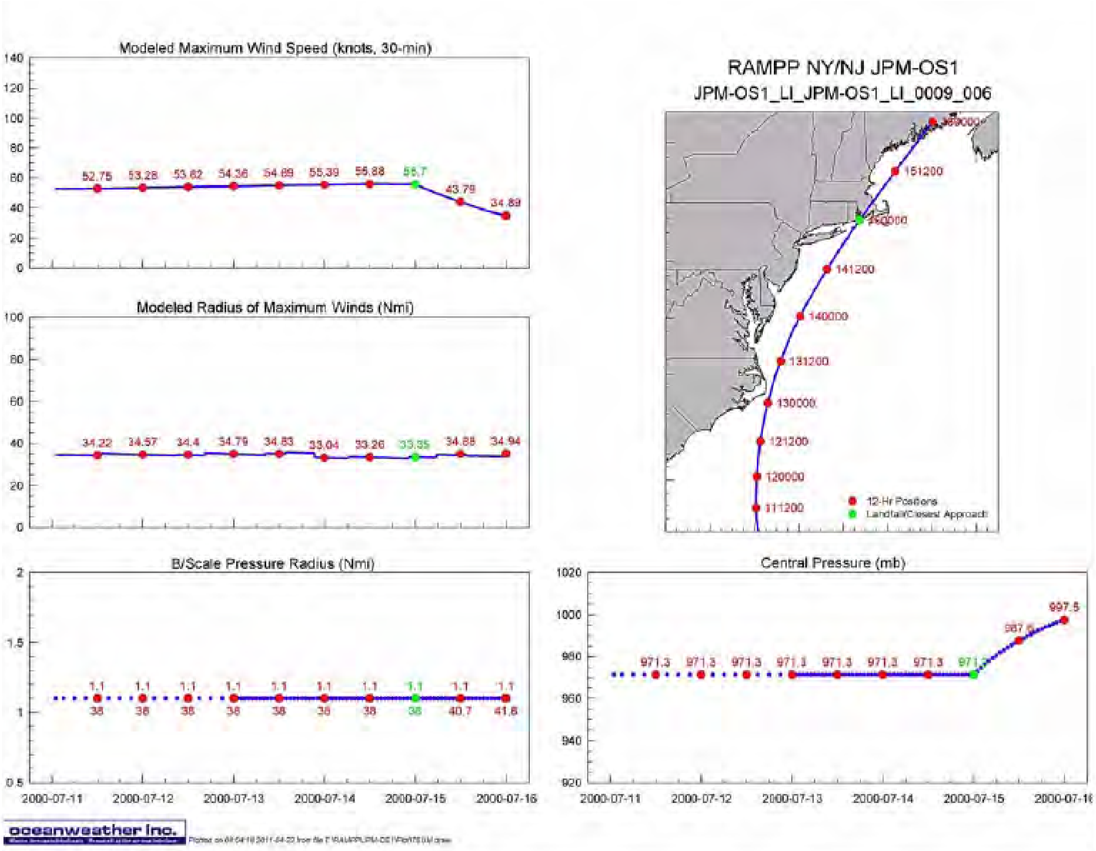
Summary Pages for Selected Storms

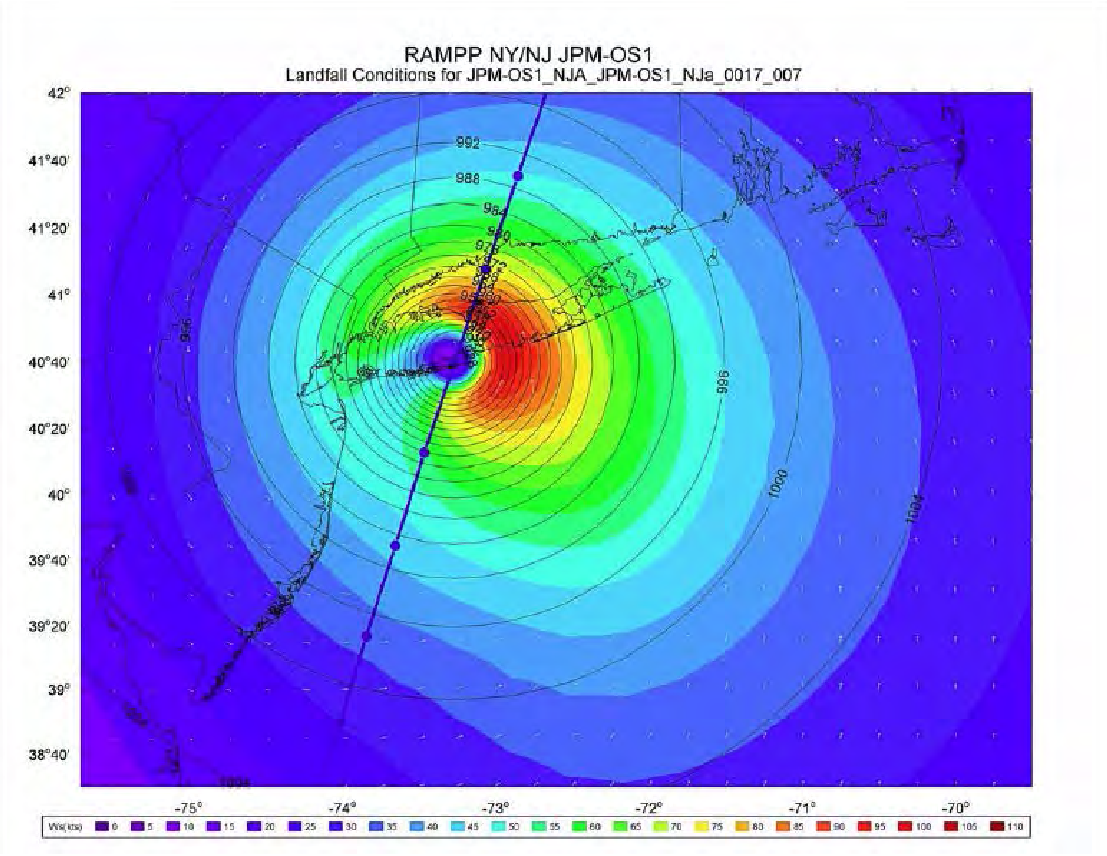

RAMPP NY/NJ JPM-OS1
Landfall Conditions for JPM-OS1_LI_JPM-OS1_LI_0030_006
42°
41°40'
41°20'
41°
40°40'
40°20'
40°
39°40'
39°20'
39°
38°40'
-75°
-74°
-73°
-72°
-71°
-70°
980
976
972
984
988
992
996
Ws(kts) 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110

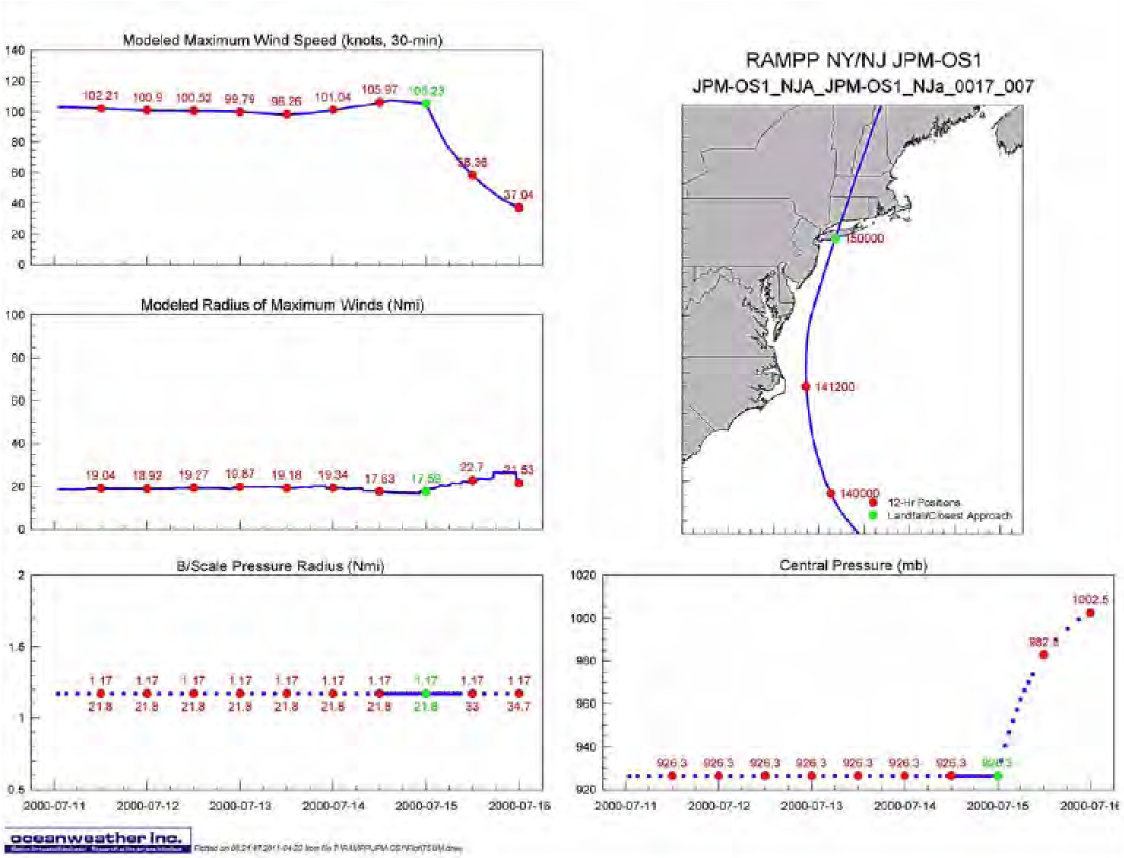
s

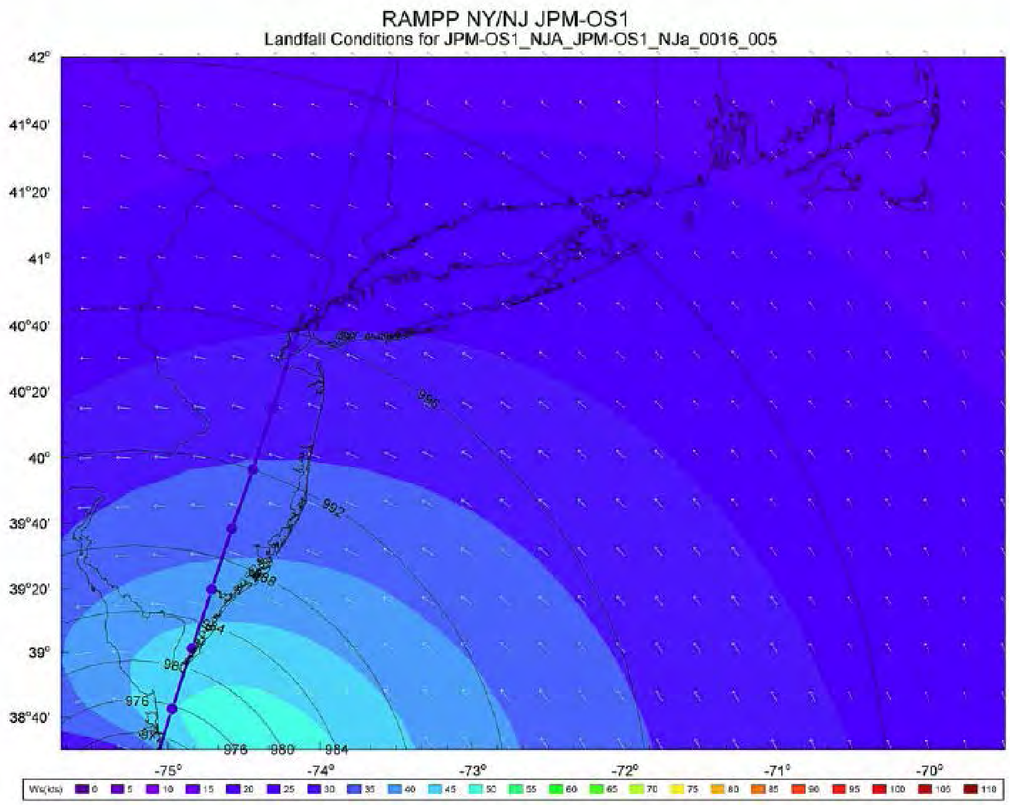

Modeled Maximum Wind Speed (knots, 30-min)
140
120
100
80
60
40
20
0
74.12
73.72
73.25
72.74
71.23
71.73
76.76
75.1
47.98
33.37
Modeled Radius of Maximum Winds (Nmi)
100
80
60
40
20
0
20.36
21.18
22.11
23.16
24.62
25.62
20.78
20.31
21.38
19.08
B/Scale Pressure Radius (Nmi)
2
1.5
1
0.5
0.77
27.2
36.9
38.8
2000-07-11
2000-07-12
2000-07-13
2000-07-14
2000-07-15
2000-07-16
RAMPP NY/NJ JPM-OS1
JPM-OS1_LI_JPM-OS1_LI_0030_006
150000
141200
140000
12-Hr Positions
Landfall/Closest Approach
Central Pressure (mb)
1020
1000
980
960
940
920
936.6
982
1000.5
oceanweather Inc.

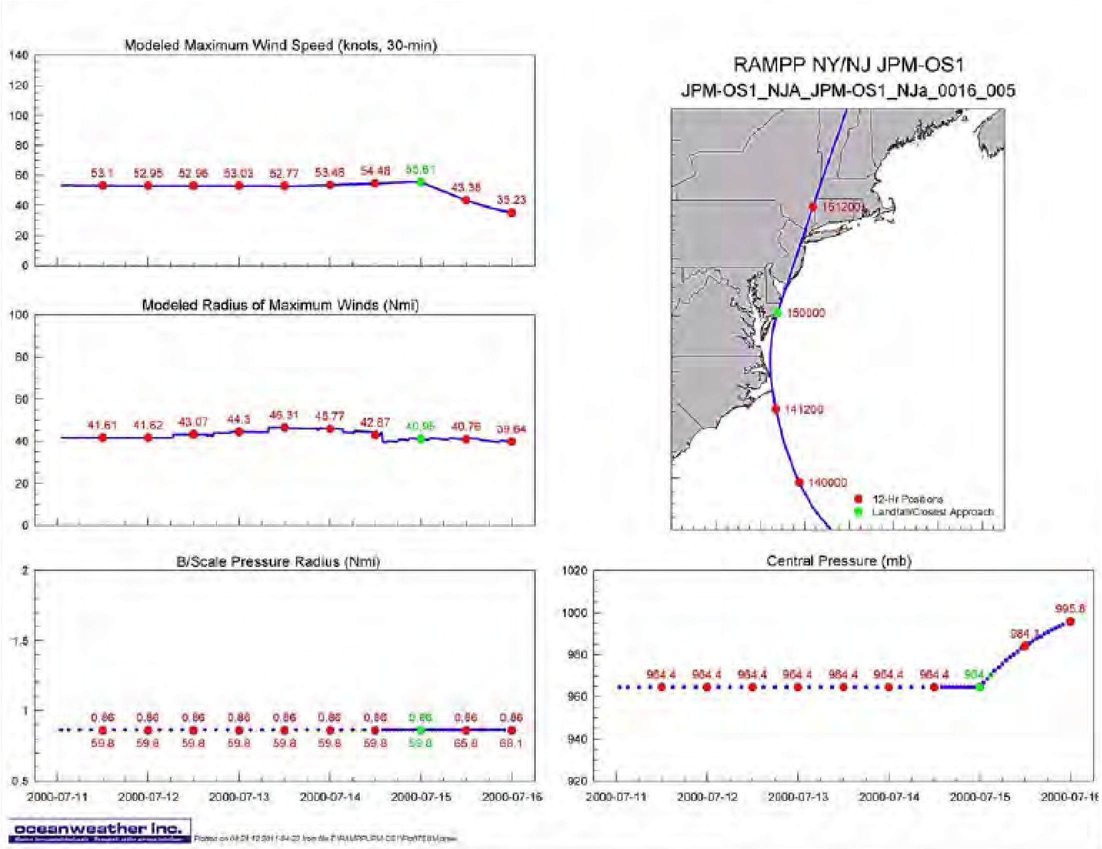

RAMPP NY/NJ JPM-OS1
Landfall Conditions for JPM-OS1_LI_JPM-OS1_LI_0009_006
42°
41°40'
41°20'
41°
40°40'
40°20'
40°
39°40'
39°20'
39°
38°40'
-75°
-74°
-73°
-72°
-71°
-70°
984
980
976
988
992
996
1000
1004
1008
Ws(kts) 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110


Modeled Maximum Wind Speed (knots, 30-min)
140
120
100
80
60
40
20
0
52.75
53.28
53.62
54.36
54.89
55.39
55.88
55.7
43.79
34.89
Modeled Radius of Maximum Winds (Nmi)
100
80
60
40
20
0
34.22
34.57
34.4
34.79
34.83
33.04
33.26
33.35
34.88
34.94
B/Scale Pressure Radius (Nmi)
2
1.5
1
0.5
1.1
38
1.1
38
1.1
38
1.1
38
1.1
38
1.1
38
1.1
38
1.1
38
1.1
40.7
1.1
41.8
2000-07-11
2000-07-12
2000-07-13
2000-07-14
2000-07-15
2000-07-16
RAMPP NY/NJ JPM-OS1
JPM-OS1_LI_JPM-OS1_LI_0009_006
160000
151200
150000
141200
140000
131200
130000
121200
120000
111200
12-Hr Positions
Landfall/Closest Approach
Central Pressure (mb)
1020
1000
980
960
940
920
971.3
971.3
971.3
971.3
971.3
971.3
971.3
971.3
987.6
997.5
2000-07-11
2000-07-12
2000-07-13
2000-07-14
2000-07-15
2000-07-16
oceanweather inc.


RAMPP NY/NJ JPM-OS1
Landfall Conditions for JPM-OS1_NJA_JPM-OS1_NJa_0017_007
42°
41°40'
41°20'
41°
40°40'
40°20'
40°
39°40'
39°20'
39°
38°40'
-75°
-74°
-73°
-72°
-71°
-70°
992
988
984
980
976
996
1000
1004
Ws(kts)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110


RAMPP NY/NJ JPM-OS1
JPM-OS1_NJA_JPM-OS1_NJa_0017_007
Modeled Maximum Wind Speed (knots, 30-min)
140
120
100
80
60
40
20
0
102.21
100.9
100.52
99.79
98.26
101.04
105.97
105.23
58.38
37.04
Modeled Radius of Maximum Winds (Nmi)
100
80
60
40
20
0
19.04
18.92
19.27
19.87
19.18
19.34
17.63
17.52
22.7
21.53
B/Scale Pressure Radius (Nmi)
2
1.5
1
0.5
1.17
21.8
33
34.7
2000-07-11
2000-07-12
2000-07-13
2000-07-14
2000-07-15
2000-07-16
150000
141200
140000
12-Hr Positions
Landfall/Closest Approach
Central Pressure (mb)
1020
1000
980
960
940
920
926.3
982.8
1002.5
oceanweather inc.


RAMPP NY/NJ JPM-OS1
Landfall Conditions for JPM-OS1_NJA_JPM-OS1_NJa_0016_005
42°
41°40'
41°20'
41°
40°40'
40°20'
40°
39°40'
39°20'
39°
38°40'
996
992
988
984
980
976
976
980
984
-75°
-74°
-73°
-72°
-71°
-70°
Wi(kts) 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110


Modeled Maximum Wind Speed (knots, 30-min)
140
120
100
80
60
40
20
0
53.1
52.95
52.96
53.03
52.77
53.48
54.48
55.61
43.38
35.23
Modeled Radius of Maximum Winds (Nmi)
100
80
60
40
20
0
41.61
41.62
43.07
44.3
46.31
45.77
42.87
40.95
40.76
39.64
B/Scale Pressure Radius (Nmi)
2
1.5
1
0.5
0.86
59.8
65.8
68.1
2000-07-11
2000-07-12
2000-07-13
2000-07-14
2000-07-15
2000-07-16
RAMPP NY/NJ JPM-OS1
JPM-OS1_NJA_JPM-OS1_NJa_0016_005
151200
150000
141200
140000
12-Hr Positions
Landfall/Closest Approach
Central Pressure (mb)
1020
1000
980
960
940
920
964.4
964
984.1
995.8
oceanweather inc.