Federal Agency:	National Oceanic and Atmospheric Administration
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Title:	Transition of the Coastal and Estuarine Storm Tide Model to an Operational Model for Forecasting Storm Surges
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Submission Date:	September 30th 2016
Recipient Organization:	Florida International University 11200 SW 8Th Street, MARC 430, Miami, FL 33199
Project Period:	(04/01/2016-09/30/2016)
Reporting Period End Date:	September 30, 2016
Report Term or Frequency:	Semi-annual
Final Annual Report:	No

1. ACCOMPLISHMENTS

We proposed to conduct experimental storm surge forecasting during 2015 and 2016 hurricane seasons and convert CEST into a fully operational model by working with NHC's Storm Surge Unit through the JHT program. The tasks of this project include (1) testing CEST on existing and recently developed SLOSH basins with track files from NHC, (2) developing CEST P-Surge through collaboration with Meteorological Development Laboratory (MDL), (3) conducting real-time surge forecasting during hurricane seasons, and (4) porting CEST to the Linux operating system used by NHC, and preparing documents and training staff members at NHC to use CEST. The status of four tasks at the end of this period is presented in Table 1.

Table 1. Status of proposed tasks and deliverables.

Tasks	Proposed Timeline	Status
Task 1: Testing CEST on existing and recently developed SLOSH basins	2016 Q2	completed
Task 2: Developing CEST P-Surge	2017 Q2	Ongoing
Task 3: Conducting real-time surge forecasting during hurricane seasons	2015 Q3 & Q4 2016 Q3 & Q4	Ongoing
Task 4: Porting CEST to NHC forecast environment	2017 Q2	Conducted CEST simulations on the Linux platform in the HPC of FIU

During this period, we converted all SLOSH basins into corresponding CEST grids and associated SLOSH tracks (Table 2) into the CEST tracks which are in xml format by following the procedures presented in the previous report. Meanwhile, CEST was ported to the Linux platform in the High Performance Computing (HPC) center of Florida International University (FIU), which employs the compiler similar to the one used by NOAA's supercomputer. We have tested the CEST model over all grids by performing simulations using hypothetical hurricane tracks provided by NHC. There are about 10,000-70,000 hypothetical hurricanes with varying intensities, forward speeds, and incoming directions for each basin. The CEST model was robust for most cases without further adjustment and produced MEOWs and MOMs comparable to those created by the SLOSH model.

Table 2. SLOSH Basins

SLOSH Name	BASIN	Version	Track Files
AP3	Apalachicola Bay	V3	Old Format
CD2	Cedar Key	V2	Old Format
CO2	Cape Canaveral	V2	Old Format
CP5	Chesapeake Bay	V4	New Format
CR3	Corpus Christi Bay	V3	Old Format
DE3	Delaware Bay	V3	Old Format
EBP3	Sabine Lake	V5	Old Format
EBR3	Laguna Madre	V3	Old Format
EFM2	Fort Myers	V3	Old Format
EGL3	Galveston Bay	V4	Old Format
HT3	Pamlico Sound	V4	Old Format
EJX3	Jacksonville	V3	Old Format
EKE2	Florida Key	V3	Old Format
EMO2	Mobile Bay	V3	Old Format
EOK3	Lake Okeechobee	V4	Old Format
OR3	Norfolk	V3	Old Format
EPN3	Pensacola Bay	V4	Old Format
ESV4	Savannah/Hilton Head	V4	Old Format
ETP3	Tampa Bay	V3	Old Format
HCH2	Charleston Harbor	V3	Old Format
HMI3	Biscayne Bay	V4	Old Format
HPA2	Panama City	V3	Old Format
IL3	Wilmington/Myrtle Beach	V3	Old Format
LF2	Vermilion Bay	V2	Old Format
MS8	New Orleans	V10	New Format
NY3	New York	V3	Old Format
PB3	Palm Beach	V3	Old Format
PN2	Penobscot Bay	V2	Old Format
PS2	Matagorda Bay	V2	Old Format
PV2	Providence Boston	V2	Old Format

Note: There are two formats (old and new) of track files for SLOSH basins. The length of the track in old format is limited by 100 hours, while the length of the track in the new format is not.

The project is on schedule. The percentage of remaining tasks and deliverables are presented in Table 3.

Table 3. Completion percentage of proposed tasks and deliverables.

Tasks	**Cumulative percent toward Completion**
Task 1: Testing CEST on existing and recently developed SLOSH basins	100%
Task 2: Developing CEST P-Surge	10%
Task 3: Conducting real-time surge forecasting during hurricane seasons	50%
Task 4: Porting CEST to NHC forecast environment	50%

The project fits the NHC-6/JTWC11 priority "Advanced coastal inundation modeling and/or applications, visualization, or dissemination technology that enhances operational storm surge forecast accuracy or delivery". The project deliverables are the CEST forecast system and associated documents and training materials.

We have discussed the principles of P-Surge with the developers of Meteorological Development Laboratory. For the next reporting period, we will develop a CEST P-Surge prototype and investigate the difference in inundation patterns of MOMs and MEOWs produced by CEST and SLOSH.

2. PRODUCTS

There are two conference papers associated with this project.

I. Li Y, Teng YC, Kelly DM, Zhang K (2016). Impacts of Storm Surges on the Hoover Dike of Lake Okeechobee. 2016 Ocean Science Meeting, New Orleans, Louisiana, USA. Available through https://agu.confex.com/agu/os16/preliminaryview.cgi/Paper87639.html

II. Li Y, Teng YC, Kelly DM, Zhang K (2016). The Effects of Land Cover and Associated Bottom Friction on Computation of Surge Inundation Extent, ECM14: 14th International Conference on Estuarine and Coastal Modeling, Kingston, Rhode Island, USA

Nine of 30 SLOSH basins including CR3 (Corpus Christi Bay), EBP3 (Sabine Lake), EBR3 (Laguna Madre), EPN3 (Pensacola Bay), ESV4 (Savannah/Hilton Head), LF2 (Vermilion Bay), NY3 (New York), PB3 (Palm Beach), PN2 (Penobscot Bay), were selected to present the comparison of the MOMs generated by SLOSH and CEST. Only results for Category 4 or 5 hurricanes were presented to limit the text length.

2.1 Comparison of Inundation Patterns of SLOSH and CEST

The comparison of MOMs between CEST and SLOSH at CR3 (Corpus Christi Bay), EBP3 (Sabine Lake), EBR3 (Laguna Madre), EPN3 (Pensacola Bay), ESV4 (Savannah/Hilton Head), LF2 (Vermilion Bay), NY3 (New York), PB3 (Palm Beach), PN2 (Penobscot Bay), for Category 4 or 5 hurricanes at mean and high tides are presented at Figs. 1, 2, 3, 4, 5, 6, 7, 8, and 9 respectively. The results show that the overall spatial pattern were similar and the maximum storm surges were comparable in most cases. The inundation areas produced by CEST were usually smaller than SLOSH.

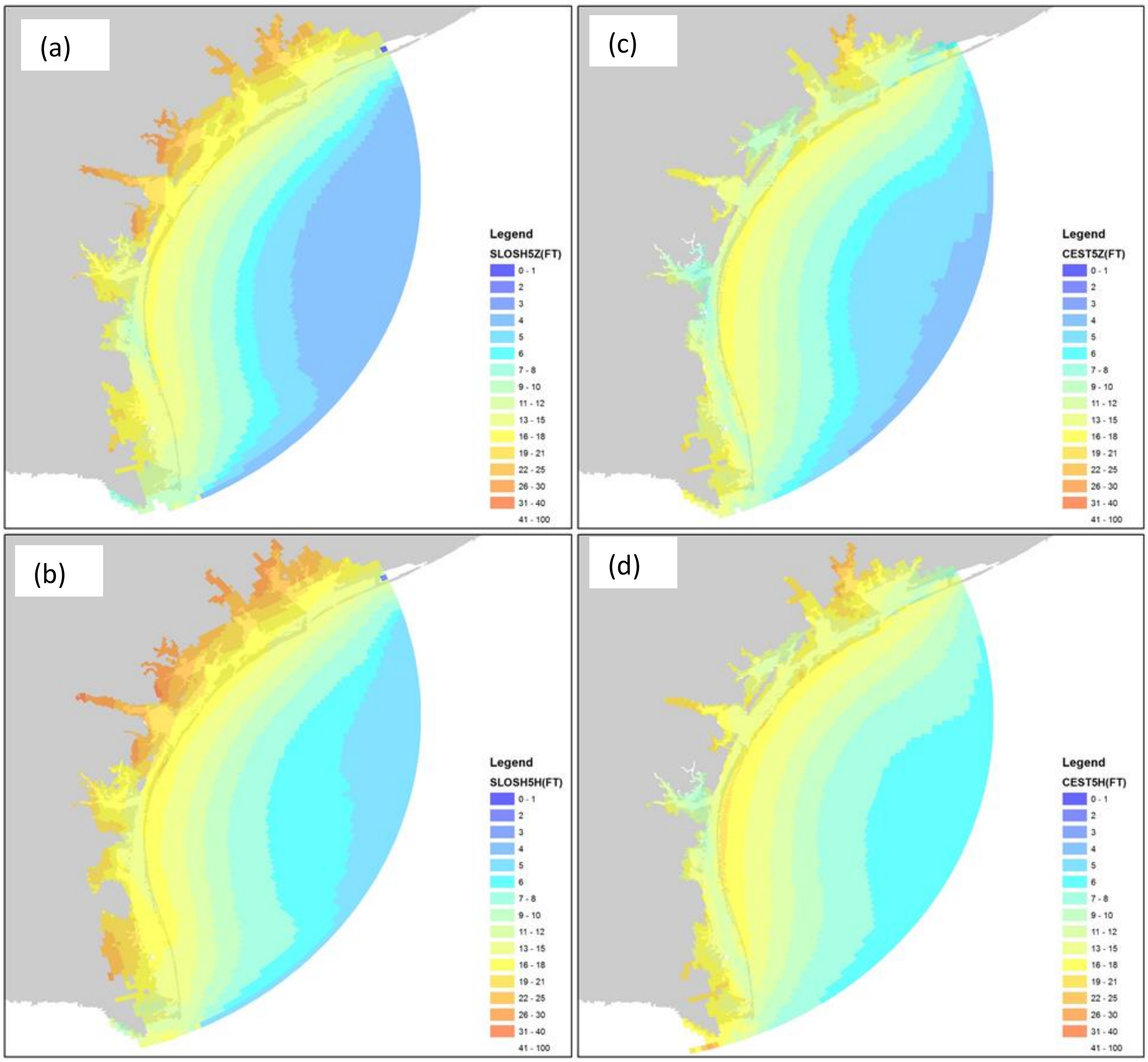

Fig. 1 The MOMs of Category 5 hurricanes in the CR3 Basin produced by SLOSH at mean tide (a) and at high tide (b), and produced by CEST at mean tide (c) and at high tide (d).

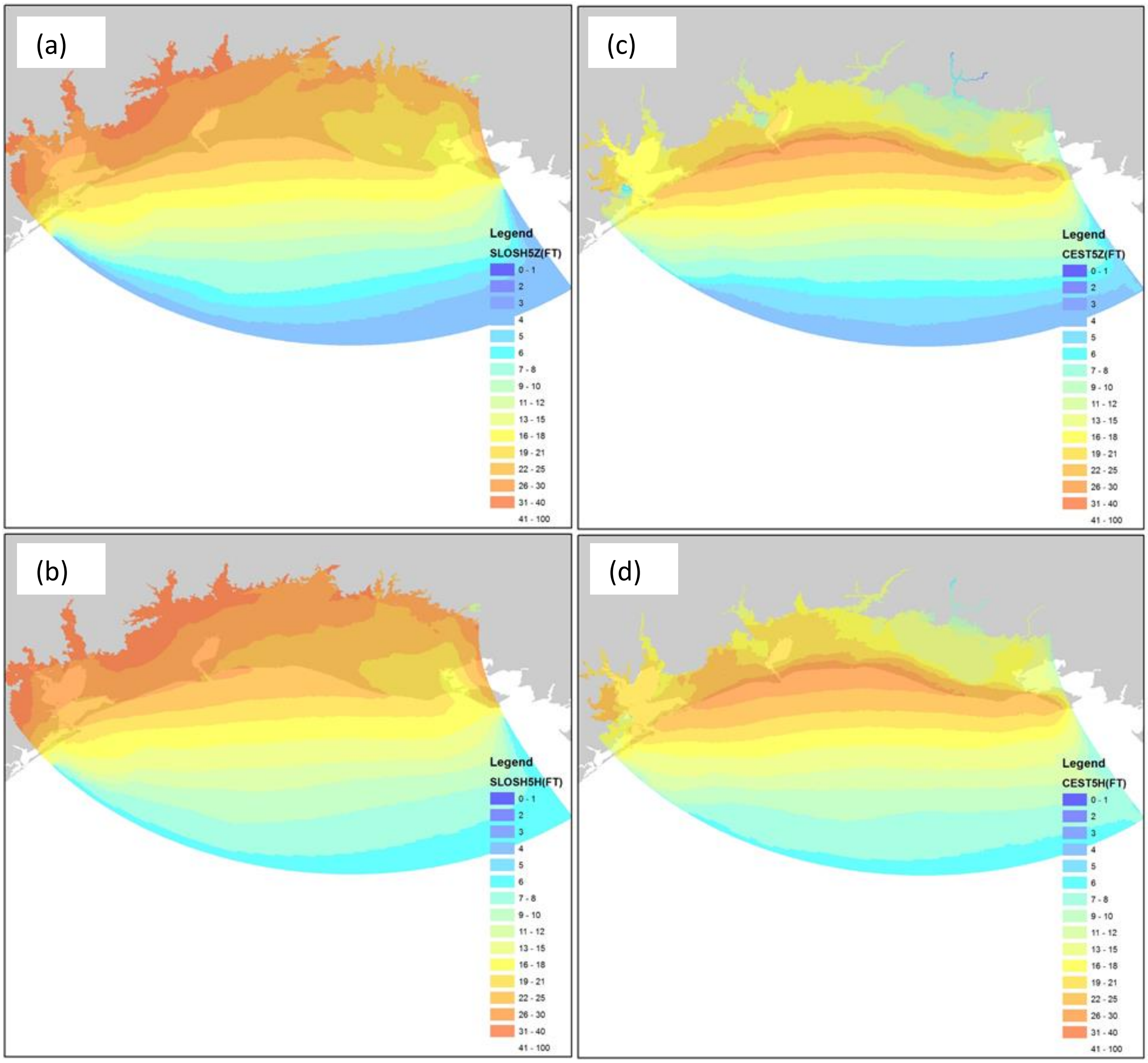

Fig. 2. The MOMs of Category 5 hurricanes in the EBP3 Basin produced by SLOSH at mean tide (a) and at high tide (b), and produced by CEST at mean tide (c) and at high tide (d).

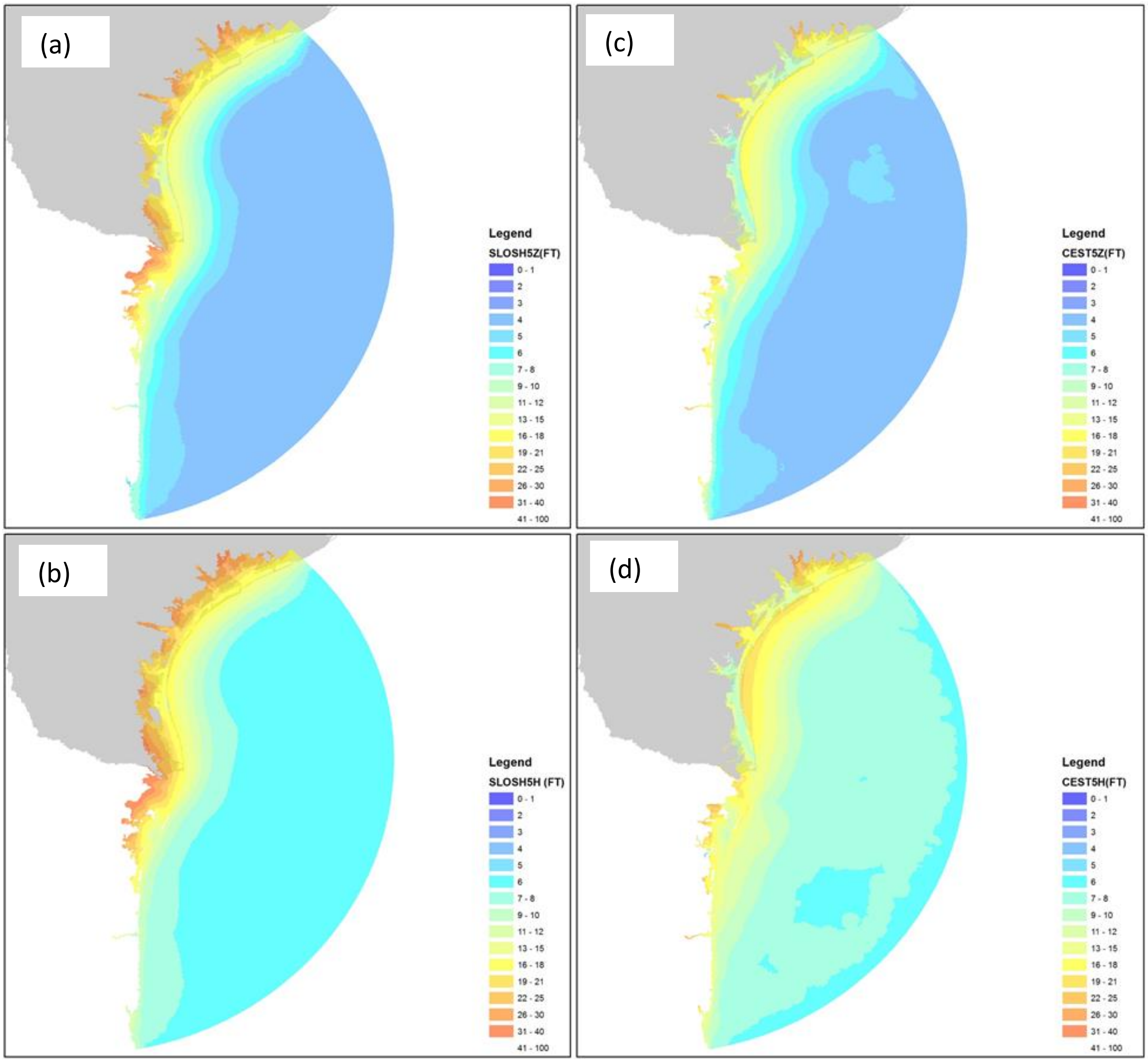

Fig. 3. The MOMs of Category 5 hurricanes in the EBR3 Basin produced by SLOSH at mean tide (a) and at high tide (b), and produced by CEST at mean tide (c) and at high tide (d).

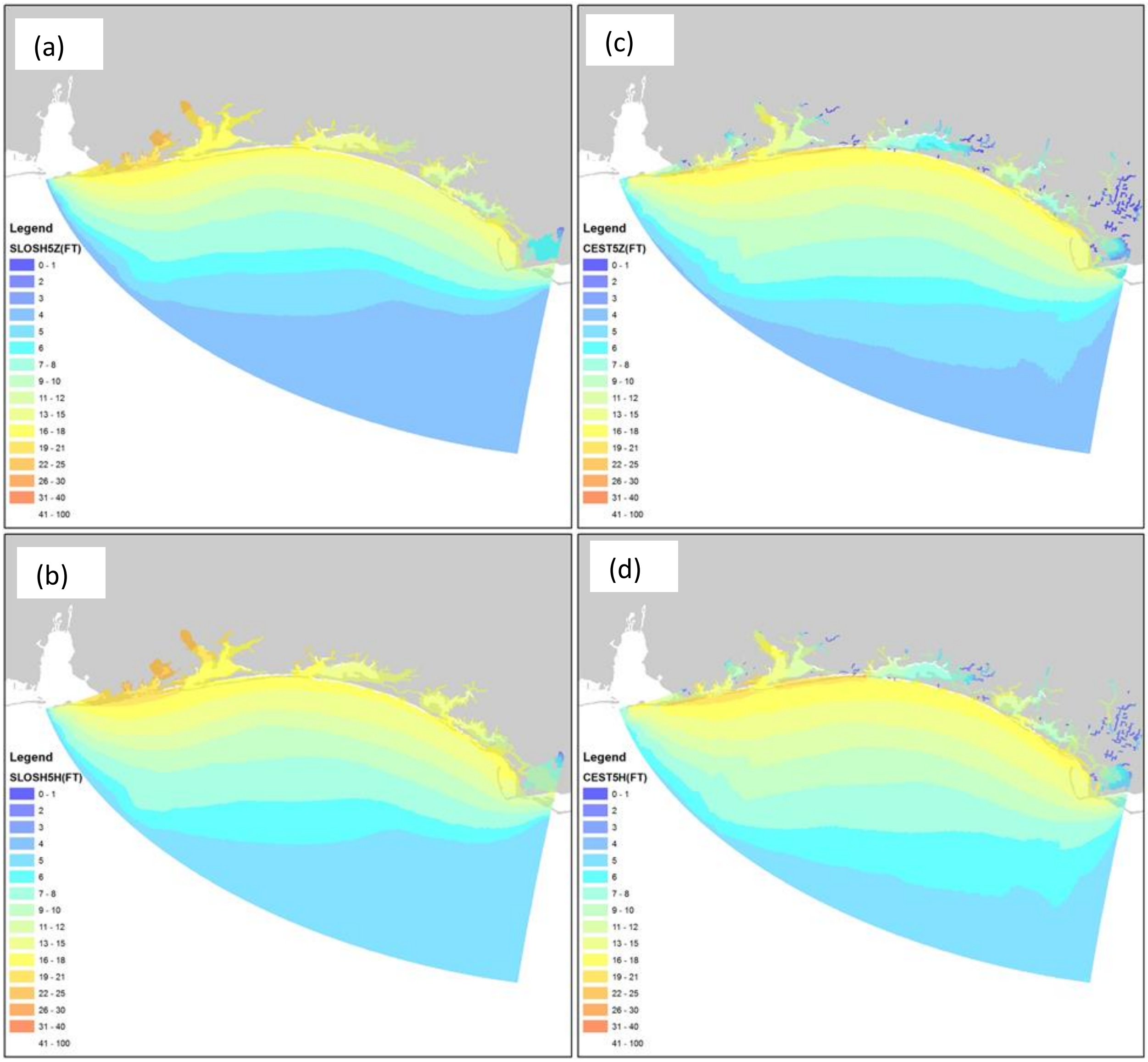

Fig. 4. The MOMs of Category 5 hurricanes in the EPN3 Basin produced by SLOSH at mean tide (a) and at high tide (b), and produced by CEST at mean tide (c) and at high tide (d).

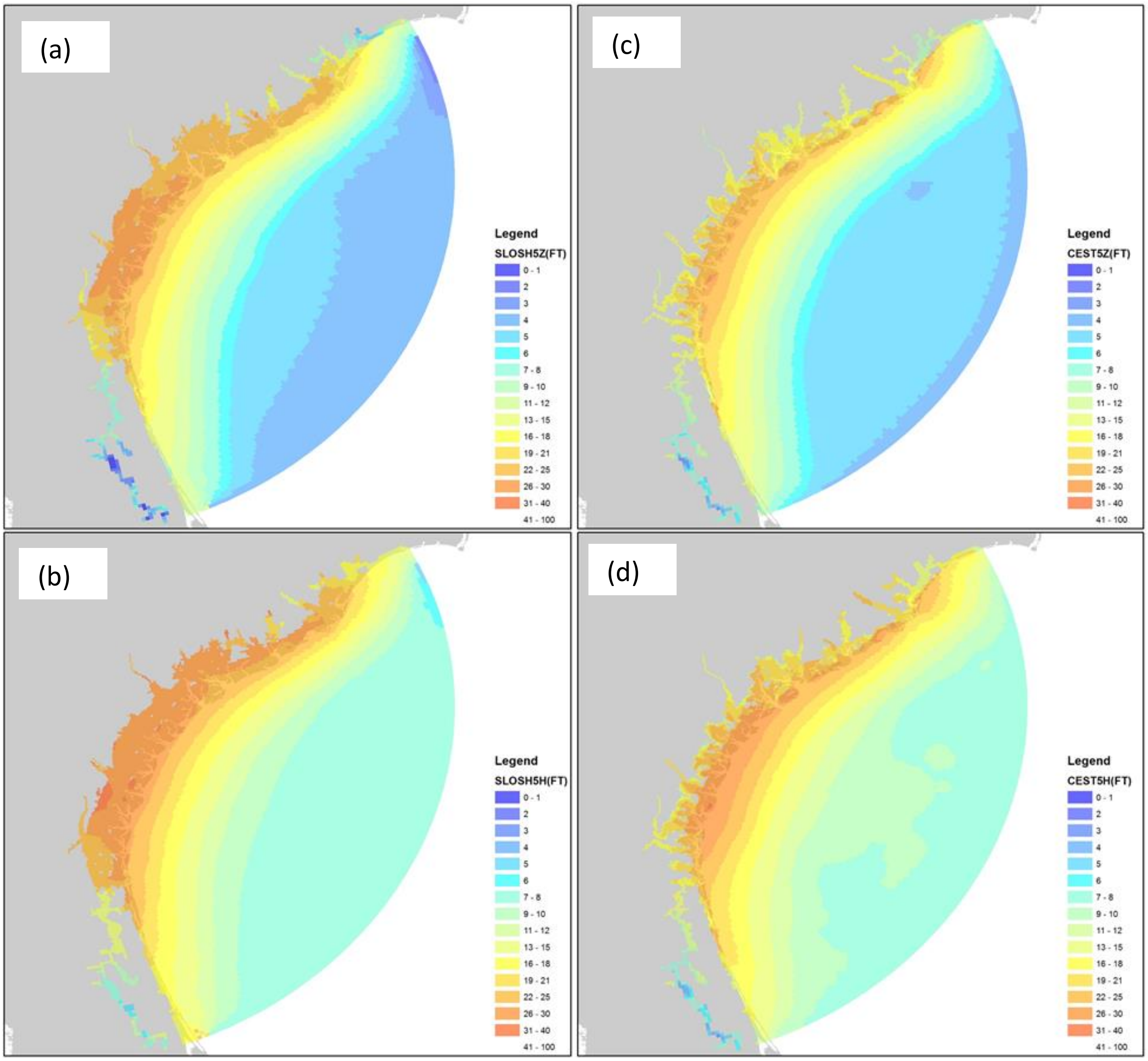

Fig. 5. The MOMs of Category 5 hurricanes in the ESV4 Basin produced by SLOSH at mean tide (a) and at high tide (b), and produced by CEST at mean tide (c) and at high tide (d).

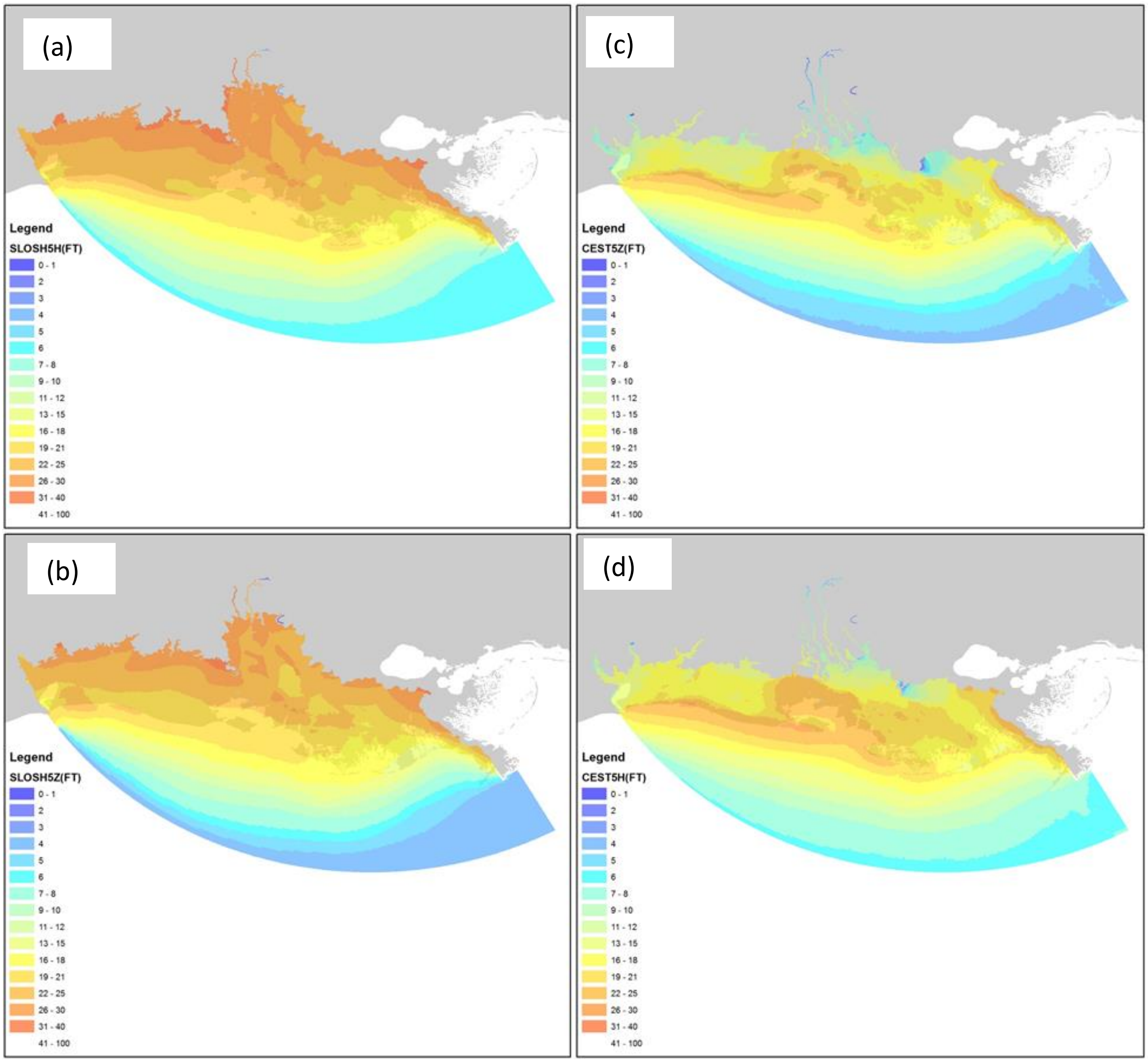

Fig. 6. The MOMs of Category 5 hurricanes in the LF2 Basin produced by SLOSH at mean tide (a) and at high tide (b), and produced by CEST at mean tide (c) and at high tide (d).

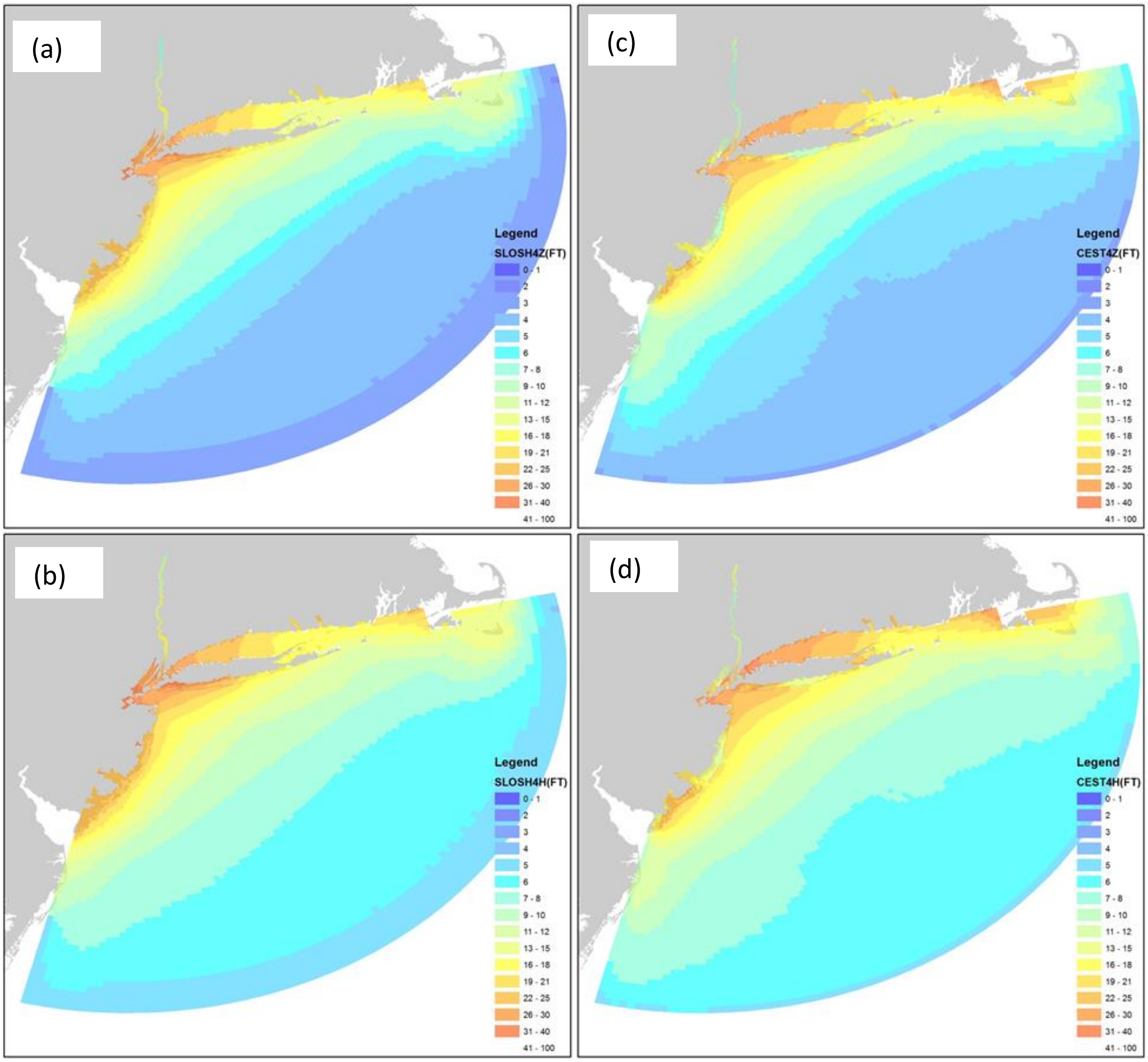

Fig. 7. The MOMs of Category 5 hurricanes in the NY3 Basin produced by SLOSH at mean tide (a) and at high tide (b), and produced by CEST at mean tide (c) and at high tide (d).

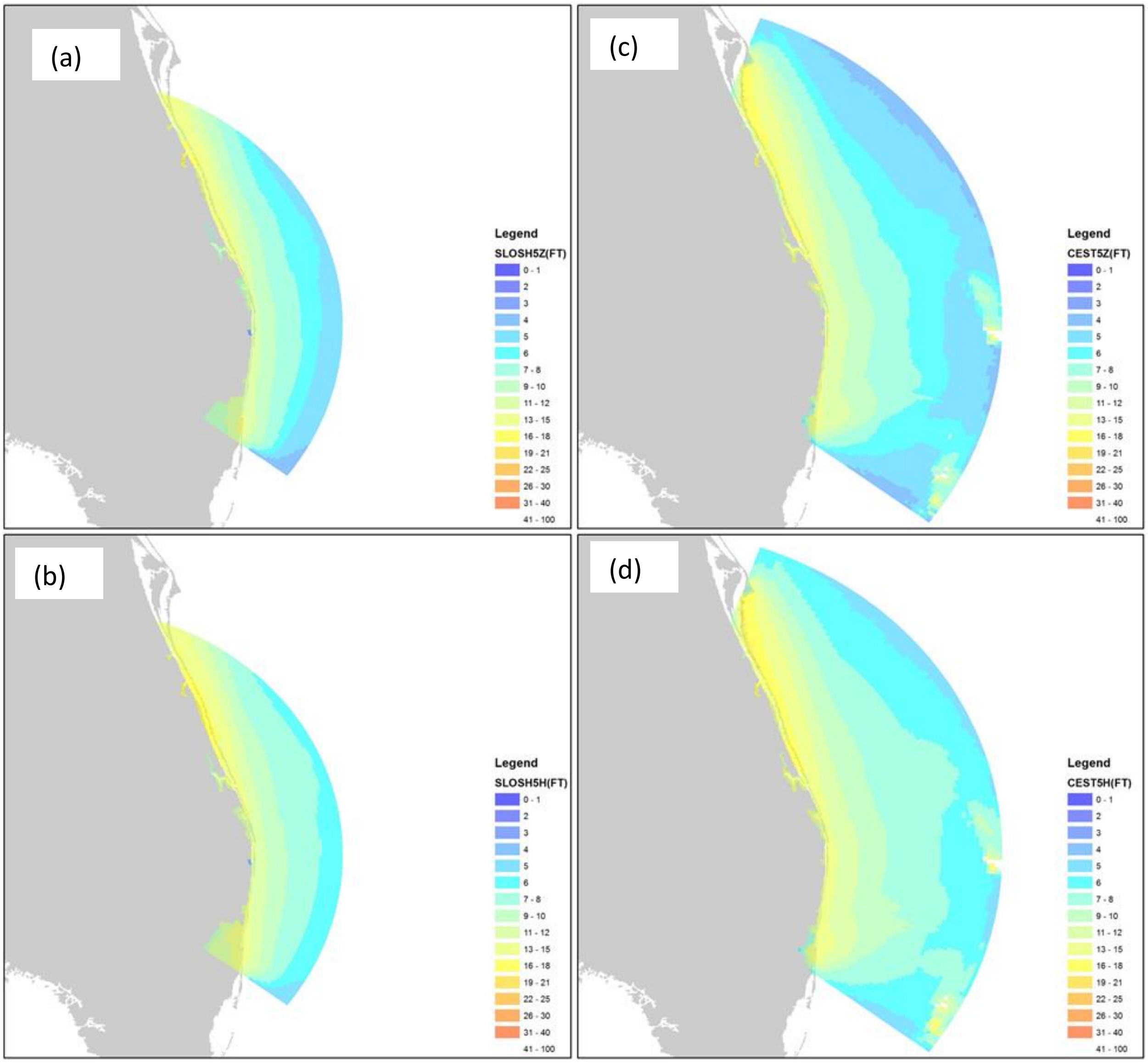

Fig. 8. The MOMs of Category 5 hurricanes in the PB3 Basin produced by SLOSH at mean tide (a) and at high tide (b), and produced by CEST at mean tide (c) and at high tide (d).

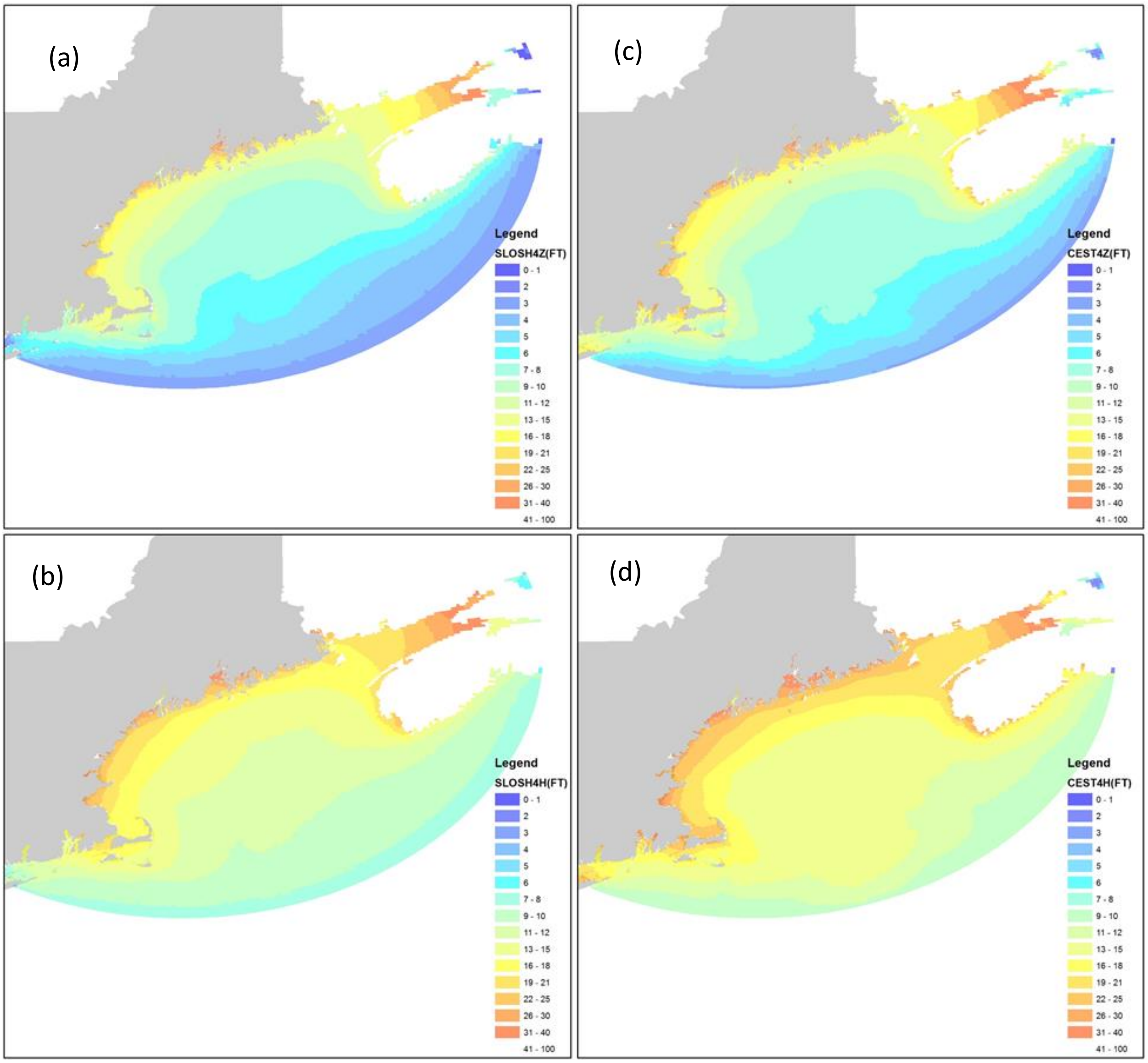

Fig. 9. The MOMs of Category 5 in the PN2 Basin produced by SLOSH at mean tide (a) and at high tide (b), and produced by CEST at mean tide (c) and at high tide (d).

2.2 Comparison of Maximum MOM Heights and Inundation Areas

In order to further examine the difference in MOMs generated by SLOSH and CEST, the maximum MOM values and inundation areas for each category of hurricanes were computed. The results were presented in the following sections.

2.2.1 CR3 Basin (Corpus Christi Bay)

For CR3 Basin, the maximum MOM heights for Categories 1 to 4 hurricanes show that CEST produced the results comparable to SLOSH (Table 4), but produced smaller maximum surges (21 and 23 feet at mean and high tides) than SLOSH (27 and 30 feet) for Category 5 hurricanes. Table 5 shows that the inundation areas from CEST were comparable to SLOSH for Categories 1 to 4 hurricanes, but less than SLOSH for Category 5 hurricanes.

Table 4. Comparison of maximum MOM heights generated by CEST and SLOSH at the mean and high tide levels in the CR3 basin.

MOMs	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (ft)	3	4	6	6
Category 2 (ft)	8	9	10	11
Category 3 (ft)	14	15	20	17
Category 4 (ft)	20	19	24	21
Category 5 (ft)	27	21	30	23

Table 5. Comparison of inundation areas simulated by CEST and SLOSH at the mean and high tide levels in the CR3 basin.

Inundation Area	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (km^2)	1147	1018	1661	1640
Category 2 (km^2)	1750	1994	2616	2651
Category 3 (km^2)	3018	3048	4214	3703
Category 4 (km^2)	4905	3901	6160	4653
Category 5 (km^2)	7130	4709	8173	5398

2.2.2 EBP3 Basin (Sabine Lake)

For EBP3 Basin, the maximum MOM heights for Categories 1 to 3 hurricanes show that CEST produced the results comparable to SLOSH (Table 6), but produced smaller maximum surges than SLOSH for Categories 4 and 5 hurricanes. The comparison of inundation areas show that CEST produced less inundation than SLOSH at all Categories of hurricanes (Table 7).

Table 6. Comparison of maximum MOM heights generated by CEST and SLOSH at the mean and high tide levels in the EBP3 basin.

MOMs	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (ft)	6	6	9	6
Category 2 (ft)	12	14	16	15
Category 3 (ft)	21	19	27	22
Category 4 (ft)	31	24	32	26
Category 5 (ft)	36	28	37	29

Table 7. Comparison of inundation areas simulated by CEST and SLOSH at the mean and high tide levels in the EBP3 basin.

Inundation Area	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (km^2)	5490	1761	7906	4214
Category 2 (km^2)	9593	5338	11093	6821
Category 3 (km^2)	13628	7984	14739	9052
Category 4 (km^2)	16145	9660	16978	10666
Category 5 (km^2)	17924	11157	18513	11941

2.2.3 EBR3 Basin (Laguna Madre)

For EBR3 Basin, CEST produced maximum MOM heights comparable to SLOSH for all Categories of hurricanes (Table 8). However, CEST produced less inundation areas for all Categories of hurricanes than SLOSH (Table 9).

Table 8. Comparison of maximum MOM height generated by CEST and SLOSH at the mean and high tide levels in the EBR3 basin.

MOMs	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (ft)	4	4	6	6
Category 2 (ft)	8	8	11	10
Category 3 (ft)	16	15	18	16
Category 4 (ft)	21	20	22	21
Category 5 (ft)	24	23	27	26

Table 9. Comparison of inundation areas simulated by CEST and SLOSH at the mean and high tide levels in the EBR3 basin.

Inundation Area	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (km^2)	1810	1512	3226	2776
Category 2 (km^2)	3614	3109	5542	4182
Category 3 (km^2)	6663	4707	8508	5783
Category 4 (km^2)	9850	6097	11874	7174
Category 5 (km^2)	13191	7427	15032	8647

2.2.4 EPN3 Basin (Pensacola Bay)

For EPN3 Basin, the maximum surges for all Categories of MOMs from CEST are comparable to SLOSH (Table 10). The inundation areas generated by CEST are larger than SLOSH in most cases, except for Category 5 hurricane at high tide levels (Table 11).

Table 10. Comparison of maximum MOMs generated by CEST and SLOSH at the mean and high tide levels in the EPN3 basin.

MOMs	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (ft)	4	6	5	6
Category 2 (ft)	8	10	9	10
Category 3 (ft)	12	12	14	13
Category 4 (ft)	18	17	20	18
Category 5 (ft)	22	21	24	23

Table 11. Comparison of inundation areas simulated by CEST and SLOSH at the mean and high tide levels in the EPN3 basin.

Inundation Area	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (km^2)	192	918	398	1037
Category 2 (km^2)	596	1292	869	1433
Category 3 (km^2)	1068	1492	1264	1637
Category 4 (km^2)	1499	1733	1624	1861
Category 5 (km^2)	1930	1974	2108	2097

2.2.5 ESV4 Basin (Savannah/Hilton Head)

For ESV4 Basin, CEST produced the maximum surges similar to SLOSH at all Categories of MOMs (Table 12), but produced less inundation areas at all Categories of MOMs than SLOSH (Table 13).

Table 12. Comparison of maximum MOM heights generated by CEST and SLOSH at the mean and high tide levels in the ESV4 basin.

MOMs	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (ft)	4	6	9	10
Category 2 (ft)	14	13	17	16
Category 3 (ft)	20	19	22	21
Category 4 (ft)	25	23	26	27
Category 5 (ft)	30	28	33	31

Table 13. Comparison of inundation areas simulated by CEST and SLOSH at the mean and high tide levels in the ESV4 basin.

Inundation Area	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (km^2)	1411	934	2913	2160
Category 2 (km^2)	3389	2254	5655	3430
Category 3 (km^2)	6666	3696	9089	4881
Category 4 (km^2)	9540	4969	11522	6293
Category 5 (km^2)	11653	6258	13522	7879

2.2.6 LF2 Basin (Vermilion Bay)

For LF2 Basin, CEST produced the maximum MOM heights similar to SLOSH for Categories 1 to 3 hurricanes (Table 14), but produced smaller maximum MOM heights for Categories 4 and 5 hurricanes. CEST produced smaller inundation areas than SLOSH for all Categories of hurricanes (Table 15).

Table 14. Comparison of maximum MOM heights generated by CEST and SLOSH at the mean and high tide levels in the LF2 basin.

MOMs	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (ft)	7	6	9	8
Category 2 (ft)	12	12	15	14
Category 3 (ft)	17	17	20	18
Category 4 (ft)	30	21	32	24
Category 5 (ft)	36	24	42	27

Table 15. Comparison of inundation areas simulated by CEST and SLOSH at the mean and high tide levels in the LF2 basin.

Inundation Area	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (km^2)	13187	5943	16921	14431
Category 2 (km^2)	19445	12402	21053	16778
Category 3 (km^2)	24327	16128	25358	18949
Category 4 (km^2)	27108	18291	27894	20352
Category 5 (km^2)	28901	19814	29589	21530

2.2.7 NY3 Basin (New York)

For NY3 Basin, CEST produced the maximum MOM heights similar to SLOSH for Category 1 hurricanes (Table 16), but smaller maximum MOM heights for Categories 2-5 hurricanes. CEST produced less inundation areas than SLOSH at all Categories of hurricanes (Table 17).

Table 16. Comparison of maximum MOM heights generated by CEST and SLOSH at the mean and high tide levels in the NY3 basin.

MOMs	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (ft)	10	10	13	12
Category 2 (ft)	20	17	24	20
Category 3 (ft)	31	24	31	27
Category 4 (ft)	38	32	39	36

Table 17. Comparison of inundation areas simulated by CEST and SLOSH at the mean and high tide levels in the NY3 basin.

Inundation Area	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (km^2)	497	298	855	565
Category 2 (km^2)	1239	729	1623	1043
Category 3 (km^2)	2157	1251	2424	1565
Category 4 (km^2)	2718	1866	2956	2230

2.2.8 PB3 Basin (Palm Beach)

For PB3 Basin, CEST produced the maximum MOM Heights comparable to SLOSH for Categories 1 to 3 hurricanes (Table 18), but higher maximum MOM heights for Categories 4 and 5 hurricanes. The comparison of inundation areas indicates that CEST produced less inundation than SLOSH at all Categories of hurricanes (Table 19).

Table 18. Comparison of maximum MOM heights generated by CEST and SLOSH at the mean and high tide levels in the PB3 basin.

MOMs	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (ft)	6	4	7	5
Category 2 (ft)	11	9	12	10
Category 3 (ft)	13	12	14	13
Category 4 (ft)	14	15	15	16
Category 5 (ft)	16	19	18	20

Table 19. Comparison of inundation areas simulated by CEST and SLOSH at the mean and high tide levels in the PB3 basin.

Inundation Area	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (km^2)	14	3	31	14
Category 2 (km^2)	66	35	142	66
Category 3 (km^2)	190	133	421	190
Category 4 (km^2)	344	270	702	344
Category 5 (km^2)	523	431	923	523

2.2.9 PN2 Basin (Penobscot Bay)

For PN2 Basin, CEST produced smaller maximum MOM heights in most cases (Table 20), and less inundation areas than SLOSH for all Categories of hurricanes (Table 21).

Table 20. Comparison of maximum MOM heights generated by CEST and SLOSH at the mean and high tide levels in the PN2 basin.

MOMs	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (ft)	13	9	17	20
Category 2 (ft)	29	19	32	23
Category 3 (ft)	32	28	36	34
Category 4 (ft)	40	34	45	44

Table 21. Comparison of inundation areas simulated by CEST and SLOSH at the mean and high tide levels in the PN2 basin.

Inundation Area	SLOSH (mean)	CEST (mean)	SLOSH (high)	CEST (high)
Category 1 (km^2)	326	248	826	750
Category 2 (km^2)	620	531	1197	1064
Category 3 (km^2)	957	855	1647	1456
Category 4 (km^2)	1281	1270	2087	1875

2.3. Preliminary Analysis of the Difference between SLOSH and CEST

The comparison of inundation patterns, maximum MOM heights, and inundation areas shows that the CEST model produced comparable maximum MOM heights, but less inundation areas than SLOSH in most cases. We speculate that the difference in the treatment of the overland friction due to the variation of land cover is the major reason to cause the different MOMs between SLOSH and CEST. In CEST, the effects of land cover on bottom friction are considered by introducing varying Manning coefficients based on the national land cover dataset (NLCD), while the land cover effect is not considered in SLOSH. Using Apalachee Bay in northwest Florida as an example, we conducted numerical experiments to examine the effect of bottom friction on storm surge computation by changing the values of Manning's coefficients in CEST. In first case, we set up Manning's coefficients at the land to be a constant value of 0.025 by ignoring the land cover effect. In the second case, we further reduced Manning's coefficients to 0.01. The results show clearly that the maximum MOM heights from CEST increase and gradually approach the values of SLOSH as Manning's coefficients decrease (Figs. 10 and 11). It is apparent that the effects of land cover and associated bottom friction have significant influence on the modeled inundation extent and should be considered in SLOSH to improve the performance.

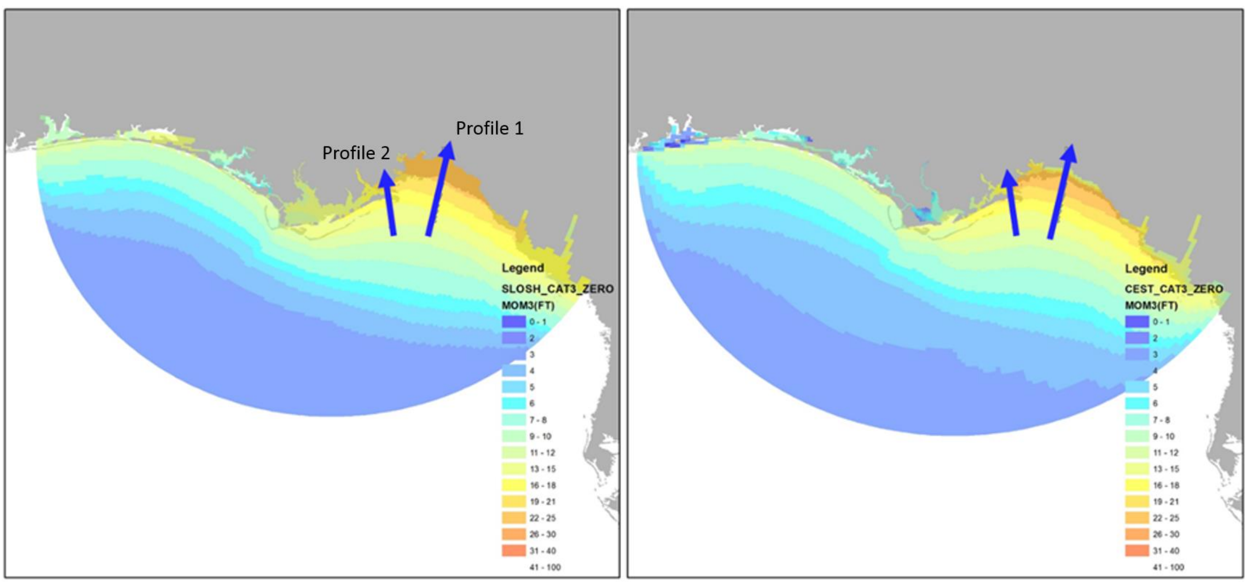

Fig. 10. Locations of Profiles 1 and 2 in the Apalachee Basin. The background maps depict the MOMs from SLOSH (a) and CEST (b) for Category 3 hurricanes.

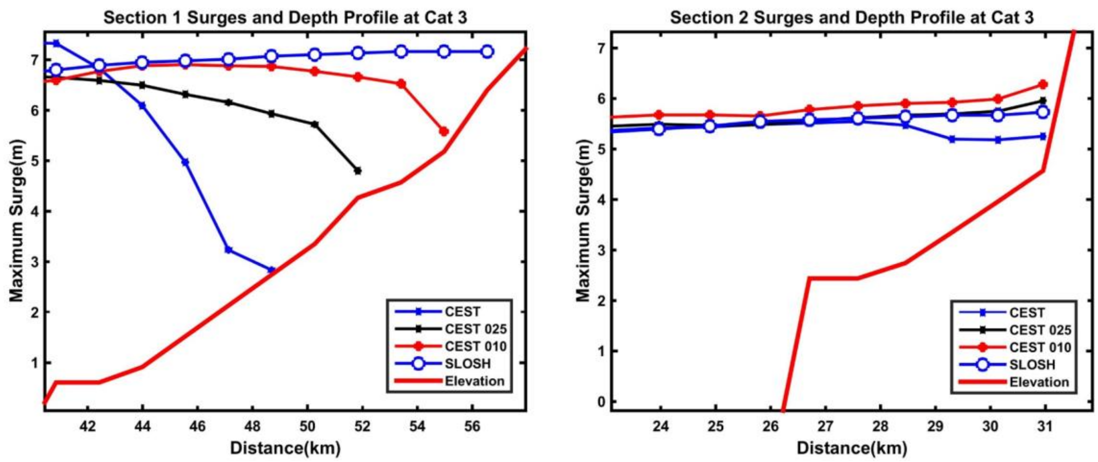

Fig. 11. The MOM heights for Category 3 hurricanes along Profiles 1 and 2 in Apalachee Bay.

We plan to further investigate this issue with two methods in addition to comparison of MEOWs and MOMs. First, we will analyze the overland decay pattern of storm surges along the profiles perpendicular to the surge prorogation direction by examining historical hurricane events with rich field observations to determine if the pattern from CEST or SLOSH fits the observations better. Although USGS, NOAA, FEMA, and USACE have collected substantial high water mark, mobile gauge, and tide gauge measurements for several hurricanes in recent years, the surge measurements along the transacts with a gently sloped terrain and perpendicular to the surge prorogation direction are lacking. So far, we have found that only the storm surge measurements for Hurricane Rita (2005) might be useful based on the preliminary examination of historical hurricanes. We are assembling a GIS database for Rita's wind and surge measurements, bathymetric and topographic data, and shoreline and hydrologic features. We will build a CEST basin based on the geodatabase and conduct storm surge simulation on the basin to compare the variation of computed overland storm surges with field observations. Second, we will build an ideal CEST basin and conduct surge simulations to examine this issue through sensitivity analysis. The spatial changes of the terrain, land cover, barriers, and flows in a real world basin can all influence the overland flooding pattern through an interactive way. The utilization of ideal basins help us to unravel the complicated interactions and figure out the major factors causing the difference.

3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Drs. Keqi Zhang, Yuepeng Li, and Yi-Cheng Teng at International Hurricane Research Center (IHRC) of FIU worked on this project. There was no change in the PD/PI(s) or senior/key personnel since the last reporting period. The FIU team met the National Hurricane Center (NHC) storm surge team four times during this performance period to discuss the project and exchange files and documents. The FIU team also had two internet video conference meetings with staff members of the Meteorological Development Laboratory and met with the team in person once.

4. IMPACT

What was the impact on the development of the principal discipline(s) of the project?

The FIU team presented the results on the effect of bottom friction on overland storm surge flooding to the Storm Surge Unit in NHC. The storm surge unit is exploring the way to increase the effect of bottom friction by adjusting related parameters in the SLOSH model. The preliminary SLOSH simulations on the experimental South Florida basin appears to improve the computation of overland flooding.

What was the impact on other disciplines?

The integration of storm surge simulations with GIS improves the capability to process big spatial data such as high-resolution light detection and ranging (LiDAR) DEMs when building geodatabases for basin development.

What was the impact on the development of human resources?

Both junior scientists Drs. Yuepeng Li and Yi-Cheng Teng obtained more experience with storm surge modeling, data analysis and real-world applications.

What was the impact on teaching and educational experiences?

Some of the GIS results from this project were introduced to FIU students in a course entitled: "EVR5044: Advanced GIS and Environmental Data Analysis" by the PI during Fall semester in 2016.

What was the impact on physical, institutional, and information resources that form infrastructure?

NA

What was the impact on technology transfer?

NOAA will receive the CEST storm surge model for forecasting storm surges at the end of this project. Currently, SLOSH is the only real-time storm surge forecast model used by NHC. The CEST model will add an alternative model for cross-validation of SLOSH forecasts and set a basis for producing ensemble surge forecasts using multiple models

What was the impact on society beyond science and technology?

An additional forecast model will help validate the NHC's storm surge inundation prediction affecting evacuation strategies and coastal flooding warnings.

What percentage of the award's budget was spent in a foreign country(ies)?

No budget was spent in a foreign country.

5. CHANGES/PROBLEMS

There is no change or problem with this project.

6. SPECIAL REPORTING REQUIREMENTS

The Readiness Level for this project is assessed at RL4-Rl5. All other items are covered in previous sections of this report.

7. BUDGETARY INFORMATION

The quantitative budget information is submitted separately in the Federal Financial Report. There are no major budget anomalies or deviations from the original planned budget.

8. PROJECT OUTCOMES

The CEST storm surge forecasting system will be transferred to NHC and operated within the organization after the completion of this project