

Evaluating Typhoon Haiyan's Performance and Identifying Storm Surge Prone Areas in Key Locations Across the Philippines using Advanced Circulation (ADCIRC)

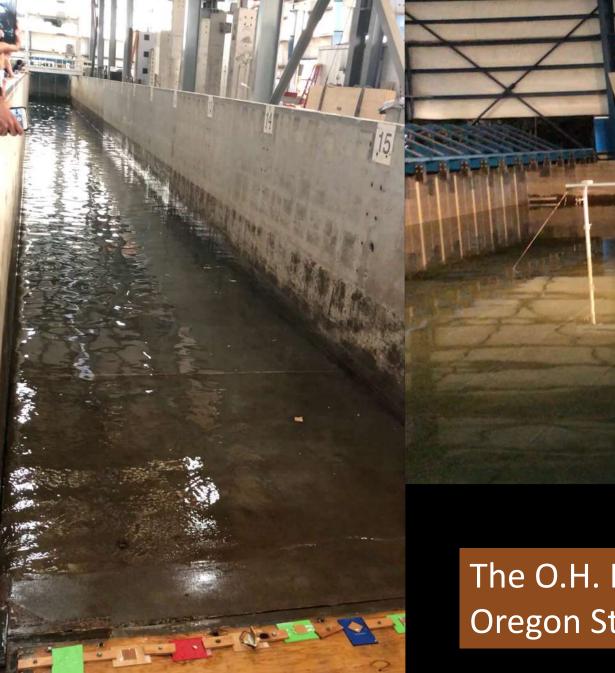
Presented By: Nilo Jr Espinoza Home University: University of Guam Mentors: Dr. Clint Dawson & Dr. Jennifer Proft EF Site: DesignSafe – University of Texas At Austin





# Natural Hazards Research Engineering Infrastructure (NHERI)

- The Wall of Wind at Florida International University
- The Advanced Technology for Large Structural Systems (ATLSS) Engineering Research Center at Lehigh University
- The O.H. Hinsdale Wave Research Laboratory at Oregon State University
- The NHERI SimCenter at University of California, Berkeley
- The Center for Geotechnical Modeling (CGM) at University of Calfornia, Davis
- The Large High Performance Outdoor Shake Table (LHPOST) at Unversity of California, San Diego
- The Powell Family Structures and Materials Laboratory at University of Florida
- The Large-Scale Mobile Shakers at University of Texas at Austin
- The NHERI Cyberinfrastructure and Data Management team at University of Texas at Austin
- The Rapid Response Research Facility (RAPID) at Unversity of Washington



The O.H. Hinsdale Wave Research Laboratory at Oregon State University

## The University of Texas - Austin



Large-Scale Mobile Shakers



Cyberinfrastructure & Data Management

# Agenda:

Introduction/Background
Methodology
Results
Discussion
Reflection
Acknowledgment & References



#### The Philippines

Northwest Pacific Basin – 26 typhoons a year Philippines Area of Responsibility (PAR) – 20 typhoons a year. Nine make landfall.



Typhoon Haiyan (2013) Central Pressure: 895 hPa Wind Speed: 315 kph Wind Gusts: 379 kph "Super Typhoon" category or Category 5 in the Saffir-Simpson Scale



DOH

1817

 6,000 fatalities
 28,000 injuries
 \$800 million in infrastructure and agricultural damage

https://www.ibtimes.co.uk/typhoon-haiyan-anniversary-40-powerful-photos-storm-that-devastated-philippines-1473294

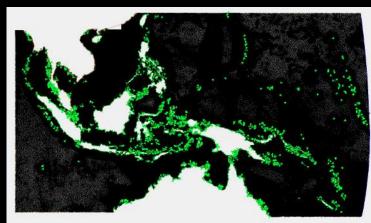
# SMS & ADCIRC

- Surface-water Modelling System (SMS) creating and simulating surface water models
- Original grid file: 9,598,293 nodes
- Modified grid file: 4,127,743 nodes

Original grid

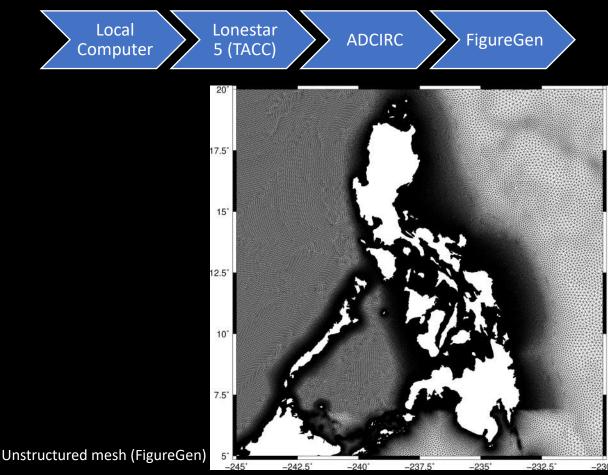
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5	96.8902500000	17.3397100000	-6.9340000000
6	96.8689350000	17.3185250000	-9.6670000000
7	96.8784200000	17.3220600000	-6.0000000000
8	96.8870090000	17.3262330000	-4.0000000000
9	96.8778500000	17.3138300000	-8.2220000000
10	96.8716070000	17.3094460000	-9.7780000000
11	96.9781610000	17.3237240000	-17.0000000000
12	96.9710360000	17.3236140000	-10.0000000000
13	96.9832330000	17.3179000000	-10.6240000000
14	96.8845200000	17.3141100000	-5.5560000000
15	96.8799800000	17.3060200000	-9.889000000
16	96.8753840000	17.3009690000	-9.778000000
17	96.9717630000	17.3181100000	1.9670000000
18	96.9632760000	17.3218240000	-3.6370000000
19	96.9982760000	17.3128380000	-11.0000000000
20	96.9909470000	17.3159540000	-10.1110000000
21	96.9801600000	17.3108500000	2.3710000000
22	96.9697880000	17.3107470000	13.1770000000
23	96.9561430000	17.3233820000	-7.564000000
24	96.9486600000	17.3250400000	-7.384000000
25	96.8925040000	17.3120440000	-2.0000000000
26	96.8878820000	17.3035490000	-7.2220000000
27	96.8827950000	17.2957290000	-9.778000000
28	96.9634410000	17.3129820000	16.0270000000
29	96.9566940000	17.3158390000	5.3120000000
30	97.0054540000	17.3093900000	-13.3330000000

SMS grid (.grd) file



Modified grid

ADCIRC – a numerical model used on unstructured triangular mesh grid to calculate and establish the relationship between the storm's intensity with the coastal characteristics to predict storm surge.



$$\frac{\partial \zeta}{\partial t} + \frac{1}{R \cos\phi} \left( \frac{\partial UH}{\partial \lambda} + \frac{\partial (VH \cos\phi)}{\partial \phi} \right) = 0, \tag{1}$$

$$\frac{\partial U}{\partial t} + \frac{1}{R \cos\phi} U \frac{\partial U}{\partial \lambda} + \frac{V}{R} \frac{\partial U}{\partial \phi} - \left( \frac{\tan\phi}{R} U + f \right) V = -\frac{1}{R \cos\phi} \frac{\partial}{\partial \lambda} \left[ \frac{p_s}{\rho_0} + g(\zeta - \alpha \eta) \right] + \frac{\nu_T}{H} \frac{\partial}{\partial \lambda} \left[ \frac{\partial UH}{\partial \lambda} + \frac{\partial UH}{\partial \phi} \right]$$

$$T_{s\lambda}$$

$$+ \frac{\tau_{s\lambda}}{\rho_0 H} - \tau_* U$$
, and (2)

$$\begin{split} \frac{\partial V}{\partial t} + \frac{1}{R\cos\phi} U \frac{\partial V}{\partial \lambda} + \frac{V}{R} \frac{\partial V}{\partial \phi} + \left(\frac{\tan\phi}{R} U + f\right) U &= -\frac{1}{R} \frac{\partial}{\partial \phi} \left[\frac{p_s}{\rho_0} + g(\zeta - \alpha \eta)\right] + \frac{\nu_T}{H} \frac{\partial}{\partial \phi} \left[\frac{\partial VH}{\partial \lambda} + \frac{\partial VH}{\partial \phi}\right] \\ &+ \frac{\tau_{s\phi}}{\rho_0 H} - \tau_* V, \end{split}$$

where

#### t = time,

- $\lambda$ ,  $\phi$  = degrees longitude and latitude,
  - $\zeta$  = the free-surface elevation relative to the geoid,
- U, V = the depth-averaged horizontal velocities,
  - $H = \zeta + h =$  the total water column,
  - h = the bathymetric depth relative to the geoid,
  - $f = 2\Omega \sin \phi$  = the Coriolis parameter,
  - $\Omega$  = the angular speed of the earth,
  - $p_s$  = the atmospheric pressure at the free surface,

- g = acceleration due to gravity,
- $\eta$  = the Newtonian equilibrium tide potential,

(3)

- $\alpha$  = the effective earth elasticity factor,
- $\rho_0$  = the reference density of water,
- $\tau_{s\lambda}$ ,  $\tau_{s\phi}$  = the applied free-surface stress,
  - $\tau_* = C_f[(U^2 + V^2)^{1/2}/H] = \text{the bottom friction}$ term,
  - $C_f$  = the nonlinear bottom friction coefficient, and
  - $\nu_T$  = the depth-averaged horizontal eddy viscosity coefficient.

# **ADCIRC Input Files**

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1	96.8764000000	17.3408400000	-7.000000000	3
2	96.8818700000	17.3488900000	-7.603000000	primitive_weight
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22	96.96978888888	17.3107470000	13.1770000000	175844 0.005000
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66 67	96.9962978888	17.2867540000	-4.5740000000	182664 0.005000
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equation



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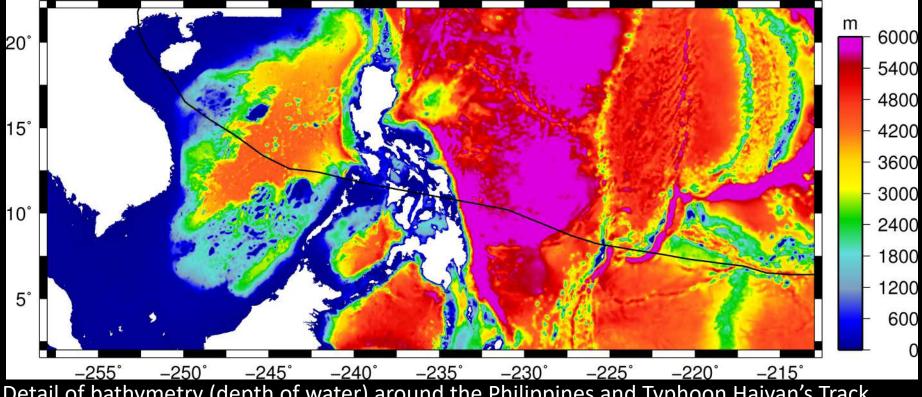
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	н.,	2013110706,	BEST	- 62		1310E.		983,		34, NEQ, 58, NEQ,	68,	86.	50,	45, 1083,	288,	"招	÷.	25, 26,	2	2	8	10	HAITAN, D.
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		2813110808,	, BEST,	- Ø.		1247E,		8997		34, MEQ,	138,			138, 1888,	228					1 Bec.			HAITAN, D,
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		2013110916, 2013110916,	BEST, BEST,	- 21		11106, 11156,			TT:	54, NEQ.	35,	60, 35,	80. 35,	35, 1885.	280	10, 10, 10,	8. 8.	- 21	N.	- B-	÷.	*	HATYAN, D.
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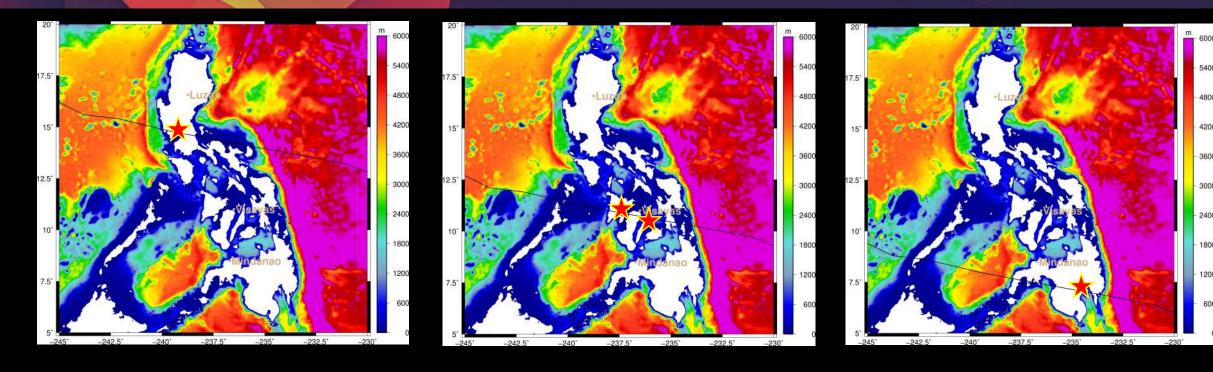
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### **Typhoon Haiyan Validation**



Detail of bathymetry (depth of water) around the Philippines and Typhoon Haiyan's Track (black line).

### Synthetic Typhoon Haiyan Tracks



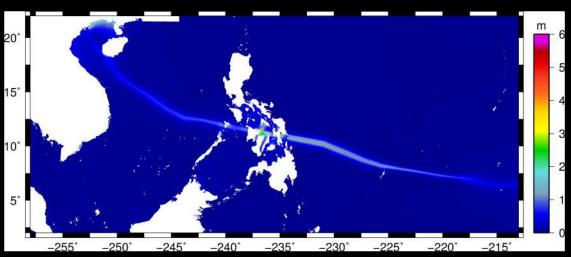
Luzon Track +3.0N or 333 km 个

Visayas Track -0.8S or 87 km 🗸 Manila: 13 million<sup>\*</sup> Cebu & Iloilo: 3.5 million<sup>\*</sup>

Mindanao Track -3.5S or 420 km 🗸 Davao: 2.5 million\*

\* Philippine Statistics Authority

### Typhoon Haiyan Original Track Results

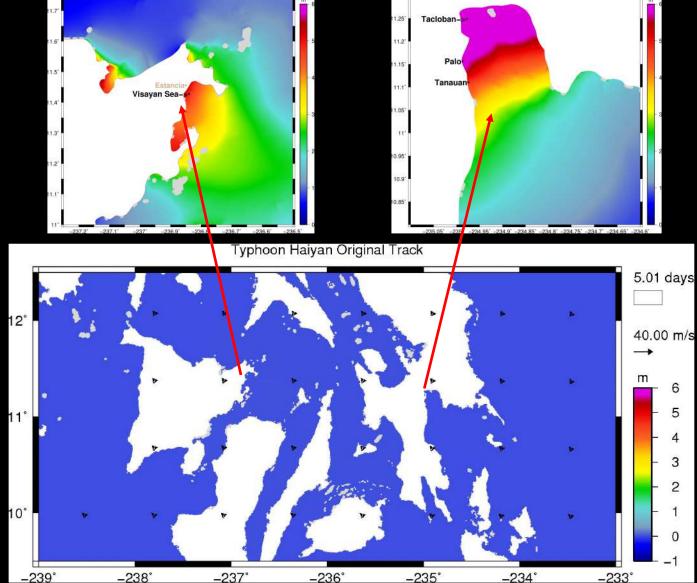


Typhoon Haiyan cyclogenesis to decay.

Location:	Modelled Result (m):	Field Data (m):
Tacloban	7.6	7.9 <sup>[*]</sup>
Palo	6.0	5.7[*]
Tanauan	5.7	5.4 <sup>[*]</sup>
Estancia	5.0	4-5[+]

[\*] (Soria et.al., 2016) [+] (Nationwide Operational Assessment of Hazards, 2013) Maximum elevation in the Visayan Sea.

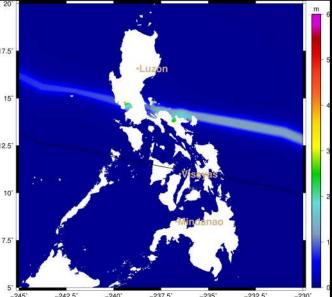
#### Maximum elevation in Leyte Gulf.

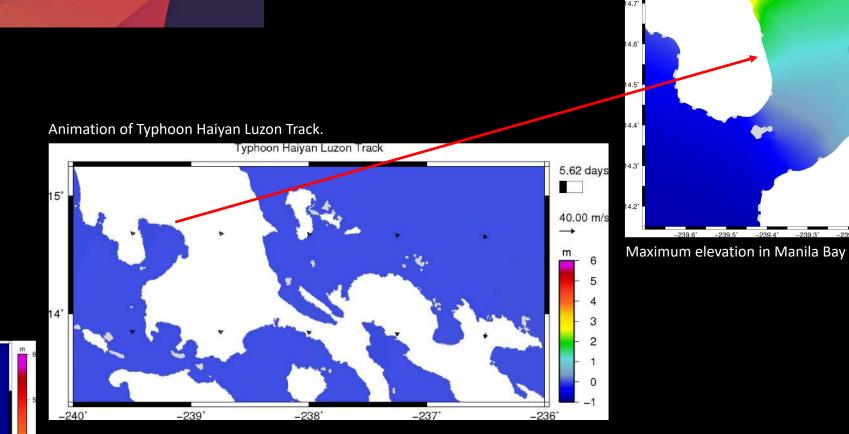


Animation of Typhoon Haiyan in the Visayas Region

## Luzon Track Results

Comparison of Luzon track and original track (black line).





Location:	Modelled result:
Manila Bay	1.9 m
North Manila Bay	5.0 m

North Manila Bay •Hagonoy

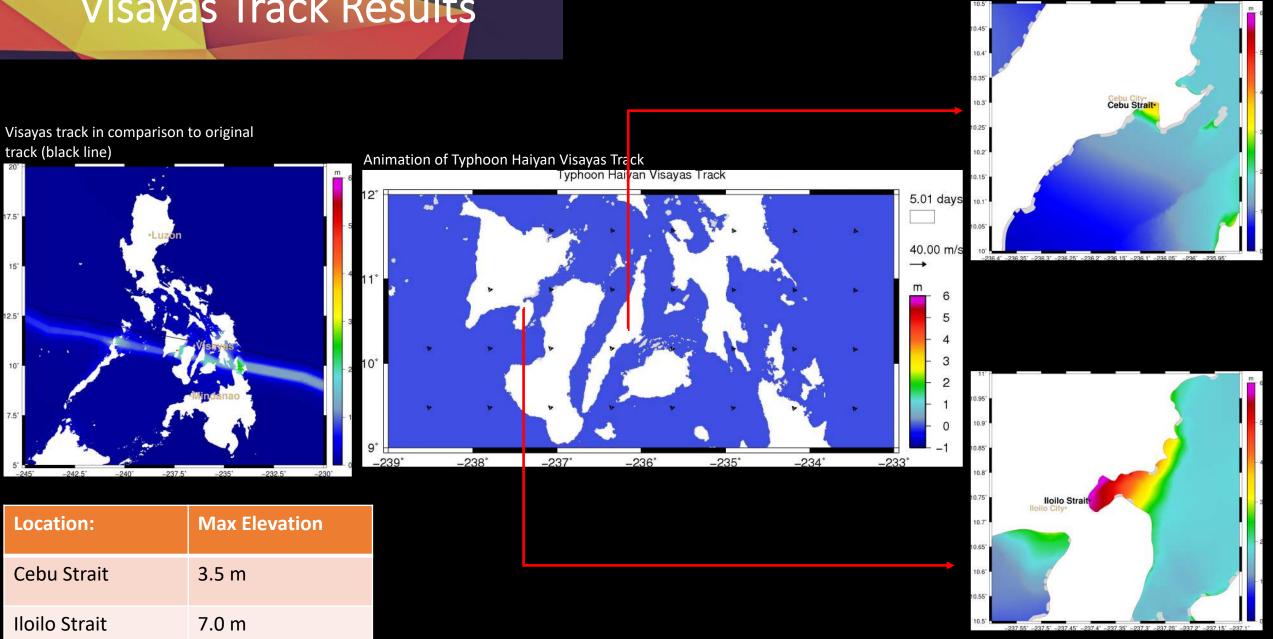
> City of Man Manila Bay•

Orani

## Visayas Track Results

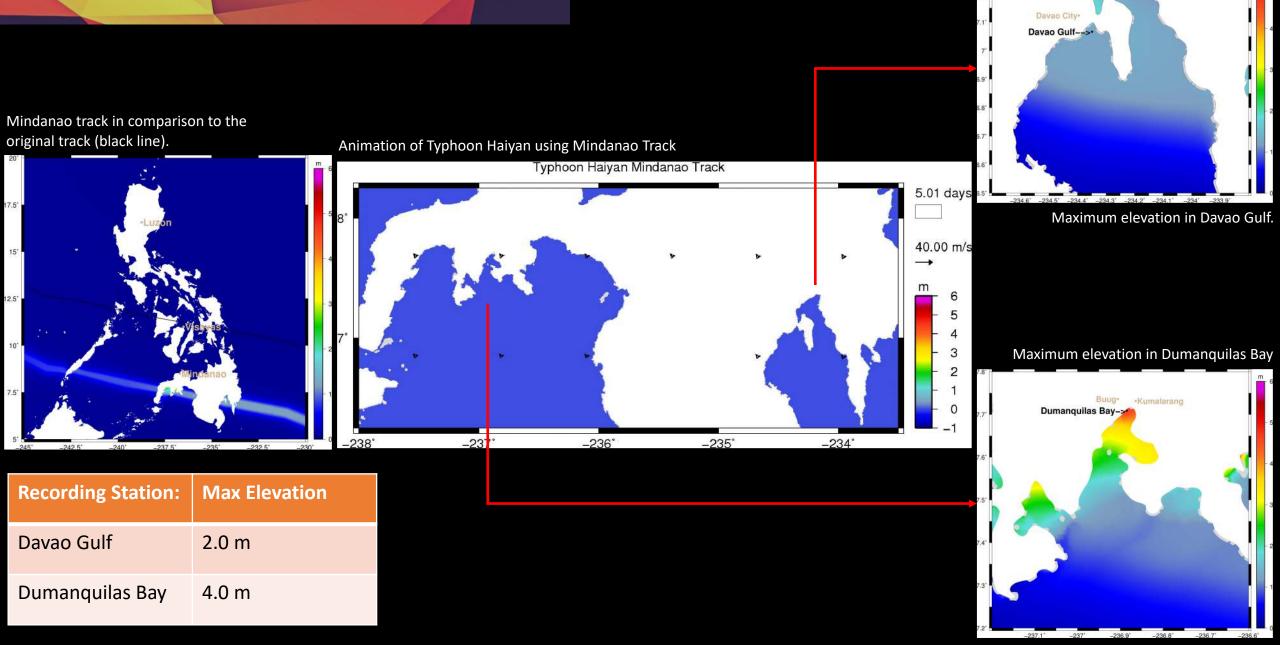
12.5

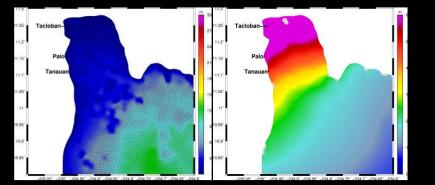
Maximum elevation in Cebu Strait

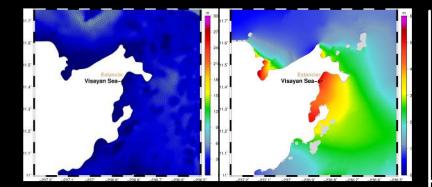


Maximum elevation in Iloilo Strait.

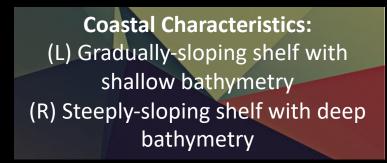


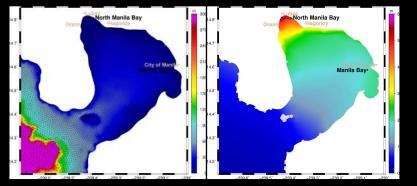




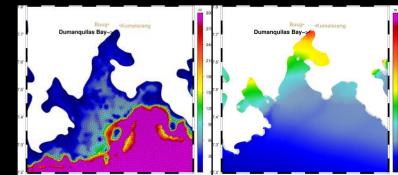


Leyte Gulf (Original Track)

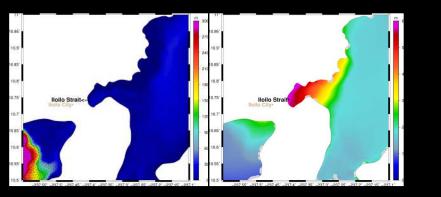


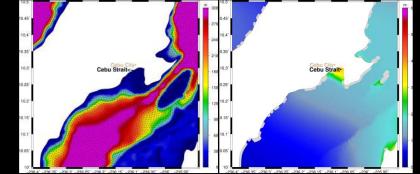


Manila Bay (Luzon Track)



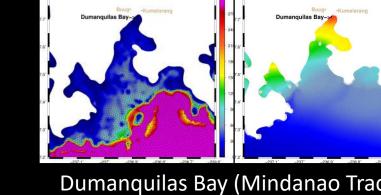
#### Dumanquilas Bay (Mindanao Track)



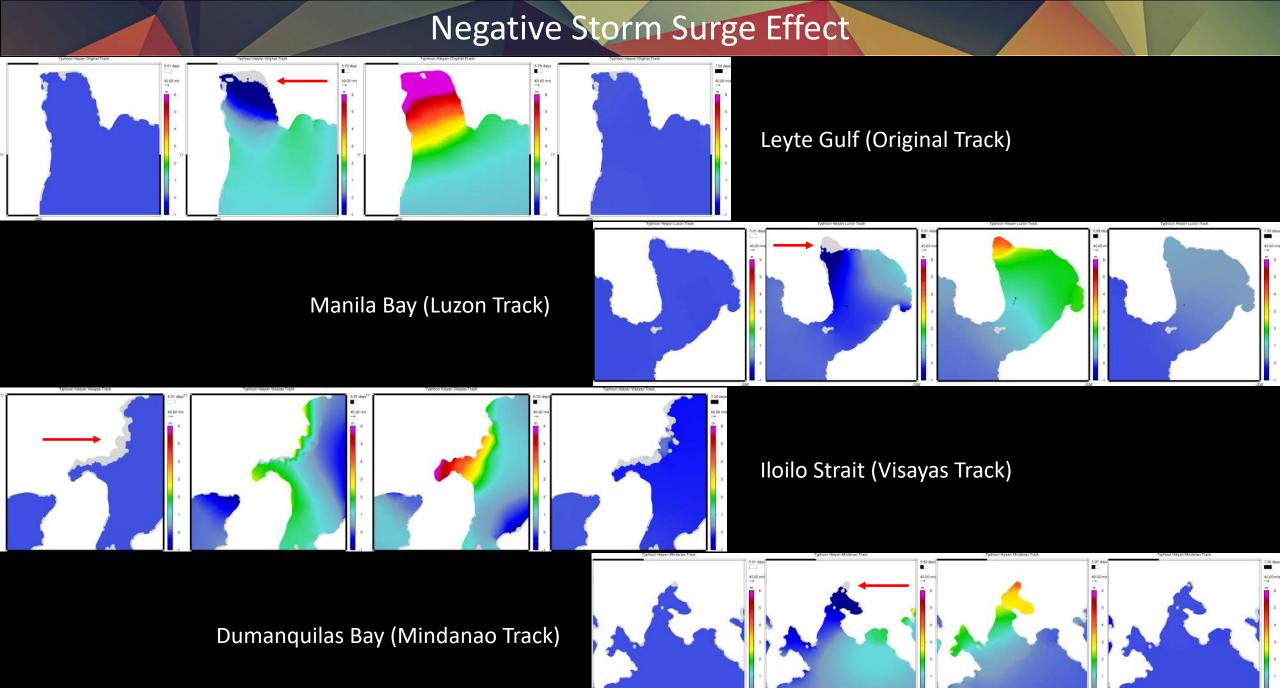


Davao Gulf-----

Davao Gulf (Mindanao Track)







## Discussion:

>Input files are archived in DesignSafe's Data Depot

➤Can be used in forecasting

Mesh refinement to include flood plains to see inundation in coastal communities

Identify all storm surge prone areas

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# Reflection

Learned Fortran, Matlab, Python, Unix terminal, and ADCIRC.

➢ Processes of how an engineering research works.

Make in impact in my community.







# Reflection

#### Future Opportunities: Computing4Change & SPICE (Supporting Pacific Indigenous Computing in Excellence)



Program November 11–16, 2018 Exhibits November 12–15, 2018

#### KAY BAILEY HUTCHISON CONVENTION CENTER DALLAS

The International Conference for High Performance Computing, Networking, Storage, and Analysis

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# References

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- Dr. Joannes J. Westerink of University of Notre Dame
- Dr. Karina Vielma and Ms. Rosalia Gomez
- Co-NHERI REU students

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