CRC 2nd Annual Meeting: February 1-3, 2017
Chapel Hill, NC

# Education for Improving Resiliency of Coastal Infrastructure

**Ismael Pagán-Trinidad (PI) [1], Ricardo R. López (Co-PI) [2]**
Civil Infrastructure Research Center (CIRC)
Department of Civil Engineering and Surveying
University of Puerto Rico at Mayagüez, Mayagüez, Puerto Rico



*1- Department Director 2- CIRC Director/Dept. Associate Director*

# HSE Educational Gap

## Resiliency of Coastal Infrastructure (RCI)

**Goal**
Help educate the community by transferring state of education and practice knowledge and experiences to stakeholders

**Target Stake Holders**
Students, faculty, professionals, first responders, work force, others)

**Motivation**
Engage stakeholders in advancing state of knowledge in coastal resilient infrastructure

**Formal Education**
Courses, internships, projects (MS theses, undergraduate research, special professional projects)

**Informal Education**
Conferences, workshops, seminars, lectures, short courses

**Resilient Coastal Infrastructure (RCI)**

# Engagement with HSE professionals and organizations

- ERDC- Coastal and Hydraulic Lab (CHL)
- PR Department of Natural and Environmental Resources-Coastal Management Program
- Puerto Rico Climate Change Council –PRCCC
- PR College of Engineers and Surveyors
- Earthquake Engineering Research Institute (EERI)
- Federal Emergency Management Agency (FEMA)
- PR Emergency Management Agency (PREMA)
- Transportation Technology Transfer Center: FHWA, PRDTPW, PRHTA
- Sea Grant and CARICOOS (NOAA)
- Government:  Federal, Local and Municipal agencies and officials

# Education Work and Accomplishments

## 2016 Summer Term Internships

- **3 students at SUMREX (2 @ OSU, 1 @ LSU/UCF), 3 mentors**
- **5 students, 5 mentors CHL-ERDC, 3 professors -UPRM. 5 research courses, proposals, reports, paper, and oral presentations. One hired by ERDC, One hired by NOAA. Both in RCI**
- **1 student, 1 mentor at UPRM. 1 research course, report, and poster. Hired by the our CRC project.**

### Summer Activities, SUMREX students

- Kevin Cueto, MSCE student, Oregon State University, Advisors Dan Cox and John Van de Lindt
  - The main objective of the project is to understand the behavior of waves on elevated structures, located near the coast.
- Diego Delgado, BSCE student, Oregon State University, Advisors Dan Cox and John Van de Lindt
  - The primary goal of this project is to understand the behavior of near-coastal structures against high surge levels and wave forces.
- Felix Santiago, MSCE student, UCF/LSU, Advisors Scott Hagen and Stephen Medeiros
  - Learn the basics of the linux command line, high performance computing and ADCIRC with particular emphasis on parameterizing surface roughness and topography.

# Education Work and Accomplishments (details follow) - continued
## Fall Term Projects/Courses/Presentations

- **BAA-ERDC1: Surge /Wave Modeling of Puerto Rico and US Virgin Islands Region, 1 professor, 1 student**
- **BAA-ERDC2: Thesis-Stochastic Simulation of Tropical Cyclones for Quantification of Uncertainty Associated with Storm Recurrence and Intensity, 1 ERDC researcher –mentor, 2 UPRM professors, and 1 student.**
- **Course: Effect of Climate Change on the Coastal Transportation Infrastructure of Puerto Rico. Student-Alexander Molano, Undergraduate Research (INCI 4998). Mentor: Benjamín Colucci, CE Professor in Transportation.**
- **Presentation: "Impacto del cambio climático en la infraestructura vial y de transporte colindante a las costas con entornos urbanos en países caribeños". Benjamín Colucci, CE Professor in Transportation. Professional Engineering Association, Dominican Republic, Nov. 25, 2016.**
- **Presentation: The Role of Universities on Disaster Risk Reduction in the Community: UPRM Case Study. Ismael Pagán-Trinidad, Ricardo López-Rodríguez, others. PI and Co-PI CRC UPRM Project. World Engng. Conf. on Disaster Risk Reduction, 5-6 December 2016, Lima, Perú.**
- **Presentation: Structural Vulnerability to Natural Hazards in Puerto Rico. Ricardo López and Ismael Pagán-Trinidad CRC Project, World Engng. Conf. on Disaster Risk Reduction, 5-6 December 2016, Lima, Perú.**
- **Presentation: Effects of Natural Hazards on Coastal Structures. Ricardo López and Ismael Pagán-Trinidad CRC Project, Anticipating Surprises and Taking Actions; Integration of CIAPR in the PRCCC, Aug 27, 2016**

# Education Work and Accomplishments (details follow) - continued
## Fall Term Projects/Courses/Presentations

- **Meeting: Coastal Engng. Research Board Meeting in San Juan. Ricardo López, Aug., 2016**
- **Meetings/Students presentations: ERDC-CHL officials, expanded collaboration and support. Ismael Pagán-Trinidad, Aug. 2016.**
- **Education Module: Rehabilitation of Coastal Structures – Dr. José O. Guevara, Professor, CE Structures (see slide sample)**
- **Education Module: Coastal Resilient Structures – Dr. Ali Saffar, Professor, CE Structures (see slide sample)**
- **MS Thesis: Effects Tsunamis on Coastal Structures. Kevin Cueto (SUMREX Participant) Advisor: Dr. Ricardo López, Ismael Pagán-Trinidad**
- **ME Thesis: Water Induced Forces on Coastal Infrastructure. Jorge Romeu, Advisor Dr. Ricardo López, Ismael Pagán-Trinidad**
- **Meetings: Multiple planning and coordinating meetings with partners and stakeholders**
- **Invited Lecture: Coastal Resiliency Building: Mainstreaming Adaptation, Ernesto Díaz, Dept of Natural Resources, January 26, 2017**

# BAA –ERDC1 Modeling of Puerto Rico and US Virgin Islands Region: (a) Surge/Wave Grid Work (b) Hydro Model Validation

**Nov. 1, 2016 to Mar. 31, 2017 and Apr 1, 2017 to Aug 31, 2017 , PI: Dr. Juan Gonzalez-López, PhD, Marine Science; Undergraduate Student: Giovani Seijo-Ellis**
**Sponsor: Dr. Norberto Nadal, ERDC – CHL $35,500**

a) **Surge/Wave Grid Work.** For the Puerto Rico and U.S. Virgin Islands region, model meshes, grids and land/bathymetry parameterizations are created or improved for surge and wave models. The coastal hydrodynamic models should include ADCIRC and either STWAVE or SWAN. Grids are typically created using the Surface Water Modeling System (SMS). The model grids/meshes typically require extensive testing and modifications to remove instabilities, and then require validation against historical measurements.

b) **Hydro Model Validation.** The validation data are used in the computation of epistemic uncertainties. Creating quality model grids is critical to stably producing accurate storm response and can take considerable time and effort. Herein we assume that we start with reasonable grids created with FEMA RiskMAP or other regional studies. This task will merge together and edit those grids to improve nearshore response prediction, and then validate models against measurements for select storms.

# BAA-ERDC2: Stochastic Simulation of Tropical Cyclones for Quantification of Uncertainty

## Thesis Proposal

Efraín Ramos-Santiago

Proposal submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

CIVIL ENGINEERING

(Environmental and Water Resources Engineering)

UNIVERSITY OF PUERTO RICO

MAYAGÜEZ CAMPUS

2016

Approved by:

Norberto Nadal-Caraballo 2016-Dec-07

# Resiliency of Coastal Transportation Infrastructure

*University of Puerto Rico*
*Mayagüez Campus*
*Department of Civil Engineering and Surveying*
*Mayagüez, Puerto Rico*

## *Effect of Climate Change on the Coastal Transportation Infrastructure of Puerto Rico*

By:
Alexander Molano Santiago
801-10-4588
Undergraduate student, B. S. Civil Engineering

Presented for:
INCI 5996-002#: Effect of Climate Change on Coastal Transportation Infrastructure
Benjamín Colucci Ríos, PhD, PE
December 18, 2016


*Figure 1 Emergency situation involving transportation infrastructure caused by Hurricane Matthew's passage 500 km south of Puerto Rico. To the left a road closure on PR-1 in the municipality of Salinas, to the right a satellite image and trajectory of Hurricane Matthew. Credits to Univisión and Noticia al Día.*

*Figure 2 Víctor Rojas bridge was torn out of its foundation by a combination of storm surge and floodplain inundation caused by Hurricane Georges in Sepctember 1998. Credit to PrimeraHora and GFR Media.*

## *Impacto del cambio climático en la infraestructura vial y de transporte colindante a las costas con entornos urbanos en países caribeños*

**Ing./Dr. Benjamín Colucci-Ríos**
Vice-Presidente, Región del Caribe UPADI
Colegio de Ingenieros y Agrimensores de Puerto Rico (CIAPR)
Catedrático, UPR-Mayagüez
Viernes, 25 de noviembre de 2016

CODIA

II Seminario Internacional de Ciclo Caribeño de Desarrollo Sostenible Urbano
Colegio Dominicano de Ingenieros, Arquitectos y Agrimensores (CODIA) - Regional Norte
Santiago de los Caballeros, República Dominicana

## Escenario de alza del nivel del mar de 1.5m en San Juan, Puerto Rico



Fuente: https://coast.noaa.gov/slr/

***WORLD ENGINEERING CONFERENCE ON DISASTER RISK REDUCTION***
***5-6 December, 2016***

# THE ROLE OF UNIVERSITIES ON DISASTER RISK REDUCTION IN THE COMMUNITY: UPRM CASE STUDY

**[1]Ismael Pagán-Trinidad, [2]Ricardo López-Rodríguez,** [3]Agustín Rullán,
[4]Oscar Perales-Pérez, [5]John Fernández-Van Cleve
[1,2,3,4] College of Engineering [5]College of Agriculture Science
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COASTAL RESILIENCE CENTER
*A U.S. Department of Homeland Security Center of Excellence*

***WORLD ENGINEERING CONFERENCE ON DISASTER RISK REDUCTION***
***5-6 December, 2016***

# Structural Vulnerability to Natural Hazards in Puerto Rico

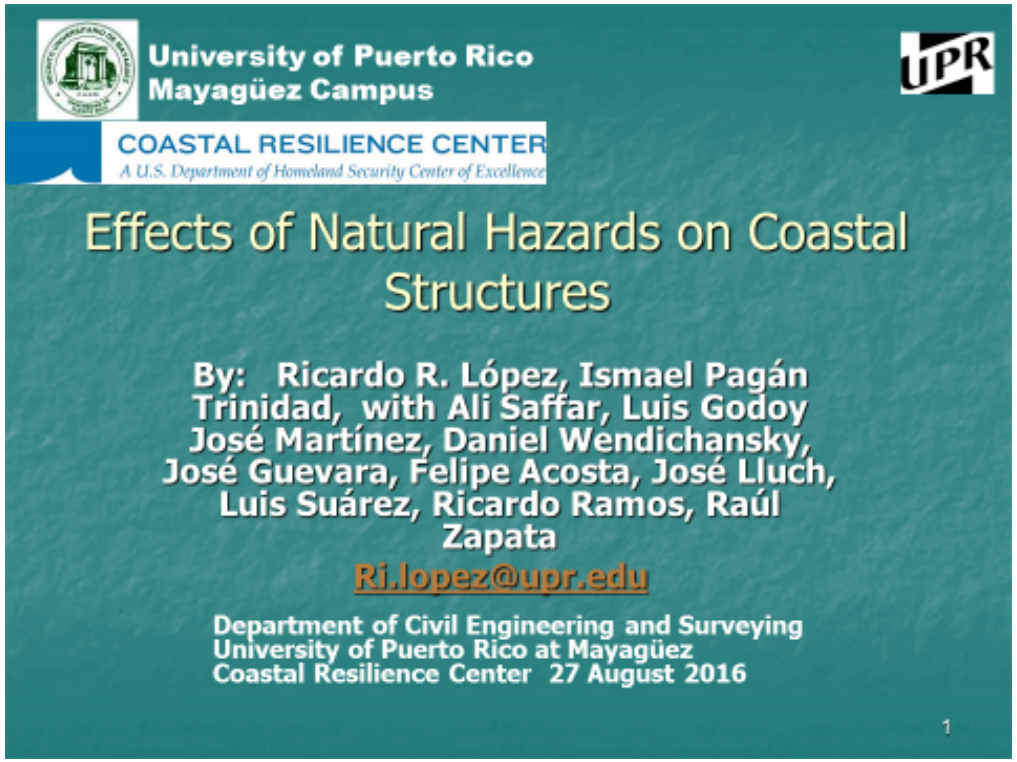
Ricardo R. López-Rodríguez, Ismael Pagán-Trinidad
Department of Civil Engineering
University of Puerto Rico at Mayagüez, Puerto Rico (UPRM)
ri.lopez@upr.edu , ismael.pagan@upr.edu

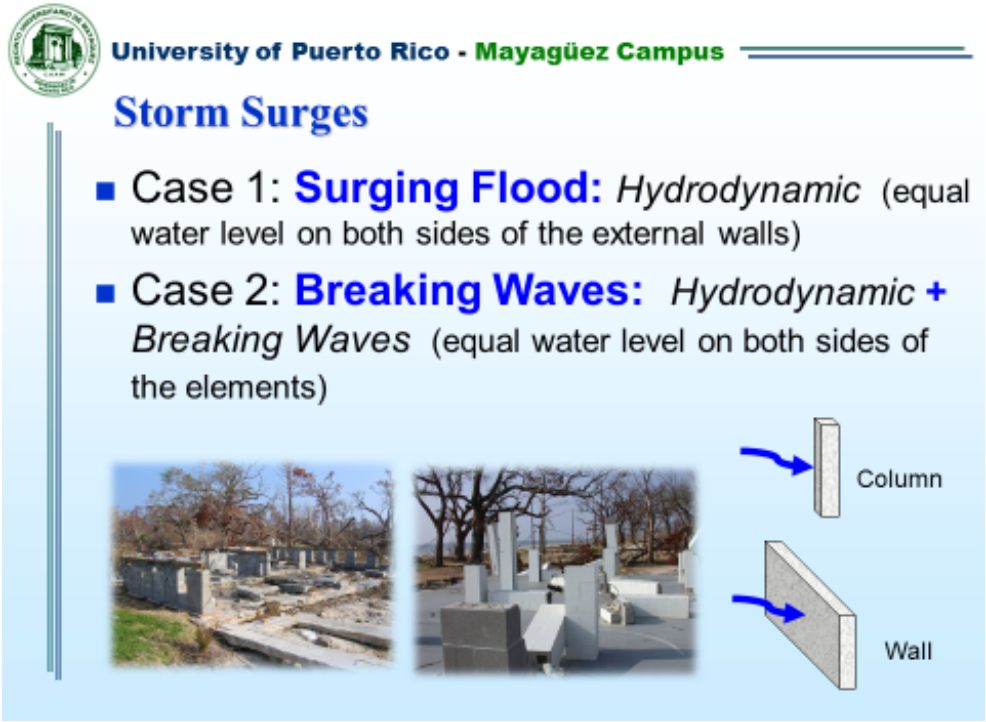
COASTAL RESILIENCE CENTER
*A U.S. Department of Homeland Security Center of Excellence*

# Presentation to Professional Engineers at UPRM, 27 August 2016

The one day activity held at UPRM August 27 of 2016 was entitled **Anticipating surprises and taking action; integration of CIAPR in the Climate Change Council.**

A group of about **30 professional engineers and surveyors visited UPRM** for a series of presentations and visits to the laboratories. Dr. Ricardo López presented **Effects of Natural Hazards on Coastal Structures**. Dr. Luis Aponte presented **Wind Engineering: Vulnerability of Tropical Cyclone in Puerto Rico.** Dr. López hosted the visit to the Civil Engineering Structures and Materials Labs.



# Participation in 2016 Coastal Engineering Research Board Meeting -San Juan, PR

- Organized by US Army Corps of Engineers.
- Held in San Juan August 8 to 10, 2016.
- Attended meetings and site visits and informed the audience about the CRC Education Project at UPRM.
- Held informal conversations with several leaders in coastal engineering.
- Participants: USACE, ERDC, DNER, UPRM, UPRRP, PRCCC

# REHABILITATION OF COASTAL STRUCTURES


Jose O. Guevara, Ph.D., P.E.

Civil Engineering Department

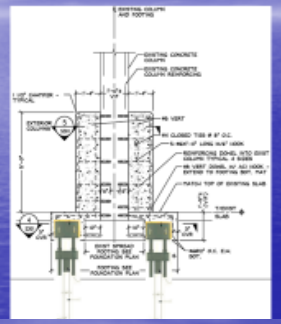
UPR Mayaguez


January 8, 2017

# REHABILITATION OF COASTAL STRUCTURES - continued

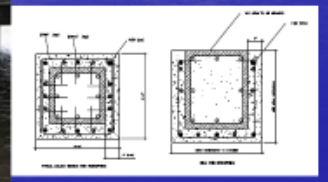
## ADAPT

- It will require jacketing




REHABILITATION OF STRUCTURES AFFECTED BY MARINE ENVIRONMENT

- PILE ENCAPSULATION, CONCRETE REINFORCEMMMENT HAD WORK EFFECTIVELY



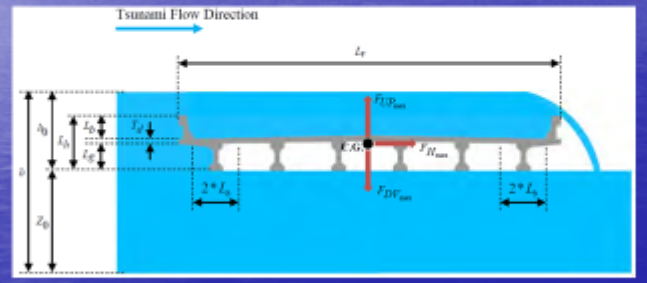
## RETREAT

- Will require move the structure



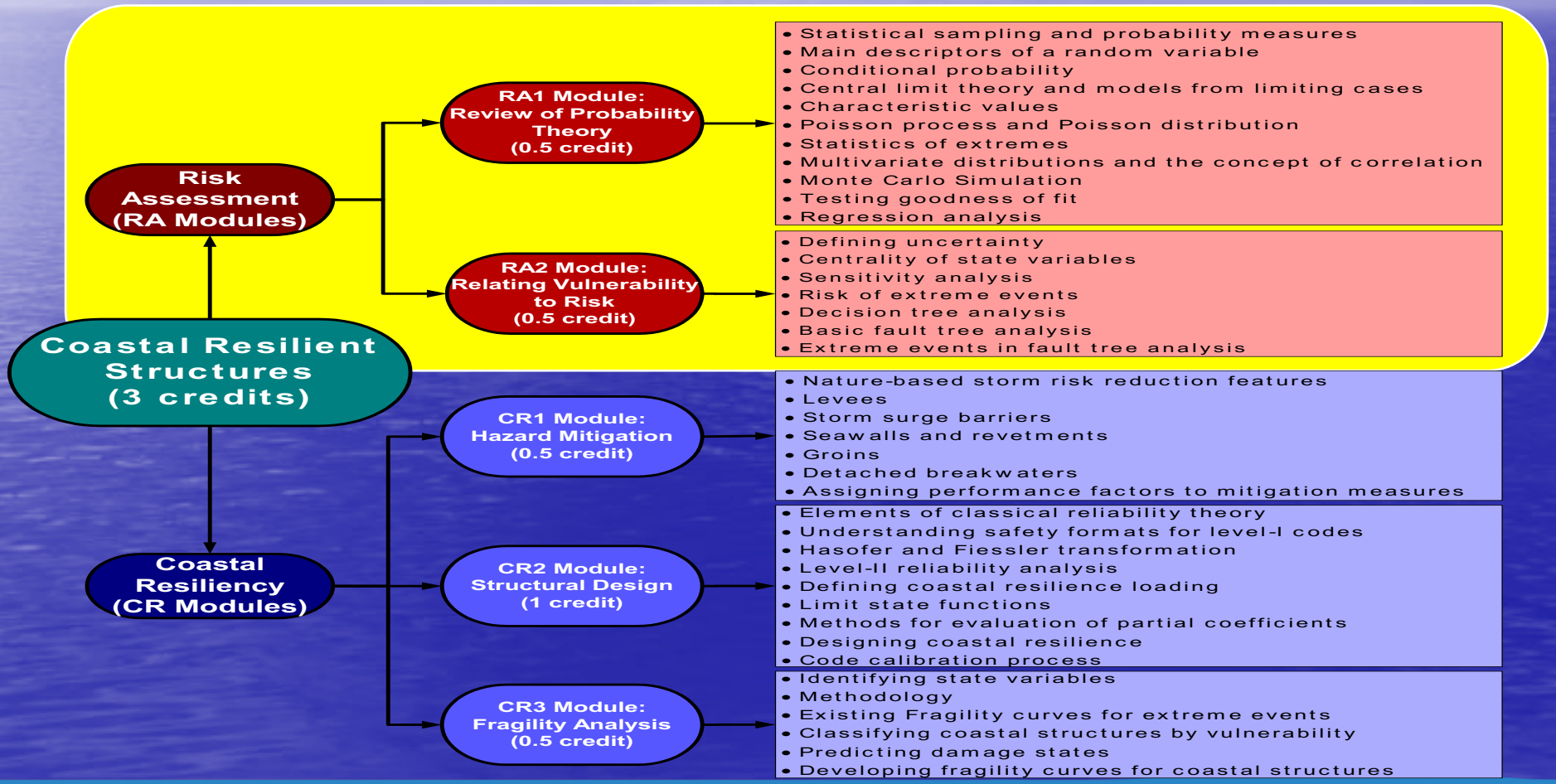
## TSUNAMIS

- BRIDGE AND PIERS



# Example New Course : Coastal Resilient Structures – 3 credits

## Dr. Ali Saffar, Professor in Structures, UPRM



# Module 1:
## Reliability Based Engineering

Dr. Ali Saffar

# UNIT 11
## Calibrated Design

Dr. Ali Saffar

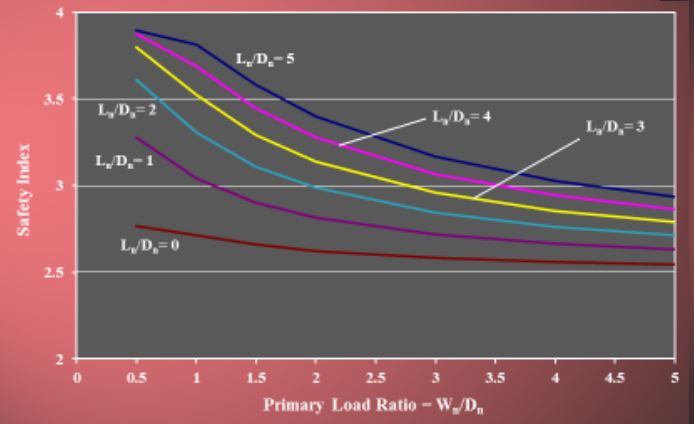
## Conventional Load Combinations

- Factored loads will include dead load plus a primary load plus one or more secondary loads.
  - Primary loads are lifetime maximums.
  - Secondary loads are arbitrary point-in-time loads.

$$Q_u = \gamma_D D_n + \gamma_P Q_P + \sum_i \gamma_{Si} Q_{Si}$$

- The load factors are evaluated based on a pre-defined set of safety indices.
- Probability weighted load ratios are assigned to each combination.

## Examples of Load Ratios




## Examples of Weighted Probabilities

- Nominal load ratios vary for different construction materials.
- For the primary live load to dead load ratios, the weighted probabilities assigned by the NBS Special Publication 577 are listed below:

| Material | $\frac{L_n}{D_n}$ | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0.25 | 0.5 | 1.0 | 1.5 | 2.0 | 3.0 | 5.0 |
| Steel | 0 | 0.10 | 0.20 | 0.25 | 0.35 | 0.07 | 0.03 |
| Reinforced Concrete | 0.10 | 0.45 | 0.30 | 0.10 | 0.05 | 0 | 0 |
| Aluminum | 0 | 0 | 0.06 | 0.17 | 0.22 | 0.33 | 0.22 |
| Glulam | 0 | 0.05 | 0.26 | 0.26 | 0.26 | 0.12 | 0.05 |
| Masonry | 0.36 | 0.36 | 0.20 | 0.06 | 0.02 | 0 | 0 |

## Performance Objectives

- The acceptable level of risk is keyed to the consequence of failure:

| Event Intensity | Consequence | | | |
|---|---|---|---|---|
| | Continued Service | Impaired Function | Life Safety | Incipient Collapse |
| Small ($\nu = 10^{-1}$ per year) | ALL | | | |
| Medium ($\nu = 10^{-2}$ per year) | II | I | | |
| Large ($\nu = 10^{-3}$ per year) | III | II | I | |
| Very Large ($\nu = 10^{-4}$ per year) | IV | III | II | I |

## ASCE-7 LRFD Flood Combinations

| Coastal A-Zones & V-Zones | Non-Coastal A-Zones |
|---|---|
| $1.4D$ | $1.4D$ |
| $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$ | $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$ |
| $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (0.5L \text{ or } 0.8W)$ | $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (0.5L \text{ or } 0.8W)$ |
| $1.2D + 1.0W + 2.0F_a + 0.5L + 0.5(L_r \text{ or } S \text{ or } R)$ | $1.2D + 1.0W + 0.5L + 0.5(L_r \text{ or } S \text{ or } R)$ |
| | $1.2D + 0.5W + 1.0F_a + 0.5L + 0.5(L_r \text{ or } S \text{ or } R)$ |
| $1.2D + 1.0E + 0.5L + 0.2S$ | $1.2D + 1.0E + 0.5L + 0.2S$ |
| $0.9D + 1.0W + 2.0F_a$ | $0.9D + 1.0W$ |
| | $0.9D + 0.5W + 1.0F_a$ |
| $0.9D + 1.0E$ | $0.9D + 1.0E$ |
| $D$ = dead load ; $L$ = live load ; $L_r$ = roof live load<br>$S$ = snow load ; $R$ = rain load ; $W$ = wind load ; $E$ = earthquake load | |

## Review of Low Frequency Events

- The existing benchmarks for the reliability index $\beta_0$ of structural components are based on the occupancy and snow load combinations.
- For any low frequency hazard $H$, the target reliability index will be reduced to:

$$P[F|H] = \Phi(-\tilde{\beta}_0) \Rightarrow \tilde{\beta}_0 = -\Phi^{-1}(P[F|H])$$

- Modelling the hazard as a Poisson process with the recurrence rate $\nu$ and the design life $t_D$:

$$P[F|H] = \frac{P[F \cap H]}{P[H]} = \frac{\Phi(-\beta_0)}{\nu t_D} \Rightarrow \tilde{\beta}_0 = -\Phi^{-1}\left(\frac{\Phi(-\beta_0)}{\nu t_D}\right)$$

# Spring Term Planned Activities

**SUMREX Participation**

**Other Internships ERDC**

**RETALK Program – 6 confirmed (dates to be confirmed)**

**The Senior CE Capstone Experience**

**(January – May )**

**Coastal Management Program: Coastal Resiliency Building-Mainstreaming Adaptation (Jan 26, 2016)**

**Lessons Learned and Best Practices: Resilience of Coastal Infrastructure (RCI) (Mar 7-9, 2017)**

**1. Climate Change Impact on Coastal Communities in the Caribbean** (Social/Governance; Agricultural, Infrastructure, Health)

2. **Hurricane Awareness Workshop –NDPTC-Hawaii**

**(June 7-8-9, 2017)**

**Rehabilitation of Coastal Infrastructure**

**Short Corse**

**José Guevarra**

**Coastal Resilient Structures**

**Short Course**

**Ali Saffar**

**Combined Effects of Storm Surge and Riverine Floods**

**Walter Silva**

**EERI Invited Lecturer**

**- Mr. Ron Eguchi, President and CEO of ImageCat, Inc., "Hurricanes, Tornados, Floods and other Disasters: A View from Space" –Feb 23, 2016**

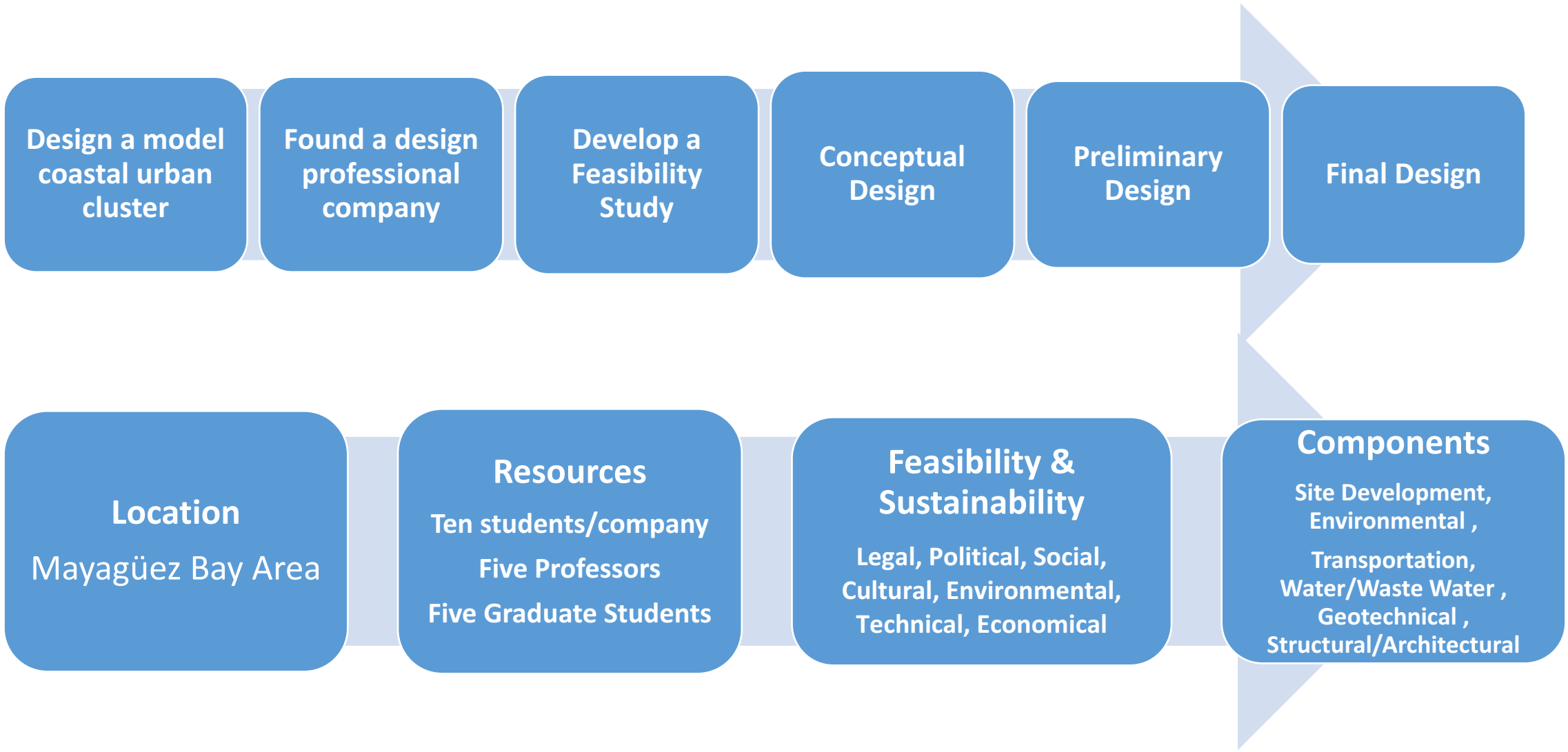
Coastal Inundation Mapping Wrokshop –NOAA

April 6-7,2017

# Invited Researchers for Visiting UPRM
# RETALK PROGRAM
# Spring –Summer 2017

- Dr. Gavin Smith, UNC
- Dr. Robert Whalin, JSU
- Dr. Daniel Cox, OSU
- Dr. John Van de Lindt, CSU
- Dr. Scott Hagen, LSU
- Dr. Stephen Medeiros, UCF
- Dr. Rick Luettich, UNC

# The Senior CE Capstone Experience:
## Incorporate coastal resilience principles



DEPARTMENT OF NATURAL AND ENVIRONMENTAL RESOURCES

PUERTO RICO COASTAL ZONE MANAGEMENT PROGRAM

# Coastal Resiliency Building: Mainstreaming Adaptation

Lecture at Capstone Course at the Department of Civil Engineering and Surveying
University of Puerto Rico-Mayagüez

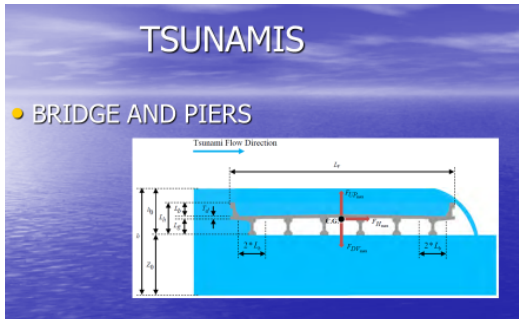
Mr. Ernesto Diaz- Director

January 26, 2017
Mayagüez, PR

- The Puerto Rico Coastal Zone Management Program
- The Puerto Rico Climate Change Council
- Human uses and modifications of coastal systems
- Sea Level Rise
- Coastal Erosion
- Erosion management: key considerations and needs
- Data and Information Sources


Sheetpile Structural Failures at Córcega Residential Complex, Rincón Puerto Rico. Matthew Hurricane. Oct. 2016. Picture courtesy-Francisco Villafañe, Grad. Stud.

# Lessons Learned and Best Practices: Resilience of Coastal Infrastructure
# March 8-9, 2017

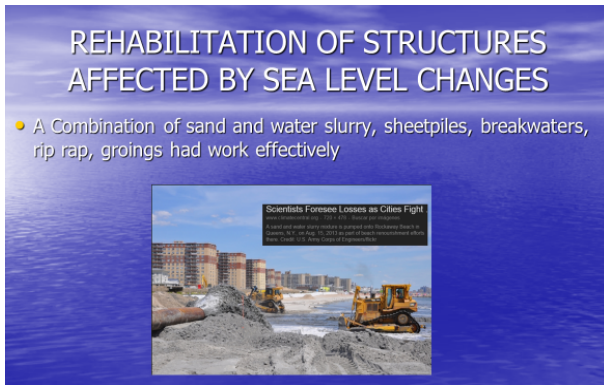


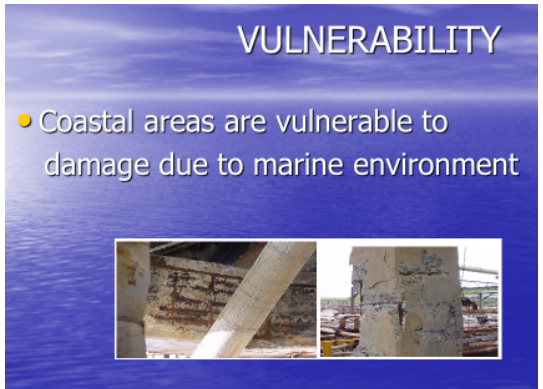

**Partners:** **UPRM-Sea Grant Program, ERDC, CIAPR (PRCES), PRDNER, CRC Partners**

**Location:** **Facilities - College of Engineers and Surveyors, Hato Rey, Puerto Rico**

**Selected topics:**

- **Coastal Hazards Drivers, Forces, and Mechanics**: Waves, Storm Surge, Earthquakes, Tsunamis, Wind
- **Coastal Infrastructure Vulnerability:** Built Infrastructure vs Natural Infrastructure
- **Past Experiences/Lessons Learned:** USA, PR, Caribbean Hurricanes –Example Mathews Hurricane
- **Natural and Nature-Based Features (NNBF) for Storm Damage Reduction**
- **Metrics and Indices (indirect indicators) of CIR by Sector and Activity within the Coastal Zone** (Beaches and Dunes, Coastal Communities Transportation) System
- **Recovery after Storms:** Quantifying Temporal and Spatial Dimensions of Recovery - Function of Storm Intensity and Preparedness
- **Rehabilitation of Coastal Structures**
- **Tsunami Structural Loads**
- **Structural Vulnerability to Natural Hazards**
- **Tools and Methods to Qualify and Quantify RCI**
- **Educational and Research Challenges in RCI**



# Coupling of Basin H/H and Storm Surge Modeling

## (Dr. Walter Silva-PI; Felix Santiago SUMREX)

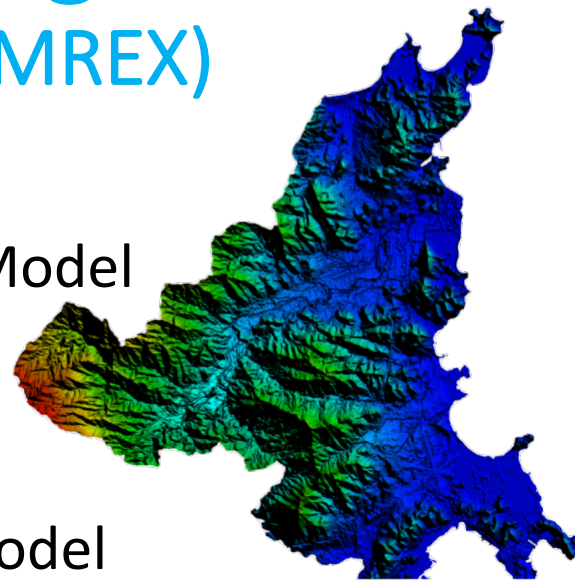
**Modeling:**

- Gridded Surface Subsurface Hydrologic Analysis (GSSHA): 2D finite difference structure grid model.
- Advanced Circulation model (ADCIRC):is a hydrodynamic circulation numerical model.
- Simulating Waves Nearshore model (SWAN): used to obtain realistic estimates of wind-generated waves.

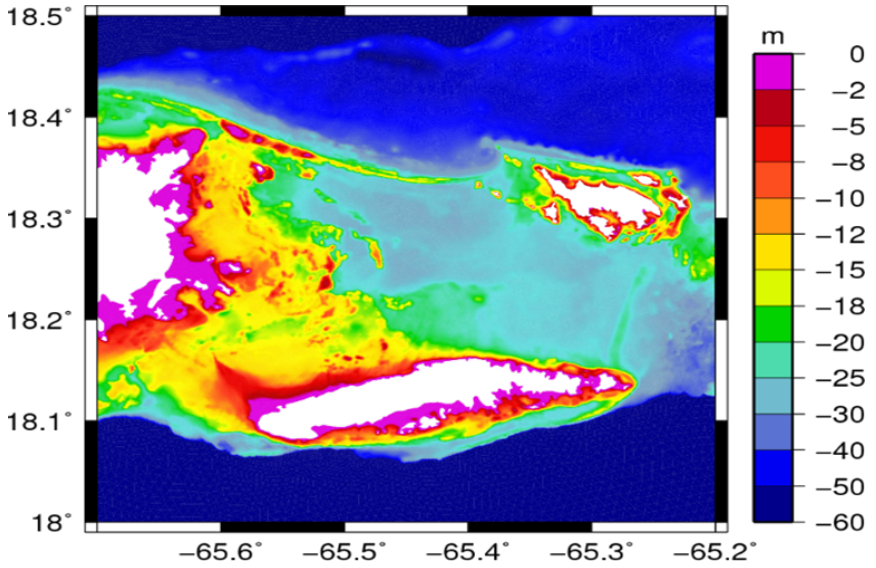
**Conclusion:**

- Results from this case study showed that overland flow could aggravate coastal flooding under storm surge conditions.

Basin Hydrologic Model



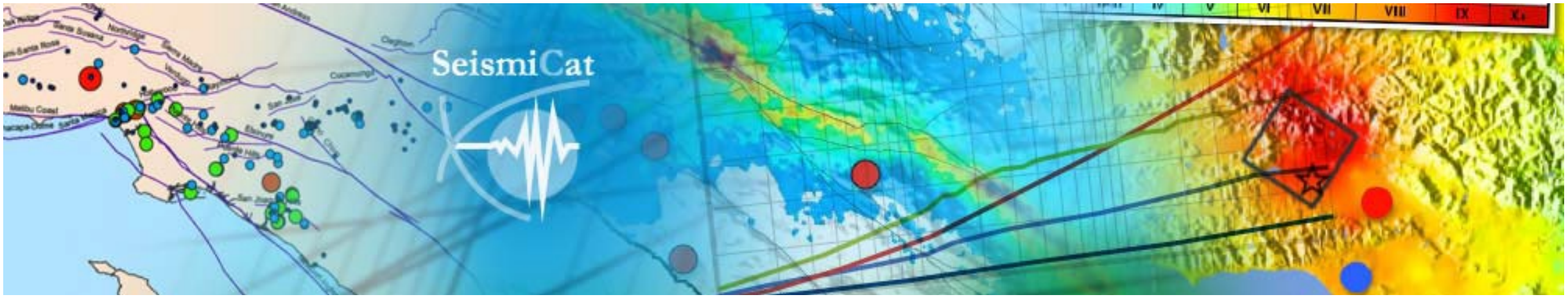
Storm Surge Model



# *Earthquakes, Hurricanes and other Disasters: A View from Space*

EERI February 23, 2017 Auditorium CE Department - UPRM

- **Ronald T. Eguchi, President and CEO of ImageCat, Inc., http://imagecatinc.com**
- **Visit and conference**: **Mr. Ron Eguchi**, President and CEO of ImageCat, Inc., a risk management company specializing in the development and use of advanced technologies for risk assessment and reduction (http://www.imagecatinc.com).
- **Sponsored:** Earthquake Engineering Research Institute as part of the *Friedman Family Visiting Professionals Program*



# Anticipated Project Impact

- **SUMREX and Internships:** Create **students pipeline and interest into RCI enterprise**, help identify **research and thesis topics**, **attract students into graduate programs and labor force** (2 students recruited , ERDC–USACE and NOAA –USA)
- **Creative/Research/ Development Projects - Students projects and theses, Faculty training modules, and presentations:** Undergraduate and graduate students, and faculty **engage in active and creative learning**, **develop teaching/learning modules**, **pursue external funding** and **long term research projects**, **develop presentations** in local and international forums, participate in **meetings and conferences** associated to RCI. This results in **human resource experts development and strengthening of the potential of labor force for RCI**.
- **Course Impacts:** Faculty has envisioned formal inclusion of new RCI material into existing and new **formal and informal courses**. The **CE curriculum will be impacted** by incorporating the RCI sustainable technology into traditional engineering analysis and design.
- **Stakeholders and Partners**: Increase **interaction, collaboration, coordination, and partnerships** to deal with RCI and HSE.

# Acknowledgement

***The authors want to acknowledge the contributions that deserve all the credit behind the work and efforts reflected in this presentation which are the results of the cooperation, collaboration, supports, creative work, and diligence of all those that are identified, mentioned, are referenced or cited, or helped in anyway for preparing this presentation. To all of them, our deepest and sincere appreciation.***

***This educational project within de Coastal Resilience Center (CRC) of Excellence is sponsored by the Department of Homeland Security (DHS) through the coordination of an outstanding team of researchers led by the University of North Carolina (UNC) for the research component and Jackson State University (JSU) for the educational component. We thank CRC leaders, administrators and staff for their continuous support. Our deepest appreciation to Dr. Robert Whalin, leader of the Educational Component for his encouragement and support.***


Thank You!