1. **Proposal Number:** RC21-B6-5028
2. **Proposal Title**: Comparative assessment of total water levels for coastal military facility readiness and resilience using numerical models
3. **Lead Principal Investigator**: Jack A. Puleo
4. **ESTCP Topic Area**: Topic B6: Coastal Total Water Level Model Comparative Assessment
5. **Lead Organization**: Center for Applied Coastal Research, University of Delaware, 259 Academy Street, Newark, DE, 19716, 302.831.2440, jpuleo@udel.edu
6. **Problem statement**: Projected sea level rise (SLR) and associated storm intensity will cause an increase in total water levels (TWL) at coastal US military facilities over the coming decades (e.g. GAO, 2019; Hall et al., 2016; UOCS, 2016). The DoD climate change roadmap (DoD, 2014) identified SLR and storm surge among the top four climate change phenomena that may impact DoD activities. Numerous scenarios exist for SLR (IPCC; Hall et al. 2016; Parris et al. 2012) with ranges from 0.2 to 2.0 m over the next 100 years. SERDP/ESTCP and other entities have funded research efforts to understand potential risk to military installations and infrastructure (e.g. Burks-Copes and many others, 2014; Donoghue et al., 2013). Past efforts focused on a single modeling group framework (Burks-Copes and many others, 2014) or may have included only SLR, tide, and wind-induced surge, but not other relevant wave-induced components such as setup, swash (Figure 1), and infragravity (IG) motions (Hall et al., 2016). Without waves, the underestimation of the TWL can be in excess of 20% (Mayo and Lin, 2019) on shallow sloping coasts and may exceed an order of magnitude on steeper coasts. We propose to assess a range of modeling approaches that include these processes, directly simulated or parameterized, to determine applicability, validity, computational cost, and skill in determining TWLs across an array of military installations with varying geomorphology and offshore forcing conditions.
7. **Technology Overview**

7a. Technical Objectives: Our objective is to enhance military installation readiness and resilience by performing a comparative assessment of a suite of projection methods for TWL and flooding. Demonstrations will be conducted at four military installations spanning a range of geomorphologies and hydrodynamic forcing conditions. Projections will be made using a range of SLR scenarios (Hall et al., 2016; Parris et al., 2012) with the main emphasis on TWL induced by extreme event forcing, such as cyclones and extra-tropical storms (ETS). Our proposal is in direct response to the FY 2021 Statement of Need for the ESTCP Resource Conservation and Resiliency (RC) program area (BAA, Topic area: B6: Coastal Total Water Level Model Comparative Assessment) that calls for projects to assess presently available empirical, analytical, and numerical models for current and future coastal TWLs.

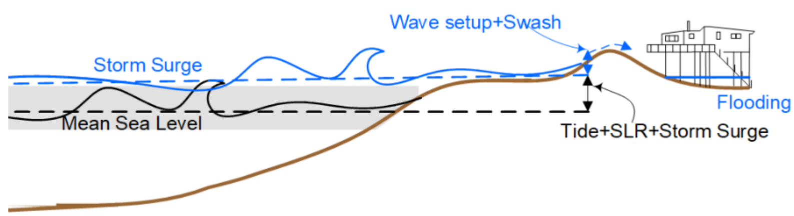


Figure 1. Schematic showing non-storm (black) and storm plus sea level rise (blue) conditions. The tide range is identified by gray shading. Note the addition of wave setup and swash not normally considered in total water level analysis.

At the project culmination we will have: 1) Tested a range of model approaches from low-cost / low-effort empirical to high-fidelity, nested, global to regional scale, three-dimensional (3D) simulations for predicting TWLs; 2) Developed web-based, graphics-driven tools for the demonstration sites enabling stakeholders and managers to easily identify water level risks associated with different predicted SLR scenarios, storm events, and modeling approaches; 3)

Provided an assessment of the cost (computational and budgetary) vs. model skill at each site; 4) Proposed the appropriate modeling framework for a range of forcing / geomorphology scenarios that exist at other military installations.

7b. Technology Description: TWLs will be predicted using a suite of simulation models from simple, low-cost empirical to complex, high cost (computation and effort) physics-based. Table STD1 provides the proposed list and technical aspects of the models. The modeling approaches can be grouped into three classes. Class I includes empirical approaches that focus on simplified equations for storm surge (Van Ormondt et al., In Review; WMO, 2011) and runup (Stockdon, et al., 2006). Class II includes (coupled) process-based numerical models which resolve tides, surges, and statistical wave conditions such as ADCIRC (Dietrich et al., 2011; Luettich and Westerink, 2004), NearCoM (Shi et al., 2013), Delft3D (Lesser et al., 2004) and COAWST (Shchepetkin and McWilliams, 2005; Warner et al., 2010) and are essentially based on the Nonlinear Shallow Water Equations (NSWE). Most of these models are dynamically coupled to wave models such as SWAN (e.g. Sebastian et al., 2014). These models (except ADCIRC) have morphodynamics modules to compute sediment transport and bed level changes. Class III includes dynamical wave models that either resolve the effect of the variation of the wave heights on the wave group time scale or resolve the waves themselves. XBeach-Surfbeat (Roelvink et al., 2009) and CSHORE (Figlus et al., 2018; Kobayashi, 2016) (group 1) can model morphological change and the effect on coastal flooding. Group 2 includes FUNWAVE (Shi et al., 2012) and XBeach-Non-Hydrostatic (Roelvink et al., 2018); that are computationally demanding wave (phase)-resolving models; only FUNWAVE contains a morphological change module. Class III models predict the effects of sea-swell, IG, and very low frequency (VLF) waves on TWL; processes largely ignored in past efforts.

7c. Technology Maturity: The numerical models described previously are robust and have been validated under a wide range of scenarios and hindcasting efforts (Figures STD1,2). Many of the models were developed by large research teams consisting of coastal engineers and numerical methods experts. All of the models are open source, are updated routinely, and have been vetted by researchers outside the development team. We note, however, that the PIs on the project are some of the high-level developers for the models to be used (Figlus: CSHORE, van Dongeren: XBeach and Delft3D, Shi: FUNWAVE and NearCom, Dietrich: ADCIRC).

7d. Technical Approach*:* The goal of the project is to identify and compare various model approaches and identify best practice in using a set of models for predicting TWL, suitable for a variety of coastal military installations. Quantitative metrics will be identified but constrained due to: 1) available boundary conditions; generally bathymetry and topography, and 2) historical information on water levels / flooding being sparse, having large errors, or existing only anecdotally (e.g. “the installation flooded” versus flood depth as a function of areal extent).

A detailed review including theories, numerical schemes, and model coupling developments of selected models will be conducted. Tests in an idealized domain will include model functions, numerical convergence, computational efficiencies, choice of wave force formulations, and capability of modeling supercritical or discontinuous flows in coastal flooding.

Four DoD demonstration sites spanning a range of forcing and morphology conditions are chosen (Table 1). The following approach will then be undertaken for each demonstration site with some items identified in the performance objectives table (Table 2): 1) Identify the relevant physics, forcing, and geomorphology at the site of interest through information extraction from available databases; 2) Use item (1) to determine the most appropriate models to use; 3) Develop model grids and synthetic extreme event tracks based on historical data and a Monte Carlo sampling method (TCWiSE; Hoek, 2017); 4) Run the models for expediency, then remove processes, coarsen grids, and/or apply lower fidelity models such as empirical relations, to identify the effect on the prediction; 5) Compare to a full physics modeling framework with model output assumed as reference; 6) Re-run the most appropriate models using the range of predicted SLR and synthetic storm tracks to identify predicted installation flooding / TWL in the future; 7) Develop web-based interfaces for the model results, parameters, forcing conditions, and SLR scenarios; discuss with site managers.

Table 1. Proposed site locations and characteristics for comparative model assessment

	US Army Aberdeen Proving Ground	**Naval Station Norfolk**	**Tyndall Air Force Base**	**Ronald Reagan Ballistic Missile Defense Test Site, Roi Namur**
General Location	Chesapeake Bay, MD	Atlantic Coast, VA	Gulf Coast, FL	Pacific Ocean, Marshall Islands
Geomorphic Setting	Sheltered Low-lying tidal wetland / marsh; cohesive sediment	Shallow continental shelf, land subsidence, bulkheads	Barrier Island fronted by shallow continental shelf, sands	Narrow coral atoll section fronted by narrow beach
Primary forcing	Microtidal, river input, SLR and bay aligned winds	Mesotidal, moderate wave climate, hurricanes and nor'easters	Microtidal, mild wave climate, ocean and bay side flooding, hurricanes	Mesotidal, moderate wave climate with large swell events
Point of Contact	Larry Birchfield	Brian Ballard	TBD	TBD

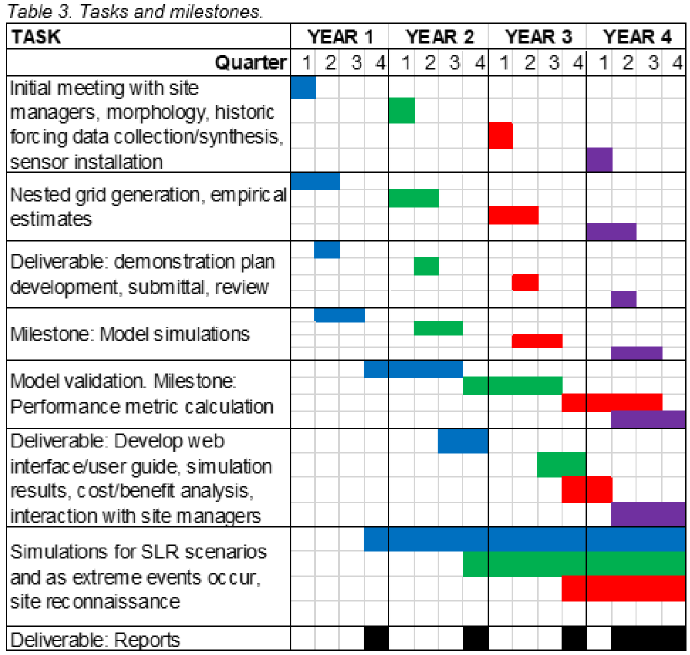
7e. Technical Risks: There is little risk in taking the technology itself from the current state to demonstration. The risk is largely associated with input to the different model systems. Hindcast predictions will rely on available forcing data that in general are robust. However, model performance relies heavily on available topographic-bathymetric data that may be coarse, contain large errors or the data collection time is not ideal relative to extreme event occurrence. Validation data from historical events may also be sparse, error-ridden, or anecdotal in nature. Risks will be minimized: 1) using optimal interpolation algorithms (Plant et al., 2002) on morphology and conducting simulations with varied grid resolution, and 2) collecting in situ data at a subset of the installations pre- and post-event for validation.

7f. Related Efforts: The open-source models described herein are under continuous development and are used widely. ADCIRC is used operationally to provide forecasts of storm surge and coastal flooding along the US Gulf and Atlantic coasts (https://cera.coastalrisk.live) with improvement efforts funded by DHS and NSF. Delft3D has been applied in >100 studies worldwide. It was adopted in 2001 by the US Navy for operational forecasts of surge and nearshore wave hydrodynamics. The flexible mesh version (Delft3D-FM) is being used by NOAA to assess compound flooding in the Chesapeake and Delaware River estuaries. XBeach was initially funded by the US Army Corps of Engineers (USACE) and has 1000s of active users. XBeach-NH for coral reef-lined coasts was funded by DoD-SERDP (RC-2334).

Table 2. Performance Objectives

Performance Objective	Metric	Data Requirements	Success Criteria
Quantitative Performance Objectives			
Test models capability: water level (non-wave-driven and wave-driven)	Comparison with available water level data and reference full physics model runs	Water level data at multiple locations within the installation	< 20% RMSE; non-wave-driven < 30% RMSE; wave-driven
Test models capability: flooding	Comparison with available flooding data	Areal extent of flooded area of installation	< 50% m^2 error in predicted flooding area relative to reference
Test models: Efficiency	Compare capability with cost ($ and computational)	Criteria from previous objectives and cost estimates	Models per site set up / results compiled in < 6 months
Qualitative Performance Objectives			
Web interface ease of use	Ability of technical-level personnel to use/understand output	Personnel feedback on interface	Technician-level personnel can select results suitable for the installation

Table 3. Tasks and milestones.



Legend: Aberdeen (Blue), Norfolk (green), Tyndall (red), Kwajalein (purple). Note there is no plan to install sensors at Kwajalein Atoll.

XBeach has been applied to natural and developed barrier islands on the Atlantic and Gulf coasts, sandy coasts in California, coral-reef lined islands in the Pacific and Atlantic, and is part of the CoSMoS prediction system of the USGS. FUNWAVE has an extensive user base, is verified and recommended by the USACE, and was recently updated with improved numerical capability. CSHORE uses a probabilistic treatment of forcing parameters for numerical efficiency and is presently being incorporated into the USACE coastal modeling system.

8. Expected DoD Benefit*:* Most TWL forecasts / simulations neglect the effect of runup and low-frequency motions that can alter TWL and flooding of military installations. Models tested in this demonstration range from simple to sophisticated and span the range of available model types for TWL applications (rather than prior studies focusing on a single model framework). The most appropriate model framework to use will always be installation-dependent due to a variety of forcing and morphology conditions. However, validating the suite of models will provide robust information on which models are suitable for particular conditions (look-up table) enabling DoD managers to choose rapidly the most appropriate prediction approach. The model frameworks are portable such that they can be set up at any coastal installation provided morphology and forcing data can be obtained.

9. Schedule of Milestone: The proposed four-year project timeline runs from 1 June 2021 to 31 May 2025 (Table 3).

10. Technology Transition: Model output for the various scenarios will be made available via interactive web interfaces enabling technician-level end users to select different parameters and immediately observe the impact at the particular installation (Figures STD2,3). Installation commanders and other personnel may also use the web interfaces but key parameters, their effects on dynamic TWL, model capability, accuracy, and cost will also be included on a separate model guidance web page. We envision a three to six month time frame to transition the findings for dissemination at each of the demonstration installations. Additional installations would require roughly six months depending on availability of forcing and morphology data.

11. Performers

Investigator	Institution	Contribution
Jack Puleo	University of Delaware (UD, Lead)	Project lead, empirical estimates, sensor installation, data collection and synthesis
Fengyan Shi	UD, Lead	Lead model expert on FUNWAVE and NearCom
Ap van Dongeren	Deltares	Lead model expert on Delft3D and XBeach
Casey Dietrich	North Carolina State University (NCSU)	Lead model expert on ADCIRC
Stephanie Smallegan	University of South Alabama (USA)	Lead model expert on XBeach, sensor installation
Jens Figlus	Texas A&M Univ. (TAMU)	Lead model expert on CSHORE
Curt Storlazzi	USGS	Numerical modeling/field expert for extreme events

12. Funding

Institution	Year1 ($K)	Year2 ($K)	Year3 ($K)	Year4 ($K)	**Totals ($K)**
UD (non-federal)	347	273	279	292	**1,191**
Deltares USA (NFP)	72	73	83	51	**278**
NCSU (non-federal)	104	105	104	105	**418**
USA (non-federal)	77	77	89	54	**297**
TAMU (non-federal)	102	93	88	84	**367**
USGS (federal)	10	10	10	10	**40**
Totals	712	631	653	596	**2,592**

Funding is requested to support experts in model testing, validation, results dissemination, interface development, travel, and reporting. The total estimated for the four-year effort is $2,592K ($648K/year average). We estimate historic data collection and analysis, grid generation, model development and validation of the most appropriate framework, interface and user-guide development for a future site to be ~$250k assuming bathymetric and topographic data are available. Direct costs (via MIPR) to federal installation partners have not yet been budgeted due to unknown final site locations and logistics requirements.

CURRICULUM VITAE – JACK A. PULEO

PERSONAL DETAILS

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EDUCATION HISTORY

2004	Ph.D. in Coastal Engineering, University of Florida
1998	M.S. in Physical Oceanography, Oregon State University
1996	B.S., B.A. in Oceanography, Mathematics, Humboldt State University

EMPLOYMENT HISTORY

2017 – Present	Director, Center for Applied Coastal Research
2017 – Present	Professor and Associate Chair, Dept. of Civil and Environmental Engineering, University of Delaware
2016 – Present	Intermittent Faculty Member, Civil Engineer, Naval Research Laboratory
2010 – 2017	Associate Professor, Dept. of Civil and Environmental Engineering, University of Delaware
2004 – 2010	Assistant Professor, Dept. of Civil and Environmental Engineering, University of Delaware
1998 – 2004	Oceanographer, Marine Geosciences Division, Naval Research Laboratory, Stennis Space Center, MS

RELEVANT RECENT GRANTS

2019 – 2021	**Puleo, J.A.**, "Intra-storm Erosion Processes on an Engineered Dune System" USCRP/USACE, $103,378.
2018 – 2021	**Puleo, J.A.**, Hsu, T., Cox, D., Wengrove, M. Feagin, R., "Collaborative Research: Physics of Dune Erosion during Extreme Surge and Wave Events", NSF, $1,134,514.
2015 – 2019	**Puleo, J.A.**, "Quantification of Hydrodynamic Forcing and Burial, Exposure and Mobility of Munitions on the Beach Face" SERDP, $1,080,359.

RELEVANT RECENT PUBLICATIONS

Borrell, S. and **J.A. Puleo**, 2019. In situ hydrodynamic and morphodynamics measurements during extreme events, *Shore & Beach,* 87(4), 23-30.

Coogan, J.S., B.M. Webb,. S. Smallegan, and **J.A. Puleo**. 2019. Geomorphic changes measured on Dauphin Island, AL during Hurricane Nate, *Shore & Beach*, **87(4), 16-22.**

Kim, Y., R.S. Mieras, Z. Cheng, D. T.–J. Hsu, **J.A. Puleo**, D. Cox. 2019. A numerical study of sheet flow driven by velocity and acceleration skewed near-breaking waves on a sandbar using SedWaveFoam, *Coastal Engineering*, 152

Figlus, J., Y-K. Song, P. Chardon-Maldonado, **J.A. Puleo**. 2018. Numerical simulation of post-storm recovery and time-averaged swash velocity on an engineered beach with ridge-runnel system, *International Journal of Offshore and Polar Engineering*, 28(2), 143-153

SPECIFIC EXPERTISE RELEVANT TO ESTCP PROPOSAL

Experience as a PI in designing, conducting and leading/managing multi-investigator international projects. Expert in field- and laboratory-based experiments aimed at understanding the physics driving hydrodynamics and sediment motion in coastal environments during extreme events. The PI also has expertise in sensor development and remote sensor system design.

CURRICULUM VITAE – CASEY DIETRICH

PERSONAL DETAILS

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EDUCATION HISTORY

2011	Ph.D. in Civil Engineering, University of Notre Dame
2005	M.S. in Civil Engineering, University of Oklahoma
2004	B.S. in Civil Engineering, University of Oklahoma

EMPLOYMENT HISTORY

2019 – Present	Associate Professor, North Carolina State University
2013 – 2019	Assistant Professor, North Carolina State University
2012 – 2013	Research Associate, University of Texas at Austin
2010 – 2012	Post-Doctoral Researcher, University of Texas at Austin

RELEVANT RECENT GRANTS

2020 – 2022	**Dietrich, J.C.** and McCord, R.J., "Improving Predictions of Estuarine Flooding and Circulation during Storms" NC Sea Grant, $119,370.
2019 – 2021	**Dietrich, J.C.** and Anderson, D.L., "Sustainability of Barrier Island Protection Policies under Changing Climates", USCRP, $222,624.
2017 – 2021	Kennedy, A.B., Bolster, D., **Dietrich, J.C.**, Wirasaet, D. "PREEVENTS Track 2: Collaborative Research: Subgrid-Scale Corrections to Increase the Accuracy and Efficiency of Storm Surge Models" NSF, $1,252,526.

RELEVANT RECENT PUBLICATIONS

Cyriac, R., **Dietrich, J.C.** et al. Accepted. Wind and Tide Effects on the Choctawhatchee Bay Plume and Implications for Surface Transport at Destin Inlet. *Regional Studies in Marine Science*.

Thomas, A., **Dietrich, J.C.** et al. 2019. Influence of Storm Timing and Forward Speed on Tide-Surge Interactions during Hurricane Matthew. *Ocean Modelling*, 137, 1-19.

Cyriac, R. **Dietrich, J.C.** et al. 2018. Variability in Coastal Flooding Predictions due to Forecast Errors during Hurricane Arthur. *Coastal Engineering*, 137(1), 59-78.

SPECIFIC EXPERTISE RELEVANT TO ESTCP PROPOSAL

Lead developer of ADCIRC, including the coupling of ADCIRC+SWAN. He worked with emergency managers in NC to develop storm surge visualizations for decision support.

CURRICULUM VITAE – AP VAN DONGEREN

PERSONAL DETAILS

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EDUCATION HISTORY

1997	Ph.D. - University of Delaware - Coastal Engineering
1992	M.Sc. - Delft University of Technology - Civil Engineering

EMPLOYMENT HISTORY

2017 – Present	Senior Specialist, Deltares
2018 – Present	Associate Professor, IHE Delft
2008 – 2016	Specialist Hydrodynamics and morphodynamics, Deltares
1999 – 2008	Project Engineer and Researcher, Deltares
1997 – 2004	Associate Researcher, Delft University of Technology

RELEVANT RECENT GRANTS

2016 – 2020	**Van Dongeren, A.R.** Increasing the Fidelity of Morphological Storm Impact Predictions, ONR, $600k
2013 –2016	**Van Dongeren A.R.** RISC-KIT, Resilience-increasing Strategies for Coasts - ToolKIT. EU Framework Program 7, $1,500k

RELEVANT RECENT PUBLICATIONS

Van der Lugt, Marlies A., Ellen Quataert, **A.R. van Dongeren**, Maarten van Ormondt, Christopher R. Sherwood, 2019, Morphodynamic modeling of the response of two barrier islands to Atlantic hurricane forcing, Estuarine, Coastal and Shelf Science https://doi.org/10.1016/j.ecss.2019.106404

Storlazzi, C.D., S.B. Gingerich., **A.R. van Dongeren**, et al. 2018,Most atolls will be uninhabitable by the mid-21st century because of sea-level rise exacerbating wave-driven flooding, Science Advances http://dx.doi.org/10.1126/sciadv.aap9741.

Smallegan, S.M., J.L. Irish and **A.R. van Dongeren**, 2017, Developed barrier island adaptation strategies to hurricane forcing under rising sea levels, Climatic Change 10.1007/s10584-017-1988-y

SPECIFIC EXPERTISE RELEVANT TO ESTCP PROPOSAL

Experience as a PI in coordinating large international projects. Expert in numerical model development and application for wave-induced hazards and impacts on sandy and coral-lined shorelines.

CURRICULUM VITAE – FENGYAN SHI

PERSONAL DETAILS

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EDUCATION HISTORY

1997	Ph.D. - Ocean University of Qingdao - Physical and Env. Oceanography
1992	M.Sc. - Ocean University of Qingdao - Physical Oceanography

EMPLOYMENT HISTORY

2019 – Present	Research Professor, University of Delaware
2012 – 2019	Research Associate Professor, University of Delaware
2007 – 2012	Research Assistant Professor, University of Delaware
1998 – 2007	Post-doc, Research Associate Scientist, University of Delaware

RELEVANT RECENT GRANTS

2018 – 2019	**Shi, F.** Implementation of the cohesive sediment transport component in FUNWAVE-TVD and model application for Freeport Sabine-to-Galveston PED coastal hazards, USACE, $126,931
2015-2016	Kirby, J.T. and **Shi, F.** Development of hydrodynamic models and accretion datasets at Bombay Hook National Wildlife Refuge for salt marsh restoration and resiliency planning, NFWF, $400,000
2012-2015	**Shi, F**. and Kirby, J.T., Best Practices for Physical Process and Impact Assessment in Support of Dredging Operations on the U.S. Outer Continental Shelf, NOAA, $120,333

RELEVANT RECENT PUBLICATIONS

Shi, F., Kirby, J. T., Harris, J. C., Geiman, J. D. and Grilli, S. T., 2012, "A high-order adaptive time-stepping TVD solver for Boussinesq modeling of breaking waves and coastal inundation", Ocean Modelling, 43-44, 36-51

Chen, J., **Shi, F.**, Hsu, T.-J., and Kirby, J. T., 2014,"NearCoM-TVD - a quasi-3D nearshore circulation and sediment transport model", Coastal Engineering, 91, 20

Shi, J., **Shi, F.**, Zheng, J., Zhang, C., and Malej, M., 2019, "Interplay between grid resolution and pressure decimation in non-hydrostatic modeling of internal waves", Ocean Engineering, DOI:10.1016/j.oceaneng.2019.06.0140-212

SPECIFIC EXPERTISE RELEVANT TO ESTCP PROPOSAL

Major developer of several public-domain community models, including NearCoM, FUNWAVE, and NHWAVE. Principle Investigator of the recent USACE-funded projects for predicting storm-induced wave effects, including wave setup, overtopping, coastal inundation, and erosion. He also led the NOAA BOEM-funded project: Best Practices for Physical Process and Impact Assessment in Support of Dredging Operations on the U.S. Outer Continental Shelf.

CURRICULUM VITAE – STEPHANIE M. SMALLEGAN

PERSONAL DETAILS

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EDUCATION HISTORY

2016	Ph.D. in Civil Engineering, Virginia Tech
2012	M.S. in Civil Engineering, Georgia Tech
2010	B.S. in Civil Engineering, Georgia Tech

EMPLOYMENT HISTORY

2016 – Present	Assistant Professor, Dept. of Civil, Coastal, and Environmental Engineering, University of South Alabama
2016 – 2016	Instructor, Dept. of Civil, Coastal, and Environmental Engineering, University of South Alabama

RELEVANT RECENT GRANTS

2019 – 2021	Smallegan, S.M., Collini, R.C. "Coastal Adaptation Pathways for Barrier Island Communities" USCRP/USACE, $200,262.
2019 - 2020	Smallegan, S.M. "Building Sea-level Rise and Flood Resilience Capacity in the Northern Gulf through Students and Teachers" NASEM, $32,853.
2018 – 2020	Smallegan, S.M., Collini, R.C., Lester, H.D., "Life Cycle Cost Analyses of Adaptive Strategies on Dauphin Island to Rising Sea Levels", U. of South Alabama, $19,204.

RELEVANT RECENT PUBLICATIONS

Smallegan, S. M., Figlus, J., Stark, N., Sasanakul I., Arboleda Monsalve, L.G., Shafii, I, Jafari, N., Ravichandran, N., Bassal, P., (accepted). Post-2017 hurricane season assessment of civil infrastructure impacts on geomorphology. International Journal of Geoengineering Case Histories.

Coogan, J.S., B.M. Webb,. **S. M. Smallegan**, and J.A. Puleo. 2019. Geomorphic changes measured on Dauphin Island, AL during Hurricane Nate, Shore & Beach, 87(4), 16-22.

Smallegan, S. M., Irish, J. L., van Dongeren, A. R., 2017. Developed barrier island adaptation strategies to hurricane forcing under rising sea levels. Climatic Change, 1-12.

SPECIFIC EXPERTISE RELEVANT TO ESTCP PROPOSAL

Expertise in hydrodynamic and morphodynamic numerical modeling to understand the physical changes of sandy beaches due to short-term and long-term processes. Co-PI uses numerical modeling techniques and field data to analyze the impacts of civil infrastructure on morphological changes on barrier islands during tropical cyclones. Co-PI has served on National Science Foundation Geotechnical Extreme Event Reconnaissance and Structural Extreme Events Reconnaissance teams where she surveyed geotechnical and structural damage due to natural hazards.

CURRICULUM VITAE – JENS FIGLUS

PERSONAL DETAILS

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EDUCATION HISTORY

2010 Ph.D. in Civil Engineering, University of Delaware
2007 M.S. in Civil Engineering, University of Delaware
2005 Dipl.-Ing. in Civil Engineering, Karlsruhe Institute of Technology (Germany)

EMPLOYMENT HISTORY

2019 – Present Associate Professor, Dept. of Ocean Engineering, Texas A&M University
2012 – 2019 Assistant Professor, Department of Ocean Engineering, Texas A&M University
2010 – 2012 Senior Engineer / Director of Business Development USA, Gauff Group

RELEVANT RECENT GRANTS

2018 – 2020 **Figlus, J.,** "Protracted Anthropogenic Effects of Navigational and Flood Control Projects, Galveston District: Hydrodynamic Field Measurements in the Corpus Christi Ship Channel", USACE/DOD, $159,213.
2015 – 2021 Brody, S., **Figlus, J.,** et al., "PIRE: Coastal Flood Risk Reduction Program: Integrated Multi-Scale Approaches for Understanding How to Reduce Vulnerability to Damaging Events", NSF, $3,595,923.
2020 – 2021 **Figlus, J.,** "Port Aransas Ferry – Impacts to Operation Analysis" TXDOT, $70,706.

RELEVANT RECENT PUBLICATIONS

Pampell-Manis, A., Horrillo, J., and **Figlus, J.** (2016). Estimating tsunami inundation from hurricane storm surge predictions along the U.S. gulf coast. *Ocean Dynamics*, 66/8: 1005-1024.

Harter, C. and **Figlus, J.** (2017). Numerical modeling of the morphodynamic response of a low-lying barrier island beach and foredune system inundated during Hurricane Ike using XBeach and CSHORE. *Coastal Engineering*, 120: 64–74.

Figlus, J., Song, Y.-K., Chardon-Maldonado, P., and Puleo, J. A. (2018). Numerical simulation of post-storm recovery and time-averaged swash velocity on an engineered beach with ridge-runnel system. *International Journal of Offshore and Polar Engineering*, 28/2: 143-153.

Feagin, R. A., Furman, M., Salgado, K., Martinez, M. L., Innocenti, R. A., Eubanks, K., **Figlus, J.,** Huff, T. P., Sigren, J., and Silva, R. (2019). The role of beach and sand dune vegetation in mediating wave run up erosion. *Estuarine, Coastal and Shelf Science*, 219: 97-106.

SPECIFIC EXPERTISE RELEVANT TO ESTCP PROPOSAL

Experience as a PI in designing and conducting collaborative projects. Expert in coastal engineering and coastal flood related field and laboratory experiments with focus on coastal hydrodynamic and morphodynamic processes. Expert in CSHORE modeling of coastal systems.

CURRICULUM VITAE – CURT D. STORLAZZI

PERSONAL DETAILS

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EDUCATION HISTORY

2000 Ph.D. in Earth Sciences, University of California at Santa Cruz
1996 B.Sc. in Geology, University of Delaware

EMPLOYMENT HISTORY

2020 – Present Senior Research Geologist, U.S. Geological Survey, Santa Cruz, CA
2004 – Present Research Associate, Institute for Marine Sciences, University of California, Santa Cruz, CA
2004 – 2019 Research Geologist, U.S. Geological Survey, Santa Cruz, CA
2002 – 2004 Research Fellow, Partnership for Interdisciplinary Studies of Coastal Oceans Consortium, Santa Cruz, CA
2000 – 2002 Post-doctoral Researcher, Institute for Marine Sciences, University of California, Santa Cruz, CA

RELEVANT RECENT GRANTS (Principal Investigator)

2018-2020: US Department of the Interior, 2017 Hurricane and Wildfire Supplemental. "*Assessing Coastal Impacts and Enhancing Tools to Forecast Vulnerability to Coastal Flooding and Erosion in Florida and Puerto Rico after the 2017 Hurricanes*" $1,245,000
2014-2017: Department of Defense, SERDP. "*The Impact of Sea-Level Rise and Climate Change on Department of. Defense Installations on Atolls in the Pacific Ocean*" $2,657,400

RELEVANT RECENT PUBLICATIONS

Storlazzi, C.D., 2018. "Challenges of forecasting flooding on coral reef–lined coasts" *Eos, 99.*

Storlazzi, C.D., Gingerich, S.B., van Dongeren, A., Cheriton, O.M., Swarzenski, P.W., and 6 others, 2018. "Most atolls will be uninhabitable by the mid-21st century because of sea-level rise exacerbating wave-driven flooding" *Science Advances*, v. 4, eaap9741.

Cheriton, O.M., **Storlazzi, C.D.**, Rosenberger, K.J., 2016. "Observations of wave transformation over a fringing coral reef and the importance of low-frequency waves and offshore water levels to runup, overwash, and coastal flooding." *Journal of Geophysical Research-Oceans*, v. 121, p. 3121-3140.

Quataert, E., **Storlazzi, C.D.**, van Rooijen, A., Cheriton, O.M., and van Dongeren, A., 2015. "The influence of coral reefs and climate change on wave-driven flooding of tropical coastlines." *Geophysical Research Letters*, v. 42, p. 6407-6415.

SPECIFIC EXPERTISE RELEVANT TO ESTCP PROPOSAL

Experience as a PI in designing, conducting, and managing large, multi-investigator scientific projects and translating that science to management actions. Expert in field- and laboratory-based experiments aimed at understanding the coastal hydrodynamics during extreme events.

Proposal Number: RC21-B6-5028

List of Acronyms

Acronym	Meaning
ADCIRC	Advanced Circulation Model
BAA	Broad Agency Announcement
D	Water depth
DHS	Department of Homeland Security
DoD	Department of Defense
FL	Florida
ESTCP	Environmental Security Technology Certificate Program
ETS	Extra Tropical Storm
FD	Finite Difference
FE	Finite Element
FUNWAVE	Fully Nonlinear Wave Model
FV	Finite Volume
GAO	Government Accountability Office
IG	Infragravity
IPCC	Intergovernmental Panel on Climate Change
K	Storm surge coefficient
MD	Maryland
NC	North Carolina
NCSU	North Carolina State University
NearCom	Nearshore Community Model
NOAA	National Oceanic and Atmospheric Administration
NFP	Not For Profit
NSF	National Science Foundation
NSWE	Nonlinear Shallow Water Equations
NTHMP	National Tsunami Hazard Mitigation Program
RC	Resource Conservation and Resiliency
RMSE	Root Mean Square Error
S	Storm surge
SERDP	Strategic Environmental Research and Development Program
SLR	Sea Level Rise
SON	Statement of Need
SWAN	Simulating Waves Nearshore
UD	University of Delaware
TAMU	Texas A&M University
TBD	To Be Determined
UOCS	Union of Concerned Scientists
US	United States
USA	University of South Alabama
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VA	Virginia
VLF	Very low Frequency
w	Wind speed

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Dietrich, J.C., Zijlema, M., Westerink, J., Holthuijsen, L.H., Dawson, C.N., Luettich, R.A., Jensen, R.E., Smith, J.M., Stelling, G.S., Stone, G.W., 2011. Modeling Hurricane Waves and Storm Surge using Integrally-Coupled, Scalable Computations. Coastal Engineering 58, 45–65.

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Figlus, J., Song, Y.K., Chardon-Maldonado, P., Puleo, J.A., 2018. Numerical simulation of post-storm recovery and time-averaged swash velocity on an engineered beach with ridge-runnel system. International Journal of Offshore and Polar Engineering 28, 11.

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Supporting technical data

Table STD1. List of proposed models for water level predictions.

Model name and equations solved	**Numerical approach**	**Coupled component**	**Basic functions**
Class I			
Empirical eqns.	Direct	N/A	Storm Surge, Runup
Class II			
ADCIRC; NSWE (2D)	FE, unstructured grid	Wave model SWAN	Tide, storm surge, wave setup
COAWST; NSWE (3D)	FD, structured curvilinear grid	Wave model WW3	Tide, storm surge, wave setup
Delft3D; NSWE (3D)	FD, structured curvilinear grid	Wave model SWAN	Tide, storm surge, wave setup
NearCoM; NSWE (2D)	FV, structured non-orthogonal curvilinear grid	Wave model SWAN, morphology	Tide, storm surge, wave setup
Class III			
CSHORE; NSWE (1D,2D)	FD, rectangular grid	Stationary wave model, morphology	Wave setup, overtopping, morphological change
FUNWAVE; Boussinesq (2D)	Hybrid FV-FD, rectangular grid, spherical grid	Morphology	Phase-resolving waves, wave setup, overtopping, IG
Xbeach-{surfbeat} XBeach-[NH] (2D)	FD, curvilinear grid	Stationary/ [non-stationary] wave model, {morphology}	Tide, storm surge, wave setup, {IG}, wave runup, {morphological change}

* Finite Element (FE), Finite Volume (FV), Finite Difference (FD)

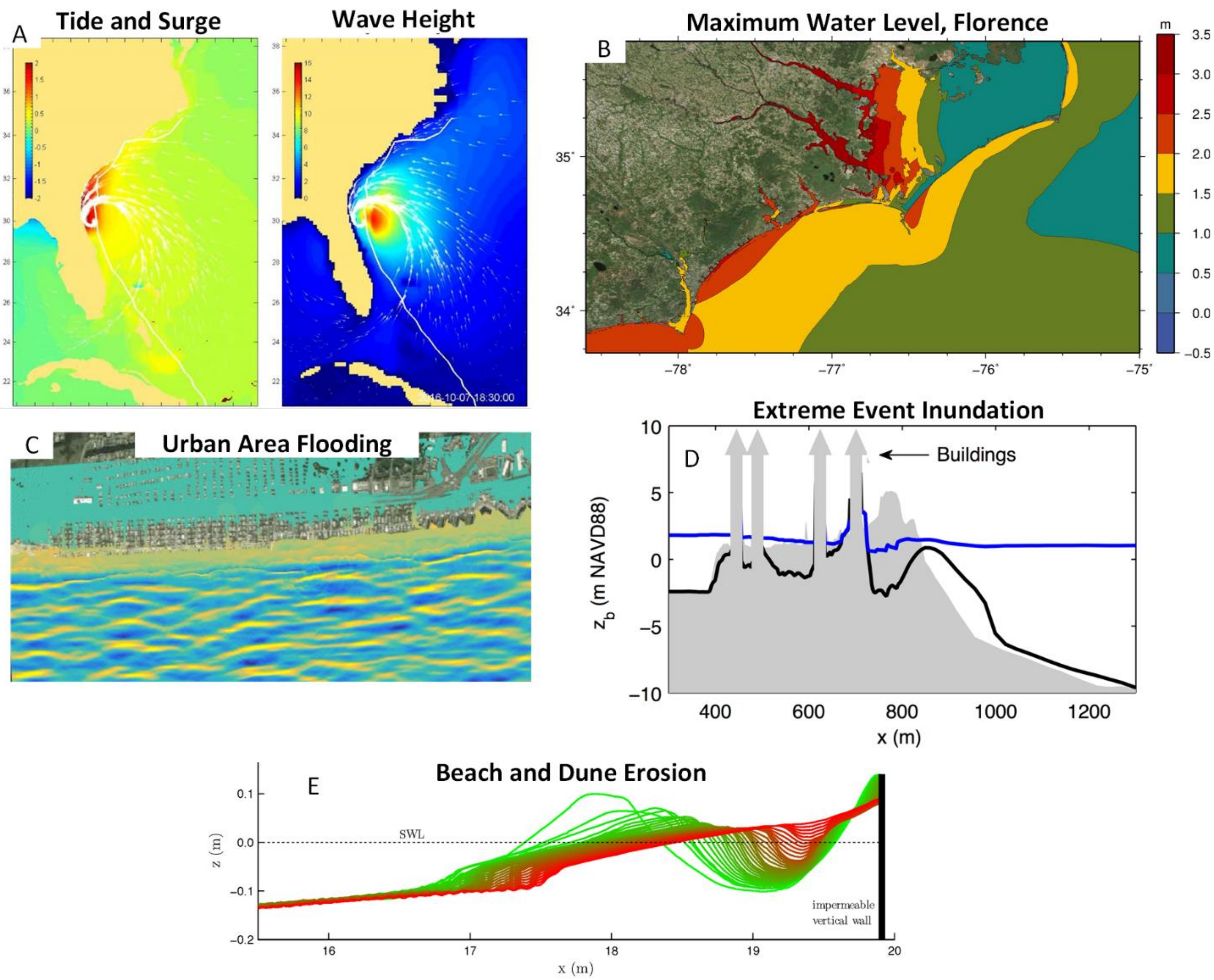

Figure STD1. Example model capabilities. A) Delft3D simulation during Hurricane Matthew showing tide and surge (left) and wave heights with SWAN model (right). B) ADCIRC maximum water levels for North Carolina region during Hurricane Florence. C) FUNWAVE simulation of flooding in an urban area due to an extreme event (alongshore extent is several kms). D) XBeach simulation of extreme event inundation (blue line) and associated erosion (black line as compared to original topography shaded in grey). E) CSHORE simulation of beach and dune erosion during an overwash event.

Figure STD2. Example data product for Naval Station Norfolk for a NTHMP (tsunami study; https://fengyanshi.github.io/NTHMP/_build/html/online_maps_VB.html). Darker blue areas show flooded regions from a landslide-generated tsunami in the Atlantic Ocean.