NTHMP FY16 Grant Project Narrative

Project Name/Title:	**U. S. East Coast: Maritime Assessments and Improvements to Source and Inundation Modeling Procedures**
Project Dates:	September 1, 2016 – August 31, 2018
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Executive Summary

In contrast to the long history of tsunami hazard assessment on the US West coast and Hawaii, tsunami hazard assessment along the US East coast (USEC) is still in its infancy, in part due to the lack of historical tsunami records and the uncertainty regarding the magnitude and return periods of potential large-scale events (e.g., transoceanic tsunamis caused by a large Lisbon 1755 type earthquake in the Azores-Gibraltar convergence zone (a.k.a. Lisbon; LSB), a large earthquake in the Caribbean subduction zone in the Puerto Rico trench (PRT) or near Leeward Islands, or a flank collapse of the Cumbre Vieja Volcano (CVV) in the Canary Islands). Moreover, considerable geologic and some historical evidence (e.g., the 1929 Grand Bank landslide tsunami, and the Currituck slide site off North Carolina and Virginia) suggests that the most significant tsunami hazard in this region may arise from Submarine Mass Failures (SMF) triggered on the continental slope by moderate seismic activity (as low as M_w = 6 to the maximum expected in the region M_w = 7.5); such tsunamigenic landslides can potentially cause concentrated coastal damage affecting specific communities (Grilli et al., 2009, 2015b; ten Brink et al., 2014).

In **FY10-12**, we began the process of hazard analysis and inundation map development for the USEC. Simulating tsunami sources from the PRT, CVV and LSB (Grilli et al., 2010, 2015a; Abadie et al., 2012; Harris et al., 2012, Tehranirad et al., 2015a; Grilli and Grilli, 2013a,b,c), together with a number of relevant near-field SMFs (Grilli et al., 2014), we concentrated on developing tsunami inundation maps (maximum envelope) for a nearly continuous coastal region extending from Ocean City, MD (Tehranirad et al.,

2014) to Cape Cod, MA, excluding major bays or estuaries such as Chesapeake Bay, Delaware Bay, Hudson River, Long Island Sound and Narragansett Bay. Draft reports describing mapping efforts may be found at http://www.udel.edu/kirby/nthmp/nthmp_protect.html (Tehranirad et al, 2014, 2015c-g).

In **FY13**, we extended the range of this mapping effort southward to include the communities of Virginia Beach, VA, Cape Hatteras, NC, Myrtle Beach, SC and Savannah, GA. This work is reported in draft form at http://www.udel.edu/kirby/nthmp/nthmp_protect.html (Tehranirad et al, 2015 h-k).

In **FY14**, we addressed several important issues as part of three tasks:
(i) We performed an investigation of dynamic tidal effects on tsunami behavior in Chesapeake Bay (Norfolk, VA) and the Hudson River estuary and New York Harbor, which are highly populated areas of the USEC with strong tidal forcing. Both of these areas were modeled as part of FY10-12 or FY13 work, but these investigations did not take into account any potential effects of the tidal conditions Based on this work, we assessed whether a combined tide-tsunami scenario could be treated as a simple linear combination of tide and tsunami, or whether there are significant nonlinearities in the superposition that potentially lead to more hazardous conditions than would be expected from linear superposition alone. The conclusion was that tidal effects in Chesapeake Bay, although causing measurable nonlinear effects on the incoming tsunami wave train, did not cause a significant increase in runup and inundation (Tajalli-Bakhsh et al., 2015); in the Hudson River estuary, however, increases in inundation during impact of the PRT, CVV and local SMF sources led to an up to 0.8 m or 25% increase in inundation (Shelby et al., 2015a,b). This will impact modeling for the next generation of inundation maps.
(ii) To perform the current phase of inundation mapping on the USEC, we modeled landslide tsunamis as resulting from 4 Currituck SMF proxies, parameterized as rigid slumps; in FY14, we started the process of refining our set of sources by: (1) extending the suite of candidate continental margin SMF sources to include a broader set of cases from the geological record; ongoing work with the Carbonate Research Group at the University of Miami has led to the development and testing of SMF landslide sources for the West Bahamas Bank (Schnyder et al., 2016). Reanalysis of east coast SMF sources using deformable slide models is underway in FY15 (see below), (2) performing a broader range of simulations for the CVV volcanic cone collapse based on events which are less extreme than the presently utilized 450 km^3 slide volume (Tehranirad et al., 2015a) (this task was completed during FY15), and (3) we examined the tendency of the wide East Coast continental shelf to provide a somewhat source-independent control on the longshore distribution of tsunami wave height, due to refractive and focusing effects. This analysis is based on a comparison of direct modeling results and use of ray-tracing and shows that predicted inundation levels can become potentially insensitive to the exact nature and location of tsunami source events, due to the refractive control by the wide USEC shelf (Tehranirad et al., 2016).
(iii) Work is ongoing to compare existing storm surge inundation maps and tsunami inundation maps for areas that have had high-resolution tsunami inundation modeling. Due to the greater likelihood of hurricane events in the South Atlantic area, it is likely that such an approach will have to take into account regional variations in storm

probability and shelf geometry that we are just developing an understanding of now (Tehranirad et al, 2016). A collaboration with the Gulf of Mexico group was established and we are working on development of a joint methodology.

In **FY15**, we are working on 3 tasks. In Task 1, we are organizing a landslide tsunami model benchmarking and validation workshop in the summer 2016. The expected outcomes will be a set of community accepted model benchmarking tests and a web-based documentation of workshop and related data.
In Task 2, continuing our FY14 effort, we are further refining and extending the set of potential SMF sources along the Atlantic margin, and applying new source modeling techniques for tsunami activity in the North Atlantic; this includes revisiting the modeling of the 4 Currituck SMF proxies (Grilli et al., 2015a,b) by applying deforming slide models such as granular slides (Ma et al., 2015), debris flows (Ma et al., 2013) or slides modeled as a dense Newtonian fluid (Kirby et al., 2015); see example in Fig. 4. As part of an established URI/USGS collaboration, whenever the analysis of field data from recent cruises is finalized, we will start integrating in our work, USGS's latest field information on SMF sources and site, characterize and parameterize new relevant extreme SMF sources in our work. This will improve our ability to site, characterize and parameterize new relevant extreme SMF sources in our geographic area (including the Florida straight; Chaytor et al., 2014). Applying deforming slide models in particular requires specifying realistic rheological and frictional properties, which must be informed by field data. Results of these simulations will be compared to the Currituck SMF proxy approach used so far to develop inundation maps. On this basis, we will extend the number, distribution of size, and parametrization of our SMF sources in order to obtain a more nuanced set of input to hazard mapping results, particularly near the northern and southern edges of our study area. In parallel we will continue examining the role of the modeling approach (i.e., solid slide, debris flow, heavy fluid flow,…) in determining the tsunami hazard associated with each event. As part of this task, we have been collaborating in the initial phase of a multistate project on "Improving tsunami warning for landslide tsunamis" proposed by California. The task also aligns with Task 1, which will lead to new benchmarks for SMF tsunami models.
In Task 3, as there is a vast area of the coastline to cover, we are continuing the FY14 effort of assessing tsunami hazard for unmodeled East Coast sites. We have been collecting additional FEMA flood maps and comparing those to our existing modeling effort. We continued applying the testing method developed during FY14 to objectively compare the FEMA and NTHMP maps and infer information for the unmodeled areas.
The modeling work to date provides a reasonably comprehensive coverage of tsunami impact along the US coast, as indicated in Figure 1. More work is being completed in FY15 to cover indicated areas in Florida.

For **FY16**, we are proposing work organized in 4 technical tasks, with an additional Task 5 which covers travel for CC member Kirby to NTHMP annual meeting, and Kirby and Grilli to MMS summer meeting; additionally this covers travel of Kirby and Grilli to the landslide tsunami workshop they are co-organizing in 2016-17. Tasks 1 and 2 involve dissemination of existing products to stakeholders and the development of new products based mainly on existing model results. Tasks 3 and 4 involve a re-examination of the theoretical and modeled basis for inundation and maritime hazard mapping, using existing models to bring the mapping effort up to the level of current scientific capabilities. Task 5 considers hazard from meteotsunamis, which have been shown to be important for the east coast, and initiates work on the aspects of return periods of the various considered tsunami sources. The 5 technical tasks include:

Task 1: Development of maritime hazard assessment products for USEC.

> Subtask 1: Examine role of wide shelf in determining maritime safety recommendations
>
> Subtask 2: Examine effects of tsunami events used for coastal hazard assessment on conditions in major ports and harbors

Task 2: Presentation of MMS mapping results to East Coast state agencies and coordination with state EMA managers on development of evacuation and warning efforts.

Task 3: Reanalysis of selected mapping products based on improved treatment of modeled physics for source description and tsunami propagation.

> Subtask 1: Continue simulating submarine mass failure (SMF) events using a range of recently developed models for landslide tsunami generation, including rigid to deformable slides with a range of modeled rheologies. Siting and parameterization of selected SMFs based on the most recent field data, in collaboration with USGS.
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> Subtask 2: Reanalysis of frictional dissipation effects and impact on shoreline tsunami amplitudes in areas with wide continental shelves.

Task 4: Simulation and evaluation of meteo-tsunami hazard and estimation of return periods of tsunami events from various sources.

> Subtask 1: Simulation of propagation and coastal impact of meteotsunamis generated on the wide EC shelf, for events of 100-200 year return period.
>
> Subtask 2: Estimate of return periods of extreme tsunamis from various sources used in inundation mapping with emphasis on landslide tsunamis

Similar to our earlier work during FY10-FY15, tsunami modeling in this project will be carried out using a set of models developed at the University of Delaware, including:

(1) FUNWAVE-TVD, a Boussinesq model in Cartesian or spherical coordinates, described in Shi et al., (2012a) and Kirby et al. (2013). FUNWAVE-TVD is used for tsunami propagation and inundation simulations (with the possibility of initialization by a co-seismic source). The model has been benchmarked for NTHMP inundation and current modeling, and has recently been extended to

include a sediment transport capability in order to analyze morphology adjustments during tsunami events (Tehranirad et al, 2015b). The pressure forcing mechanism required for meteo-tsunami simulations in Task 5.1 has also already been implemented in the model.

(2) NHWAVE, a three-dimensional, sigma-coordinate RANS model for modeling fully non-hydrostatic free surface flows (Ma et al, 2012). NHWAVE is used to model dispersive wave response to SMF ground motions. Three models of SMF motion have been implemented to date: bottom motion described by motion of a solid mass (Ma et al, 2012), response to gravity currents modeled as suspended sediment load (Ma et al, 2013), and non-hydrostatic water column response to the motion of a depth-integrated, deformable slide layer on the bottom. The latter case has been applied using rheologies corresponding to heavy viscous flows (Kirby et al, 2016) or granular debris flows (Ma et al, 2015).

FUNWAVE and the basic version of NHWAVE are open source, publically available models, which have been benchmarked according to NTHMP standards (Tehranirad et al, 2011, 2012; Shi et al, 2012b) for use in NTHMP-sponsored work. Both codes are efficiently parallelized using MPI and use a one-way coupling methodology, allowing for large scale computations of tsunami propagation and coastal impact to be performed in a series of nested grids of increasingly finer resolution. Both models deal with breaking dissipation via a TVD algorithm and also implement bottom friction. As in previous work, we will use NHWAVE to compute the initial tsunami waves generated from SMF sources including rigid translational slides or rotational slumps, but also debris and granular flows; and once the tsunamigenic part of the SMF is complete, we will continue simulating tsunami propagation in FUNWAVE. While so far in our work we have mostly considered rigid SMFs (Grilli et al., 2015a,b), which are believed to yield worst case scenario SMF tsunamis, during FY15 we have started modeling deformable SMFs using the most recent versions of NHWAVE (Ma et al., 2013, 2015; Kirby et al., 2016). We are starting to assemble a set of model results based on deforming slide calculations, but this work will need to be continued during FY16 (Task 3.1), and we will be coordinating the siting and parametrization of the selected SMFs with USGS. These newer models will be benchmarked for NTHMP use, as part of the SMF model validation workshop (in the fall 2016 or winter 2017).

It should be pointed out that no new model development, particularly for SMF tsunamis, will be done in FY16 using NTHMP funding, and the pressure boundary condition for generating meteo-tsunamis in FUNWAVE is merely a small adaptation of existing options in the code. Regarding SMF tsunamis, the PIs have been awarded a NSF project by the Engineering for Natural Hazard program (2015-2018) to "develop the next generation of landslide tsunami simulation models". The five technical tasks indicated here are thus primarily intended to support the MMS outcome "Tsunami hazard assessment that supports informed decision making in tsunami-threatened communities." Task 1 and 4.2 addresses the MMS strategy to "Develop new tsunami hazard products to assist the maritime community and meet emergency management and other NTHMP customer requirements". Task 2 is to support basic dissemination of project results to individual state stakeholders. Tasks 3 and 4.1 address the specific MMS strategy to "Update previously developed inundation maps as necessary based on new tsunami source information, improved digital-elevation models, and/or improved modeling technology ".

Background

Provide Background information including history of NTHMP partnership, experience with tsunamis, and past achievements with NTHMP funding (5,000 characters or less):

The proposing team of Kirby and Shi (UD), and S. Grilli and A. Grilli (URI) has been conducting NTHMP-funded work since FY10. Work to date has been entirely on topics related to MMS strategies and outcomes. Specifically, we have modeled inundation resulting from potential coseismic, submarine mass failure (SMF) and volcanic cone failure events, in support of the goal of developing tsunami inundation maps for coastal communities. FY10-12 project work centered on development of an initial set of tsunami sources and high resolution mapping of DEMs stretching from Ocean City, MD to Cape Cod, MA. FY13 work was aimed at additional modeling of regions further to the south, including Virginia Beach VA, Savannah, GA, and Myrtle Beach, SC using existing sources, and Miami FL and vicinity using a SMF source based on the West Bahama Banks (Mulder et al., 2012). This last study leverages a collaboration with U. Miami, who have performed the initial analysis and modeling of the source. Work in FY14 and FY15 involved a continuation of the mapping effort, with the development of extreme SMF proxy sources off the upper USEC. New work was also conducted to (i) estimate tsunami inundation risk and magnitude in the not-yet-mapped areas, based on FEMA maps developed for storm surge and an analysis of the effect of the continental shelf in determining tsunami wave height distribution, and (ii) study and model tsunami-tide interactions in estuaries and harbors with strong tidally-induced flow (e.g., Chesapeake Bay, Hudson River, New York Harbor), and evaluate how this affects tsunami inundation. Project work on sources has been documented in a series of reports and peer-reviewed papers, which are available at http://www.udel.edu/kirby/nthmp.html. Inundation reports and map products are in draft stage and will be distributed to stakeholders for evaluation shortly. These reports provide guidance on accessing modeling results, stored as raster based data sets in ArcGIS format. Tabulated results include inundation limits, inundation depths, maximum velocities and maximum momentum fluxes for initially dry areas, and maximum elevation, velocity and vorticity for initially submerged areas.

The PIs have extensive experience in tsunami model development and application to ocean scale propagation, SMF generation mechanisms, and inundation modeling. Kirby and Grilli developed the first fully-nonlinear Boussinesq model, and this theory served as the basis for the first open source, publically available version of such a model, FUNWAVE (Wei et al., 1995). FUNWAVE has recently been extensively revised in order to improve its accuracy in performing simulations of tsunami runup and inundation (Shi et al., 2012a), and it has been extended to include a spherical coordinate system, with Coriolis effects, for use at ocean scale (Kirby et al., 2013). The model has been fully documented and benchmarked (Shi et al., 2011; Tehranirad et al., 2011) according to NTHMP standards (Synolakis et al, 2007; Horrillo et al., 2014). The PIs have also been instrumentally involved in the development of methods for performing simulations of either solid or deforming submarine mass failures (SMF) using Navier-Stokes solvers, with either high resolution VOF modeling (Abadie et al., 2010, 2012), or a more efficient, lower resolution surface and terrain following model (Ma et al., 2012, 2013). This latter model, NHWAVE, has been used for SMF simulations in NTHMP work during FY10-15 (Grilli et al., 2015a,b) (see example in Fig. 4), and has been benchmarked for NTHMP use (Tehranirad et al., 2012) using a solid slide. The model has recently been extended to include granular slide modeling (Ma et al, 2015) and has been tested against multiple data sets for subaerial slide configurations. The PIs have made a number of significant contributions to the understanding of wave generation by SMFs, and the group has carried out highly accurate simulations of near and far-field response to seismic tsunami events including the 2004 Indian Ocean event (Grilli et al, 2007; Ioualalen et al, 2007) and the 2011 Tohoku event (Grilli et al, 2013; Kirby et al, 2013; Tappin et al, 2014). In an effort parallel to NTHMP, but with support from UNESCO, the group has also performed a first comprehensive assessment of tsunami hazard along the North Sore of Hispaniola (Grilli et al., 2016a).

In this box, provide the title of each task.

The tasks listed should reflect priorities for sustainment of current activity and participation in NTHMP supported projects and should be consistent with the NTHMP Strategic Plan.

Explain carefully how this new grant will not overlap or duplicate any work under current NOAA grants which, with no-cost extensions, could overlap in time periods for execution.

Task 1: Development of maritime hazard assessment for U. S. East Coast.

Subtask 1: Examine role of wide shelf in determining maritime safety recommendations

Subtask 2: Examine effects of tsunami events used for coastal hazard assessment on conditions in major ports and harbors

Task 2: Presentation of MMS mapping results to East Coast state agencies and coordination with state EMA managers on development of evacuation and warning efforts.

Task 3: Reanalysis of selected mapping products based on improved treatment of modeled physics for source description and tsunami propagation.

Subtask 1: Landslide events using a range of recently developed models for landslide/tsunami employing deformable slides with a range of modeled rheologies.

Subtask 2: Reanalysis of frictional dissipation effects and impact on shoreline tsunami amplitudes in areas with wide continental shelves.

Task 4: Simulation and evaluation of meteotsunami hazard and estimation of return periods of tsunami events from various sources.

Subtask 1: Simulation of propagation and coastal impact of meteotsunamis generated on the wide EC shelf, for events of 100-200 year return period.

Subtask 2: Estimate of return periods of extreme tsunamis from various sources used in inundation mapping with emphasis on landslide tsunamis

Task 5: Travel expenses for CC member and project personnel to NTHMP meetings

Tasks 1-4 represent new efforts or new reanalysis of existing model results which have not been carried out in previously proposed work. There is no overlap with existing FY15 work.

Task Project Narratives

Describe task(s)

Using the table below include a brief description of the tasks that support NTHMP Strategic Outcomes and Strategies

Task 1. Development of maritime hazard assessment for U.S. East Coast.

Brief task description:

Funded tasks for the east coast team have not included a maritime hazard assessment up to date. However, the model results needed for such an analysis have been collected throughout the ongoing mapping effort and are available now for the relevant analysis. We propose to take on this task in FY16, following NTHMP Guidance documents and building on the experience of other NTHMP partners such as California and Oregon. We will utilize input from the State of California on templates for maritime playbooks, and will use their expertise to help evaluate draft maritime playbooks and other documents.
We will consult with various organizations such as the Coast Guard and various organizations operating port facilities, such as the Delaware River Authority and similar regional organizations alongthe east coast, in order to determine existing emergency plans and perceived needs.

This task will be pursued with two focus areas in mind.

Subtask 1: Examine role of wide shelf in determining maritime safety recommendations

West coast partners have developed guidance for ships and smaller craft at sea that involve getting to a depth greater than some minimum value during a warning period. This approach is facilitated by the fact that the West coast continental shelf is typically narrow, and such depth are relatively easy to reach in a reasonable amount of time. The situation on the east coast and gulf coast is very different: the continental shelf is wide and, in some cases, water depths corresponding to those being adopted in the present guidelines may not even occur until the shelf break is reached. Further, given the typical situation where waves are relatively large at the shelf break and then decay in amplitude due to frictional effects across the shelf (Tehranirad et al, 2015a), the possibility exists that continuing to move towards a greater desired depth could put a craft at greater risk. The problem associated with shelf width is illustrated in Figures 2 and 3, based on model data generated as part of the modeling for the Ocean City, MD NGDC DEM (Tehranirad et al, 2014). Figure 2 shows a plot of maximum occurring currents vs water depth. This plot is quite consistent with Figure 10 in the draft NTHMP Maritime Guidance document, indicating a similarity relation in the velocity results. On the other hand, Figure 3 shows a plot of the same data vs an estimate of offshore distance for each point, indicating a very slow drop off in velocity with distance offshore.

With these questions in mind, we will examine the choice of appropriate guidance based on an east coast (and possibly gulf coast) focus. We will examine not only the issue of maximum velocity and flow complexity vs depth, but also the same quantities vs distance from shore, to determine what is actually doable within an appropriate warning time frame.

Subtask 2: Examine effects of tsunami events used for coastal hazard assessment on conditions in major ports and harbors.

Existing model results are available to assess quantities like maximum current speeds and presence of eddies in harbors and navigable waterways, as utilized in development of hazard maps for various west coast harbors. We will perform similar hazard assessment for several east coast facilities, following the guidelines and graphical standards developed in prior west coast cases. Facilities will include large harbors such as New York, NY and Norfolk, VA, which have been the subject of detailed first generation inundation mapping and which have also been the subject of NTHMP studies of tsunami-tide interaction in FY14. We will also choose one or two smaller harbors, which will be identified after a screening of sites to choose examples which show more risk for large tsunami events.

List all NTHMP Strategic Plan Outcome and Strategies that this task addresses.

(MMS) Develop new tsunami hazard products to assist the maritime community and meet Emergency Management and other NTHMP customer requirements.

(MMS) Outcome: Tsunami Hazard Assessment that Supports Informed Decision Making in Tsunami-Threatened Communities.

Date of expected completion	Describe what will be achieved (bullet/short form)
August 31, 2018	• East-coast-specific recommendations for steps to be taken for maritime safety in the event of a warning • Hazard maps for current conditions in selected east coast ports and harbors
	Task 1 Total Cost: $47,978

Task 2. Presentation of MMS mapping results to East Coast state agencies and coordination with state EMA managers on development of evacuation and warning efforts.

Brief task description:

We will first establish a means for transferring GIS databases for map products to individual state agencies, using a dedicated internet data server. (This is in addition to presentation of map products and reports on project web page and NTHMP web page.)

We will meet with individual state agencies to describe the mapping process and map results. Funding is requested for up to three trips to support this effort. This activity is needed since the modeling and initial development of inundation maps is being done for the entire coast, without the involvement of individual state agencies. We anticipate that individual state agencies may request specific modifications to map products and results, or may want to take the map information into their own mapping systems as a preliminary step towards development of evacuation maps.	
List all NTHMP Strategic Plan Outcome and Strategies that this task addresses. (MMS) Outcome: Tsunami Hazard Assessment that Supports Informed Decision Making in Tsunami-Threatened Communities.	
Date of expected completion August 31, 2017	Describe what will be achieved (bullet/short form) • Transfer of GIS databases for map products to individual state agencies. • Meet with individual state agencies to describe the mapping process and map results.
	Task 2 Total Cost: $23,845

Task 3: Reanalysis of selected mapping products based on improved treatment of modeled physics for source description and tsunami propagation.

Brief task description:

> Subtask 1: Continue simulating submarine mass failure (SMF) events using a range of recently developed models for landslide tsunami generation, including rigid to deformable slides with a range of modeled rheologies. Siting and parameterization of selected SMFs based on the most recent field data, in collaboration with USGS.
>
> Building on our FY14/FY15 effort, we will apply the newer deforming slide models, such as granular slides (Ma et al., 2015), debris flows (Ma et al., 2013), or slides modeled as a dense Newtonian fluid (Kirby et al., 2015), to the simulation of tsunami generation from both our earlier SMF proxy sources (used along the Atlantic margin for developing the first generation of inundation maps on the USEC) and new SMFs identified by USGS; in collaboration with the latter agency, we will use their field data to site and parameterize the selected SMFs. URI has an established collaboration with USGS to help in the analysis of geotechnical data from their regular cruises aimed at studying historical SMFs off

of the USEC. Such data will improve our ability to site, characterize and parameterize new relevant extreme SMF sources in our geographic area, including extending the current selection of sources further south, to the Florida straight (Chaytor et al., 2014). In particular, field data will be used to select parameters for the newer deforming slide tsunami generation models, that have a variety of rheologies and frictional properties to choose from; results of these simulations will be compared to the Currituck SMF proxy approach used so far to develop inundation maps.

For instance, Figure 4 shows results of NHWAVE simulations of landslide tsunamis generated off of the Hudson River canyon by a rigid slump modeled as a Currituck SMF proxy, as in Grilli et al. (2015a), compared to simulations for a deforming slide modeled as a dense fluid layer (Kirby et al.'s (2016) modeling approach), with same initial geometry, location, volume, and runout at the time the slump stops moving, as the Currituck SMF proxy (about 12 min). While tsunami wave patterns generated by each SMF are similar, in the deforming slide case, waves have lower elevations, particularly, onshore propagating waves which will cause coastal impact. Additionally, waves generated by the deforming SMF are more asymmetric in the direction perpendicular to that of SMF failure that those of the rigid slump, because the deforming slide material can more closely follow the terrain which, in the present case, leads the slide to "flow" in the southwest direction. This asymmetry will also affect coastal tsunami hazard.

In the continuation of such FY15 work, this Task will be performed towards the goal of extending the number, distribution of size, and parametrization (based on site-specific field data) of our SMF sources, in order to obtain a more realistic set of input to hazard mapping results, particularly near the northern and southern edges of our study area. As part of this task, we have been collaborating in the initial phase of a multistate project on "Improving tsunami warning for landslide tsunamis" proposed by California.

Subtask 2: Reanalysis of frictional dissipation effects and impact on shoreline tsunami amplitudes in areas with wide continental shelves.

Once a tsunami source is initialized in the long wave propagation model used in this work, FUNWAVE-TVD, besides bathymetry and the model grids, the only parameter left to select that affects tsunami propagation and surface elevations, particularly in shallow water, is the bottom friction coefficient. Up to now in this inundation mapping work, we used the recommended value of bottom friction coefficient for coarse sand, C_f = 0.0025, in our quadratic bottom friction law, assuming, this should be conservative as far as tsunami propagation and inundation. While friction does not have a significant effect on tsunami propagation in deep water, owing to the very small tsunami-induced velocities (a few cm/s), earlier work has indicated a significant sensitivity of tsunami elevations to bottom friction in shallow water, particularly when there is a wide shelf (e.g., Geist et al., 2009 for SMF tsunamis). This was confirmed in a more detailed analysis of tsunami propagation over the Florida Shelf (which has a simple bathymetry, with bottom contours parallel to a fairly straight shore; hence little refraction), we performed for the Cumbre Vieja Volcano (CVV) subaerial slide source (Teharanirad et al., 2015a). We found that maximum surface elevations were significantly damped from the shelf break to shore (for CVV, from 8-10 m down to 2-3 m) and, comparing to an analytical formula, that this was essentially a result of bottom friction dissipation. Hence, it appears that in such cases, where there is a wide shelf and moderate refraction, for a specific incident tsunami, the level of coastal hazard estimated in model simulations (i.e., inundation and runup) is controlled by the selected bottom friction coefficient value. In this task, we will perform an in-depth reanalysis of frictional dissipation effects and impact on shoreline tsunami amplitudes in areas with wide continental shelves. In particular, we will estimate more realistic site specific values for the bottom friction (or Manning) coefficient, in areas with a wide shelf. To do so, we will use results of tide propagation models as a proxy for tsunami propagation. Such models typically use space-varying bottom friction coefficients obtained from both the nature of the local seafloor and a calibration of model results with actual observations at tide gauges. We will also seek guidance from both theoretical and experimental work, regarding boundary layers of tidal flows. Based on results of this task, we will issue recommendations as of a more relevant approach for selecting bottom friction coefficient values for the next generation of tsunami inundation maps along the USEC.

It should be pointed out that a similar approach was already pursued in the dynamic tsunami-tide interaction simulations performed during FY14/FY15 in Chesapeake Bay and in the Hudson Canyon (Tajalli-Bakhsh et al., 2005; Shelby et al., 2015a,b). Here, we first modeled the tide propagation in each estuary with FUNWAVE-TVD and calibrated the bottom friction values to obtain a good agreement with measurements made at may tide gauges in the estuaries. We then used the same values of bottom friction coefficients for both the tsunami alone and tsunami-tide interaction simulations in the estuaries.

List all NTHMP Strategic Plan Outcome and Strategies that this task addresses.
(MMS) Update previously developed inundation maps as necessary based on new tsunami source information, improved digital-elevation models, and/or improved modeling technology.

(MMS) **Outcome**: Tsunami Hazard Assessment that Supports Informed Decision Making in Tsunami-Threatened Communities.

Date of expected completion	Describe what will be achieved (bullet/short form)

August 31, 2018	• New siting/parameterization based on recent field data and simulations of submarine mass failure (SMF) events, using new tsunami generation models with a range of SMF rheologies. • Assessment of frictional dissipation effects and impact on shoreline tsunami amplitudes in areas with wide continental shelves.
	Task 3 Total Cost: $93,304

Task 4: Simulation and evaluation of meteo-tsunami hazard and estimation of return periods of tsunami events from various sources.

Subtask 1: Simulation of propagation and coastal impact of meteo-tsunamis generated on the wide EC shelf, for events of 100-200 year return period.

One type of tsunami that has not yet been considered in our tsunami hazard study and can be significant along the US East Coast, which is bordered by wide shallow shelves, is the meteotsunami (e.g., Thomson et al., 2009), which can be created by a derecho (i.e., a fast-moving band of severe thunderstorms) whose translation speed can be near the long wave velocity on the shelf. In this case, energy can be easily transferred from the pressure-induced surface deformation caused by the storm to the tsunami, causing it to grow. On June 13, 2013, the Northeast was struck by a significant meteotsunami which was apparently generated by a radidly moving storm which tacked across New Jersey and moved directly offshore (Wertman et al., 2014). The resulting meteotsunami waves induced resonances in a number of harbors along the East Coast, causing some damage. The event's effects were felt as far away as Puerto Rico (ten Brink et al., 2014). Long waves were measured at 30 tide gauges along the coast from North Carolina to Massachusetts, with the largest elevations, 1.8 m, being measured in New Jersey and about 0.3 m measured in Newport, RI. Recent modeling work by Geist et al. (AGU, 2014; manuscript 2015) reveals that the storm created offshore-moving long tsunami-like waves. Upon reaching the shelf break, some of these waves refracted to eventually propagate onshore in both NW and SW directions, while part of the waves continued in the SE-S direction towards Puerto Rico. Geist et al. indicated that, when considering 100-200 year return periods for such an events, one could expect up to 2 m tsunami elevations at the coast, which are of a size similar to those caused by the other far- and near-field Atlantic sources considered so far in our work.

Hence, in this task, we propose to initiate the modeling of the generation, propagation, and coastal impact of extreme meteotsunamis (similar to or even slightly stronger than the 2013 event). Our particular interest will be to examine the interaction between storm size, forward speed and track and the resulting potential for meteotsunami wave generation. Further, we will assess the spatial distribution and variability of coastal impacts for conditions leading to large meteotsunami. The tsunami generation phase will

be modeled using FUNWAVE, which already has the capability for specifying a moving pressure distribution on the surface as an extension of the free surface dynamic boundary condition (see Figure 5 for an idealized example). Meteotsunami events will be generated in the same grids now used for coastal ocean simulations (i.e., the largest scale UTM Cartesian grids) as described in previous inundation reports (see Tehranirad et al, 2014, for example) We will initially generate events by specifying a moving, elongated low-pressure patch as an idealization of a severe storm or thunderstorm. Further nesting to evaluate nearshore wave properties, shoreline inundation and maritime hazard would be carried out using FUNWAVE in a series of nested grids of increasingly fine resolution towards shore, by a one-way coupling methodology, as is our standard procedure for previous and ongoing modeling.
We note that the Alaska Tsunami Warning Center recently reached out to our group, asking whether we could simulate a few typical meteotsunamis off of the upper US East Coast in order to help with their effort of assessing their possible detection using existing CODAR high-frequency (HF) radars. An a posterior analysis of data acquired by such radars had in fact shown the signature of the June 2013 meteotsunami (Lipa et al., 2014). Our group has recently worked on the development of algorithms for tsunami detection for shore-based HF radars (Grilli et al., 2015c, 2016b), and have used the models to be employed in this study as standard means for testing these algorithms. We will thus be able to address the warning center's request as part of this task.

Subtask 2: Estimate of return periods of extreme tsunamis from various sources used in inundation mapping with emphasis on landslide tsunamis.

As in all other NTHMP states, our first-generation tsunami inundation maps are envelopes of maximum inundation caused by a series of extreme far- and near-field tsunami sources in the Atlantic Ocean Basin, without considering their return period (or probability). While some of our sources may have a return period on a scale of a few hundred years to 1,000 years (i.e., the M9 seismic sources in Puerto Rico trench and Acores convergence zone; Grilli et al., 2010, 2015a), the return period of the large Currituck SMF proxy used as near-field tsunami sources (Grilli et al., 2015b) is unknown and perhaps on a scale of hundreds to a few thousand to tens of thousand years, and that of an extreme collapse of the Cumbre Vieja Volcano (CVV) in the Canary Island could be anywhere from 100,000+ years (Abadie et al., 2012) to as little as 1000 years (based on recent field work; Day, personal communication, 10/2015). As to the likelihood of a massive "en masse" CVV collapse causing a mega-tsunami, rather than a gradual multi-stage failure causing more modest tsunamis, a recent study of the Fogo volcano on Cape Verde island by Ramalho et al. (2015) showed that a flank collapse may have catastrophically happened 73ka ago, with at least one fast voluminous event that triggered tsunamis of enormous height and energy, causing over 270-m runup on the nearby Santiago island.

While tsunami inundation maps that are envelopes of extreme sources are useful in indicating the maximum flood hazard that can be expected along the US East Coast from any tsunami at a given site, these do not really put the risk of this happening in perspective with other more probable flood risks, such as from hurricanes with 100 or

500 year periods.. This concern was expressed by East Coast CC member Ed Frato, who indicated that emergency managers may only be sensitized to the reality of tsunami risk along the East Coast if they are presented with flood maps reflecting return periods commensurate with those of other hazard such as hurricanes, hence on the order a few hundred years, but not thousands. This differs, for instance, from the typical hazard assessment for critical coastal facilities such as nuclear power plants, for which tsunamis with return periods of 10,000 years are typically considered in flood hazard analyses. Hence, to address this request, we propose in this subtask to initiate work for estimating return periods of extreme tsunamis from various sources used in inundation mapping, which will pave the way for conducting future Probabilistic Tsunami Hazard Analysis (PTHA). In this initial work, we propose to only study the return periods of landslide tsunamis, in part because our earlier work indicates that they pose the highest tsunami flooding hazard for a large part of the US East Coast (e.g., Grilli et al., 2015a) and also because more geological work may be needed to consider the return period of other types of sources. Indeed, it appears from discussions at the recent USGS workshop in Boulder that more geophysical/seismological and field work/data is required for estimating the return period of the two large seismic events considered in our work (i.e., M9 earthquakes in Puerto Rico and in the Azores). In contrast, in the past few years, USGS has been conducting extensive field work and surveyed past SMFs on the Atlantic margin (e.g., ten Brink, 2014); the large data base of geological/geophysical data that resulted from this work can serve as a basis for estimating SMF tsunami return periods. Accordingly, the proposed study of SMFs for FY16 will be based on revisiting and improving the earlier Monte Carlo analysis of Grilli et al. (2009, see details below), in light of the recent field data made available by USGS, as well as using our recent SMF tsunami generation models (see Task 3.1). The return periods of other types of tsunami soures will be studied in following years.

While some states (e.g., California) have initiated work on PTHA, this is not yet the norm for NTHMP as both the modeling effort required and the necessary geophysical data are much more significant. Indeed, a proper PTHA first requires information on return periods of tsunami sources. For seismic sources, for instance, this involves estimating the relationship between earthquake magnitude/slip distribution and probability of occurrence, which requires in-depth marine geology/geophysics and paleo-tsunami deposit analyses; note that such deposits are mostly lacking along the East Coast due to the effects of glaciers for older deposits and the confusion with hurricane deposits for more recent deposits. For SMF sources, this requires even more data on slide/slump size, distribution, age and mode of failure (including rheology), together with an estimate of their tsunamigenic potential. To estimate the 100 and 500 year runup expected from SMF sources along the US East Coast, for instance, Grilli et al. (2009) developed a probabilistic SMF tsunami analysis based on Monte-Carlo slope stability analyses (for randomized seismicity and SMF geometrical and geological parameters) coupled to simplified equations to estimate tsunami generation, propagation and coastal impact. This earlier work, which identified an elevated tsunami flooding risk from SMFs north of the Carolinas, however, was based on fairly sparse field data and used empirical equations for tsunami generation by rigid slides or slumps; tsunami propagation was then simply performed using Green's law, without refraction effects, with an empirical spreading of the coastal impact following a Gaussian curve. Here, we propose to estimate the probability/return period of tsunami inundation caused by SMFs along the East Coast by performing an improved Monte Carlo (MC) analysis informed by the much broader and detailed field data sets acquired by USGS since our earlier work was performed (from 2005 to 2008) and using the more accurate physics based models for SMF tsunami generation that are now available for both rigid and deforming underwater slides and slumps (see Task 3.1). One caveat, however, is that a MC analysis may require simulating 100,000 or more random SMFs failures and resulting tsunami generation/propagation, in order to properly estimate the probability distribution of the induced coastal inundation. Hence, as in Grilli et al. (2009) we will have to simplify some of the modeling in order to make this work computationally viable, which will likely require the development of new methods for rapidly estimating SMF tsunami sources based on SMF parameters. As done for rigid 2D slides and slumps by Grilli and Watts (2005) and Watts et al. (2005), this will require performing a series of canonical simulations for many combinations of relevant parameters and developing methods for interpolating between the corresponding tsunami sources for other combinations of parameters.

Finally, while we will use a MC analysis approach similar to that of Grilli et al. (2009), we will update it in light of recent NTHMP work performed in the Gulf of Mexico (Pampell-Manis et al, 2016). Indeed, in applying Grilli et al.'s (2009) methodology, the GOM group noted that there were significant statistical correlations between SMF geometrical parameters which were previously assumed to be independent. These correlations need to be accounted for in order to truly have statistically independent realizations in the MC analysis. This led the GOM group to modify Grilli et al.'s (2009) methodology using a Cholesky matrix decomposition method, and we will be using this more recent formalism in the proposed work for this task.

List all NTHMP Strategic Plan Outcome and Strategies that this task addresses.

Task 4.1 addresses the MMS strategy to "Develop new tsunami hazard products to assist the maritime community and meet emergency management and other NTHMP customer requirements".

Task 4.2 addresses the specific MMS strategy to "Update previously developed inundation maps as necessary based on new tsunami source information, improved digital-elevation models, and/or improved modeling technology ".

Date of expected completion	Describe what will be achieved (bullet/short form)
August 31, 2018	Parameters promoting meteotsunami response on US East Coast shelf will be determined.

	Probabilistic analysis of east coast SMF events and resulting tsunamis will be revised based on updated information on shelf sediments and geotechnical properties in order to estimate the return period of these events.
	Task 4 Total Cost: $56,116

Task 5: Travel to NTHMP meetings

At the request of the NOAA Tsunami Program Office, UD is proposing travel for its members of the NTHMP Coordinating Committee to attend and participate in NTHMP-sponsored meetings planned to occur during the grant performance period. Support is requested for CC member Kirby (UD) to attend NTHMP Annual Meeting, MMS technical meeting, and Landslide Workshop (Travel Category 1).

Support is requested for Grilli (URI) to attend the MMS technical Meeting and the Landslide Workshop (Travel Category 4- Non CC member to NTHMP meetings)

1. Landslide technical workshop

    This two-day workshop will focus on developing a set of community-accepted benchmark tests for validating models for landslide tsunami generation.

    The meeting location has not been determined by the NTHMP. Average rates and cost estimates provided by the NOAA Tsunami Program were used.

    The Science representative (Kirby) appointed to represent the U.S. East Coast will attend and participate in this workshop, along with co-PI and co-organizer Grilli (URI).

2. NTHMP Annual Meeting

    This is a five-day series of meetings for NTHMP subcommittees, cross-functional collaboration meetings, a two-day Annual Meeting, a NTHMP grantee's meeting, and a Coordinating Committee meeting.

    The meeting location has not been determined by the NTHMP. Average rates and cost estimates provided by the NOAA Tsunami Program were used.

    The Science representative (Kirby) appointed to represent the US East Coast will attend and participate in this meeting.

3. Mapping & Modeling Subcommittee Scientific Exchange Meeting

    This three-day meeting is a regular meeting to exchange tsunami science

information, mapping, and modeling details which enhances collaboration and consistency among NTHMP partners. The meeting location has not been determined by the NTHMP. Average rates and cost estimates provided by the NOAA Tsunami Program were used. The Science representative (Kirby) appointed to represent US East Coast will attend and participate in this meeting. MMS member Grilli will attend and participate in this meeting where it is expected that much time will be devoted to follow up work related to the landslide tsunami workshop Kirby and Grilli will be co-organizing.	
List all NTHMP Strategic Plan Outcome and Strategies that this task addresses. **Outcome**: Successful Execution of NTHMP Tsunami Mapping, Modeling, Mitigation, Planning and Education Efforts	
Date of expected completion August 31, 2017	Describe what will be achieved (bullet/short form) Kirby (CC) and Grilli attend NTHMP meetings
	Task 5 Total Cost: $15,415

COLLABORATION AND SYNERGIES

1. Collaboration is defined as two or more grantees working on the same project in their respective states and/or territories. Collaboration does not include merely sharing resources or information with each other. This section of the Project Narrative is about jointly-funded NTHMP grant activities shared among one or more NTHMP grant partners.

   If there are no jointly-funded shared tasks with another NTHMP Grantee, then check this box and leave the rest of this page blank:

   _X__ No jointly-funded tasks with any other NTHMP Grantee.

2. List any tasks above that will be directly worked on collaboratively with any other NTHMP grantee. State the Task and task number from your grant as well as the name of the other NTHMP grantee and its specific Task and task number for this same activity. For this activity to count as being collaborative, your Task/Task must

also appear on your collaborative partner's FY15 NTHMP Grant Narrative in this same space.

This grant Task #	Grant partner name & Task #	Short description of collaborative task

3. Describe with whom and how you will work collaboratively on the task(s) listed in the table above.

Summary of Tasks

Task	Expected Completion month/year	Requested funding
1. Development of maritime hazard assessment for U. S. East Coast	**8/31/2018**	**$47,978**
2. Presentation of MMS mapping results to East Coast state agencies and coordination with state EMA managers on development of evacuation and warning efforts.	**8/31/2017**	**$23,845**
3. Reanalysis of selected mapping products based on improved treatment of modeled physics for source description and tsunami propagation	**8/31/2018**	**$93,304**
4. Simulation and evaluation of meteo-tsunami hazard and estimation of return periods of tsunami events from various sources (landslide tsunamis only).	**8/31/2018**	**$56,116**
5. Travel to NTHMP meetings	**8/31/2017**	**$15,415**
Total FY16 Grant Request	**------------------**	**$236,658**

Attach the following to this application:

1. Resume or C.V. for each person serving in a grant-funded role.

2. All required documentation listed in the checklist on the last page of the Budget Narrative.

REFERENCES

Abadie, S., Morichon, D., Grilli, S.T. and Glockner, S. 2010. Numerical simulation of waves generated by landslides using a multiple-fluid Navier-Stokes model. *Coastal Engng.*, **57**, 779-794, doi:10.1016/j.coastaleng.2010.03.003.

Abadie, S., J.C. Harris, S.T. Grilli and R. Fabre 2012. Numerical modeling of tsunami waves generated by the flank collapse of the Cumbre Vieja Volcano (La Palma, Canary Islands) : tsunami source and near field effects. *J. Geophys. Res.*, **117**, C05030, doi:10.1029/2011JC007646.

Chaytor, J. et al. 2014. Preliminary source characterization and tsunami modeling of submarine landslides along the Yucatan Shelf/Campeche Escarpment, southern Gulf of Mexico. *EOS Trans. AGU*, **95** (52), Fall Meet. Suppl., Abstract OS33B-1063.

Day, S. J., P. Watts, S.T. Grilli and Kirby, J.T. 2005. Mechanical models of the 1975 Kalapana, Hawaii earthquake and tsunami. *Marine Geology*, **215**(1-2), 59-92.

Enet, F. and Grilli, S.T. 2007. Experimental study of tsunami generation by three-dimensional rigid underwater landslides. *J. Waterway Port Coastal and Ocean Engineering*, **133**(6), 442-454.

Fine I., Rabinovich A., Bornhold B., Thomson R. and Kulikov E., 2005. The Grand Banks landslide-generated tsunami of Novermber 18, 1929: Preliminary analysis and numerical modeling. *Mar. Geol.*, **215**, 45-57.

Fritz H.M., Hager W.H. and Minor H.-E., 2001. Lituya Bay case: Rockslide impact and wave run-up. *Sci. Tsunami Hazards*, **19**, 3-22.

Fritz H.M., Hager W.H. and Minor H.-E., 2004. Near-field characteristics of landslide generated impulse waves. *J. Waterw. Port Coastal Ocean Eng.*, **130**, 287-302.

Fritz H.M., Mohammed F. and Yoo J., 2009. Lituya bay landslide impact generated mega-tsunami 50th anniversary. *Pure Appl. Geophys*., **166**, 153-175.

Geist E., Lynett P., Chaytor J. 2009. Hydrodynamic modeling of tsunamis from the Currituck landslide. *Mar. Geol.,* **264**, 41-52.

Greene H.G., Murai, L. Y., Watts, P., Maher, N. A. , Fisher, M. A., Paul, C. E., and Eichhubl, P., 2006. Santa Barbara submarine landslides in the channel as potential tsunami sources. *Natural Hazards and Earth System Sciences*, **6**, 63-88.

Greene, H.G. and S.N. Ward, 2003. Mass movement features along the central California margin and their modeled consequences for tsunami generation. *Submarine Mass Movements and Their Consequences*. Springer Netherlands, 343-356.

Grilli, S.T., Taylor, O.-D. S., Baxter, D.P. and S. Maretzki 2009. Probabilistic approach for determining submarine landslide tsunami hazard along the upper East Coast of the United States. *Marine Geology*, **264**(1-2):74-97, doi:10.1016/j.margeo.2009.02.010.

Grilli A.R. and S.T. Grilli, 2013a. Modeling of tsunami generation, propagation and regional impact along the U.S. East Coast from the Azores Convergence Zone. *Research Report no.* **CACR-13-04**. NTHMP Award, #NA10NWS4670010, US National Weather Service Program Office, 20 pp.

Grilli A.R. and S.T. Grilli, 2013b. Far-Field tsunami impact on the U.S. East Coast from an extreme flank collapse of the Cumbre Vieja Volcano (Canary Island). *Research Report no.* **CACR-13-13**. NTHMP Award, #NA10NWS4670010, US National Weather Service Program Office, 13 pp.

Grilli A.R. and S.T. Grilli, 2013c. Modeling of tsunami generation, propagation and regional impact along the upper U.S East coast from the Puerto Rico trench. *Research Report no.* **CACR-13-02**. NTHMP Award, #NA10NWS4670010, US National Weather Service Program Office, 18 pp.

Grilli, S.T. and Watts, P. 1999. Modeling of waves generated by a moving submerged body. Applications to underwater landslides. *Engineering Analysis with Boundary Elements,* **23**, 645-656.

Grilli, S.T., Vogelmann, S. and Watts, P. 2002. Development of a 3D Numerical Wave Tank for modeling tsunami generation by underwater landslides. *Engng. Analysis Boundary Elemt.* **26**(4), 301-313.

Grilli, S.T. and P. Watts, 2005. Tsunami generation by submarine mass failure Part I : Modeling, experimental validation, and sensitivity analysis. *J. Waterway Port Coastal and Ocean Engineering*, **131**(6), 283-297.

Grilli, S.T., Taylor, O.-D. S., Baxter, D.P. and S. Maretzki, 2009. Probabilistic approach for determining submarine landslide tsunami hazard along the upper East Coast of the United States. *Marine Geology*, **264**(1-2), 74-97, doi:10.1016/j.margeo.2009.02.010.

Grilli, S.T., Ioualalen, M, Asavanant, J., Shi, F., Kirby, J. and Watts, P. 2007. Source Constraints and Model Simulation of the December 26, 2004 Indian Ocean Tsunami. *J. Waterway, Port Coastal and Ocean Engng.*, **133**, 414-428.

Grilli, S.T., S. Dubosq, N. Pophet, Y. Pérignon, J.T. Kirby and F. Shi 2010. Numerical simulation and first-order hazard analysis of large co-seismic tsunamis generated in the Puerto Rico trench: near-field impact on the North shore of Puerto Rico and far-field impact on the US East Coast. *Natural Hazards and Earth System Sciences*, **10**, 2109-2125, doi:10.5194/nhess-2109-2010.

Grilli, S. T., Harris, J. C., Tajalli Bakhsh, T., Masterlark, T. L., Kyriakopoulus, C., Kirby, J. T. and Shi, F., 2013. Numerical simulation of the 2011 Tohoku tsunami based on a new transient FEM co-seismic source: Comparison to far- and near-field observation. *Pure and Applied Geophysics*, **170**, 1333-1359.

Grilli, S.T., Grilli, A.R., Tehranirad, B. and J.T. Kirby 2015a. Modeling tsunami sources and their propagation in the Atlantic Ocean for coastal tsunami hazard assessment and inundation mapping along the US East Coast. To appear in *Proc. 2015 COPRI Solutions to Coastal Disasters Conf*. (Boston, USA. September 9-11, 2015), ASCE, 12 pps., http://personal.egr.uri.edu/grilli/COPRI15_sgrilli.pdf.

Grilli S.T., O'Reilly C., Harris J.C., Tajalli-Bakhsh T., Tehranirad B., Banihashemi S., Kirby J.T., Baxter C.D.P., Eggeling T., Ma G. and F. Shi, 2015b. Modeling of SMF tsunami hazard along the upper US East Coast: Detailed impact around Ocean City, MD. *Natural Hazards*, **76**(2), 705-746, doi: 10.1007/s11069-014-1522-8.

Grilli, S.T., Grosdidier S. and C.-A. Guérin 2015c. Tsunami detection by High Frequency Radar beyond the continental shelf. I. Algorithms and validation on idealized case studies. *Pure and Applied Geophysics*, 40pps., doi: 10.1007/s00024-015-1193-8 (published online 10/28/15).

Grilli, S.T., Grilli A.R., David, E. and C. Coulet 2016a. Tsunami hazard assessment along the north shore of Hispaniola from far- and near-field Atlantic sources. *Natural Hazards*, 34 pps., doi: 10.1007/s11069-016-2218-z (published online 2/17/2016).

Grilli S.T., M. Shelby, A.R. Grilli, C.-A. Guérin, Samuel Grosdidier and T. Lado Insua 2016b. Algorithms for tsunami detection by High Frequency Radar : development and case studies for tsunami impact in British Columbia, Canada. To appear in *Proc. 26th Offshore and Polar Engng. Conf.* (ISOPE16, Rodos, Greece. June 2016), 8 pps. Intl. Society of Offshore and Polar Engng.

Harris, J.C., S.T. Grilli, S. Abadie and T. Tajalibakhsh, 2012. Near- and far-field tsunami hazard from the potential flank collapse of the Cumbre Vieja Volcano. In *Proc. 22nd Offshore and Polar Engng. Conf.* (ISOPE12, Rodos, Greece, June 17-22, 2012), Intl. Society of Offshore and Polar Engng., 242-249.

Heller V. and Hager W.H., 2010. Impulse product parameter in landslide generated impulse waves. *J. Waterw. Port Coastal Ocean Eng.*, **136**, 145-155.

Horrillo J., Wood A., Kim G.-B. and Parambath A., 2013. A simplified 3-D Navier-Stokes numerical model for landslide-tsunami: Application to the Gulf of Mexico. *J. Geophys. Res. Oceans*, **118**, 6934-6950.

Horrillo J., Pampell-Manis A. and B. Sweetman (2015). Construction of Five Additional Tsunami Inundation Maps for the Gulf of Mexico and A Probabilistic Methodology for Hazard Assessment Generated by Submarine Landslides in the Gulf of Mexico. NOAA Project Report (Awards NA12NWS4670014 and NA13NWS4670018), 217 pps. Ocean Engineering, Texas A&M University in Galveston.

Horrillo J., Grilli S.T., Nicolsky D., Roeber V., and J. Zhang 2014. Performance benchmarking tsunami operational models for NTHMP's' inundation mapping activities. *Pure and Applied Geophysics*, **172**, 869-884, doi: 10.1007/s00024-014-0891-y.

Ioualalen, M., Asavanant, J., Kaewbanjak, N., Grilli, S. T., Kirby, J. T. and Watts, P., 2007, ``Modeling the 26 December 2004 Indian Ocean tsunami: Case study of impact in Thailand'', *J. Geophys. Res.*, **112**, C07024, doi:10.1029/2006JC003850.

Kirby J.T., Shi F., Tehranirad, B., Harris J.C. and Grilli, S. T. 2013. Dispersive tsunami waves in the ocean: Model equations and sensitivity to dispersion and Coriolis effects. *Ocean Modelling*, **62**, 39-55.

Kirby, J. T., Shi, F., Nicolsky, D. and Misra, S., 2016. The 27 April 1975 Kitimat, British Columbia submarine landslide tsunami: A comparison of modeling approaches. *Landslides*, under revision.

Kirby, J. T., Nicolsky, D., Ma, G., Shi, F., Hsu, T.-J. and Schnyder, J. S. D., 2014. Two-layer models for landslide-generated tsunamis. *AGU Fall Meeting*, Abstract OS31E-04, San Francisco, December 15-19.

Lipa BJ, Parikh H, Barrick DE, Roarty H, Glenn S (2014) High frequency radar observations of the June 2013 US East Coast meteotsunami. *Natural Hazards*, 74:109–122

Liu P.L.-F., Wu T.-R., Raichlen F., Synolakis C.E. and Borrero J.C., 2005, Runup and rundown generated by three-dimensional masses, *J. Fluid. Mech*., **536**, 107-144.

Lopez-Venegas, A.M., U.S. ten Brink, and E.L. Geist, 2008. Submarine landslide as the source for the October 11, 1918 Mona Passage tsunami: Observations and modeling." *Marine Geology* **254**(1): 35-46.

Lynett P. and Liu P.L.-F., 2003. A numerical study of submarine landslide-generated waves and runup. *Proc. Roy. Soc.* A, **458**, 2885-2910.

Ma G., Shi F. and Kirby J.T. 2012. Shock-capturing non-hydrostatic model for fully dispersive surface wave processes. *Ocean Modelling*, **43-44**, 22-35.

Ma G., Kirby J.T. and Shi F., 2013. Numerical simulation of tsunami waves generated by deformable submarine landslides. *Ocean Modelling*, **69**, 146-165.

Ma G., Kirby J.T., T.-J. Hsu and Shi F., 2015. A two-layer granular landslide model for tsunami wave generation: Theory and computation. *Ocean Modelling*, **93**, 40-55.

Mohammed F. and Fritz H.M., 2012. Physical modeling of tsunami generated by three-dimensional deformable granular landslides. *J. Geophys. Res*., **117**, C11015, doi: 10.1029/2011JC007850.

Mulder T., E. Ducassou, G.P. Eberli, V. Hanquiez, E. Gonthier, P. Kindler, M. Principaud, F. Fournier, P. Léonide, I. Billeaud, B. Marsset, J.J.G. Reijmer, C. Bondu , R. Joussiaume, and M. Pakiades. 2012, New insights into the morphology and sedimentary processes along the western slope of Great Bahamas Bank. *Geology,* **40**(7), 603–606.

NTHMP, 2012. *Proceedings and results of the 2011 NTHMP model benchmarking workshop*. http://nthmp.tsunami.gov/documents/nthmpWorkshopProcMerged.pdf, NOAA, June 2012, 435 pps.

Pampell-Manis, A., Horrillo, J., Shigihara, Y. and Parambath, L. 2016. Probabilistic assessment of landslide tsunami hazard for the Northern Gulf of Mexico. *J. Geophys. Res: Oceans*, in press, doi:10.1002/2015JC011261.

Ramalho RS, Winckler G, Madeira J, Helffrich GR, Hiplito A, Quartau R, Adena K, Schaefer JM (2015) Hazard potential of volcanic flank collapses raised by new megatsunami evidence. *Scientific Adv*., **1**(9):e1500456

Schnyder, J. S. D., Eberli, G. P., Kirby, J. T., Shi, F., Tehranirad, B., Mulder, T., Ducassou, E., Hebbeln, D. and Wintersteller, P., 2016. Paleo-tsunamis caused by submarine slope failures along western Great Bahama Bank. Submitted to *Geology*, January.

Shelby, M., Grilli, S. T. and Grilli, A. R., 2015a. Dynamic tide-tsunami interaction in the Hudson River estuary. *Research Report No*. **CACR-15-10**, 55 pps., Center for Applied Coastal Research, Dept. of Civil and Environmental Engineering, University of Delaware.

Shelby, M., Grilli, S. T. and Grilli, A. R., 2015b. Tsunami hazard assessment in the Hudson River Estuary based on dynamic tsunami-tide simulations. *Pure and Applied Geophysics*, 53 pps. (submitted)

Shi, F., Kirby, J. T., Tehranirad, B., Harris, J. C. and Grilli, S. T., 2011. FUNWAVE-TVD, Fully nonlinear Boussinesq wave model with TVD solver, documentation and user's manual (Version 2.0). Research Report No, CACR-11-04, Center for Applied Coastal Research, Univ. of Delaware, Newark.

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

Shi, F., Kirby, J. T. and Tehranirad, B., 2012b. Tsunami benchmark results for spherical coordinate version of FUNWAVE-TVD (Version 1.1). *Research Report No.* **CACR-12-02**, Center for Applied Coastal Research, Univ. of Delaware, Newark.

Synolakis, C. E., Bernard, E. N., Titov, V. V., Kanoglu, U. and Gonzalez, F. I., 2007. "Standards, criteria and procedures for NOAA evaluation of tsunami numerical models. NOAA Technical Memorandum OAR PMEL-135.

Tajalli-Bakhsh, T. S., Grilli, S. T. and Grilli, A. R., 2015. Dynamic tidal effects on tsunami coastal hazard in large estuaries: Case of the Chesapeake Bay/James River, USA. *Research Report No*. **CACR-15-09**, 42 pps., Center for Applied Coastal Research, Dept. of Civil and Environmental Engineering, University of Delaware. http://personal.egr.uri.edu/grilli/Tajelli-etal-cacr-15-09.pdf

Tappin, D.R., Watts, P., Grilli, S.T. 2008. The Papua New Guinea tsunami of 1998: anatomy of a catastrophic event. *Natural Hazards and Earth System Sciences*, **8**, 243-266. www.nat-hazards-earth-syst-sci.net/8/243/2008/

Tappin D.R., Grilli S.T., Harris J.C., Geller R.J., Masterlark T., Kirby J.T., F. Shi, G. Ma, K.K.S. Thingbaijamg, and P.M. Maig, 2014. Did a submarine landslide contribute to the 2011 Tohoku tsunami ? *Marine Geology*, **357**, 344-361 doi: 10.1016/j.margeo.2014.09.043.

Tehranirad, B., Shi, F., Kirby, J. T., Harris, J. C. and Grilli, S., 2011. Tsunami benchmark results for fully nonlinear Boussinesq wave model FUNWAVE-TVD, Version 1.0. Research Report No. CACR-11-02, Center for Applied Coastal Research, Univ. of Delaware, Newark.

Tehranirad, B., Kirby, J. T., Ma, G. and Shi, F., 2012. Tsunami benchmark results for non-hydrostatic wave model NHWAVE (Version 1.1). Research Report No. CACR-12-03, Center for Applied Coastal Research, Univ. of Delaware, Newark.

Tehranirad, B., Banihashemi, S., Kirby, J. T. and Shi, F., 2014. Tsunami inundation mapping for the Ocean City MD NGDC DEM. Research Report No, CACR-14-04, Center for Applied Coastal Research, Univ. of Delaware, Newark.

Tehranirad B., Harris J.C., Grilli A.R., Grilli S.T., Abadie S., Kirby J.T. and F. Shi 2015a. Far-field tsunami hazard in the north Atlantic basin from large scale flank collapses of the Cumbre Vieja volcano, La Palma. *Pure and Applied Geophysics*, **172**(12), 3,589-3,616 doi:10.1007/s00024-015-1135-5.

Tehranirad, B., Kirby J. T., Shi, F., and Grilli, S., 2015b. Does morphological adjustment during tsunami inundation increase levels of hazard ?. To appear in *Proc. 2015 COPRI Solutions to Coastal Disasters Conf*. (Boston, USA. September 9-11, 2015), ASCE, 10 pps., http://personal.egr.uri.edu/grilli/COPRI_Babak_2015 .pdf

Tehranirad, B., Kirby, J. T., Callahan, J. A. and Shi, F., 2015c. Tsunami inundation mapping for Atlantic City, NJ NGDC DEM. Research Report No. CACR-15-01, Center for Applied Coastal Research, Department of Civil and Environmental Engineering, University of Delaware. (DRAFT)

Tehranirad, B., Kirby, J. T., Callahan, J. A. and Shi, F., 2015d. Tsunami inundation mapping for the northern half of the State of New Jersey. Research Report No. CACR-15-02, Center for Applied Coastal Research, Department of Civil and Environmental Engineering, University of Delaware. (DRAFT)

Tehranirad, B., Kirby, J. T., Callahan, J. A. and Shi, F., 2015e. Tsunami inundation mapping for New York City. Research Report No. CACR-15-03, Center for Applied Coastal Research, Department of Civil and Environmental Engineering, University of Delaware. (DRAFT)

Tehranirad, B., Kirby, J. T., Callahan, J. A. and Shi, F., 2015f. Tsunami inundation mapping for Montauk, NY NGDC DEM. Research Report No. CACR-15-04, Center for Applied Coastal Research, Department of Civil and Environmental Engineering, University of Delaware. (DRAFT)

Tehranirad, B., Kirby, J. T., Callahan, J. A. and Shi, F., 2015g. Tsunami inundation mapping for Nantucket, MA NGDC DEM. Research Report No. CACR-15-05, Center for Applied Coastal Research, Department of Civil and Environmental Engineering, University of Delaware. (DRAFT)

Tehranirad, B., Kirby, J. T. and Shi, F., 2015h. Tsunami inundation mapping for Virginia Beach, VA NGDC DEM. Research Report No. CACR-15-11, Center for Applied Coastal Research, Department of Civil and Environmental Engineering, University of Delaware. (DRAFT)

Tehranirad, B., Kirby, J. T. and Shi, F., 2015i. Tsunami inundation mapping for Cape Hatteras, NC NGDC DEM. Research Report No. CACR-15-12, Center for Applied Coastal Research, Department of Civil and Environmental Engineering, University of Delaware. (DRAFT)

Tehranirad, B., Kirby, J. T. and Shi, F., 2015j. Tsunami inundation mapping for Myrtle Beach, SC NGDC DEM. Research Report No. CACR-15-13, Center for Applied Coastal Research, Department of Civil and Environmental Engineering, University of Delaware. (DRAFT)

Tehranirad, B., Kirby, J. T. and Shi, F., 2015k. Tsunami inundation mapping for Savannah, GA NGDC DEM. Research Report No. CACR-15-14, Center for Applied Coastal Research, Department of Civil and Environmental Engineering, University of Delaware. (DRAFT).

Tehranirad, Kirby J.K., Grilli, S.T., Grilli, A.R., and F. Shi 2016. Is continental shelf bathymetry the main control of tsunami hazard for the US East Coast?. *Geophysical Research Letters* (in preparation).

ten Brink U. et XIII alia 2008. *Evaluation of Tsunami Sources with the Potential to Impact the U.S. Atlantic and Gulf Coasts*. An updated report to the Nuclear Regulatory Commission by Atlantic and Gulf of Mexico tsunami hazard assessment group. US Nuclear Regulatory Commission, 332 pps.

ten Brink, U.S., J.D. Chaytor, E.L. Geist, D.S. Brothers and B.D. Andrews, 2014. Assessment of tsunami hazard to the US Atlantic margin. *Marine Geology,* **353**: 31-54.

Thomson, R. E., Rabinovich, A. B., Fine, I. V., Sinnott, D. C., McCarthy, A., Sutherland, N. A. S., and Neil, L. K., 2009. Meteorological tsunamis on the coasts of British Columbia and Washington. *Physics and Chemistry of the Earth Parts A/B/C*, **34**(17):971–988.

Viroulet S., A. Sauret and O. Kimmoun, 2014.Tsunami generated by a granular collapse down a rough inclined plane. *Europhysics Lett.,* **105**(34004) doi:10.1209/0295-5075/105/34004.

Watts, S. T. Grilli, J. T. Kirby, G. J. Fryer, and Tappin, D. R. 2003. Landslide tsunami case studies using a Boussinesq model and a fully nonlinear tsunami generation model. *Natural Hazards and Earth System Sciences*, **3**, 391-402

Watts, P., Grilli, S.T., Tappin and Fryer, G.J. 2005. Tsunami generation by submarine mass failure Part II : Predictive Equations and case studies. *J. Waterway Port Coastal and Ocean Engineering*, **131**(6), 298-310.

Wei, G., Kirby, J. T., Grilli, S. T. and Subramanya, R., 1995. A fully nonlinear Boussinesq model for surface waves. I. Highly nonlinear, unsteady waves, *J. Fluid Mech.*, **294**, 71-92.

Weiss R., Fritz H.M. and Wuennemann K., 2009. Hybrid modeling of the mega-tsunami runup in Lituya Bay after half a century. *Geophys*. *Res. Lett*., **36**, L09602, doi:10.1029/2009GL037814.

Wertman, C. A., Yablonsky, R. M., Shen, Y., Merrill, J., Kincaid, C. R. and Pockalny, R. A., 2014. Mesoscale convective system surface pressure anomalies responsible for meteotsunamis along the U. S. East Coast on June 13th, 2013. *Scientific Reports* 4, 7143, doi:10.1038/srep07143

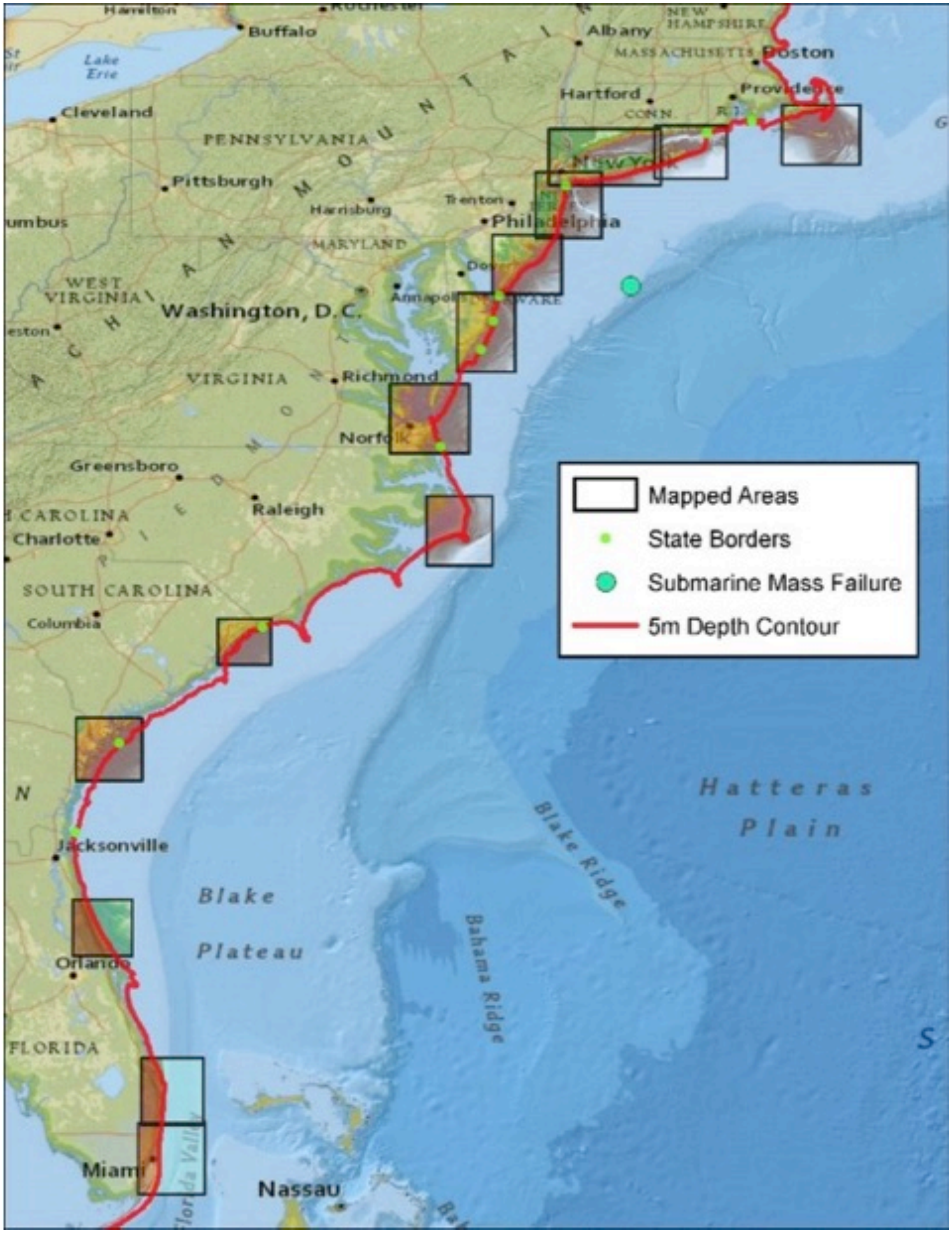

Figure 1. Regions covered by high resolution modeling

(Florida sites to be completed in FY15).

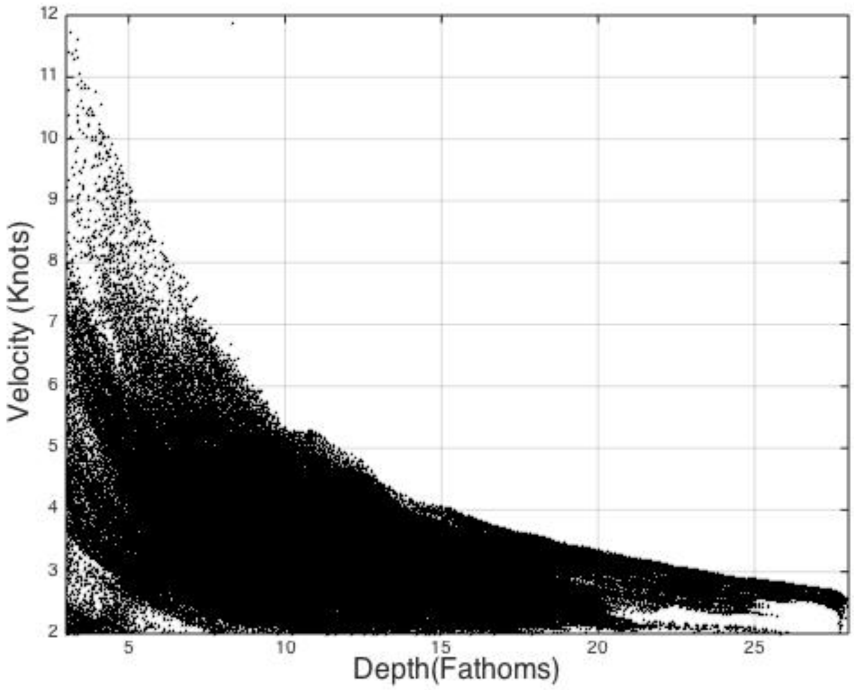

Figure 2. Maximum occurring velocity at individual grid points as a function of water depth. Ocean City, MD NGDC DEM (Tehranirad et al, 2014)

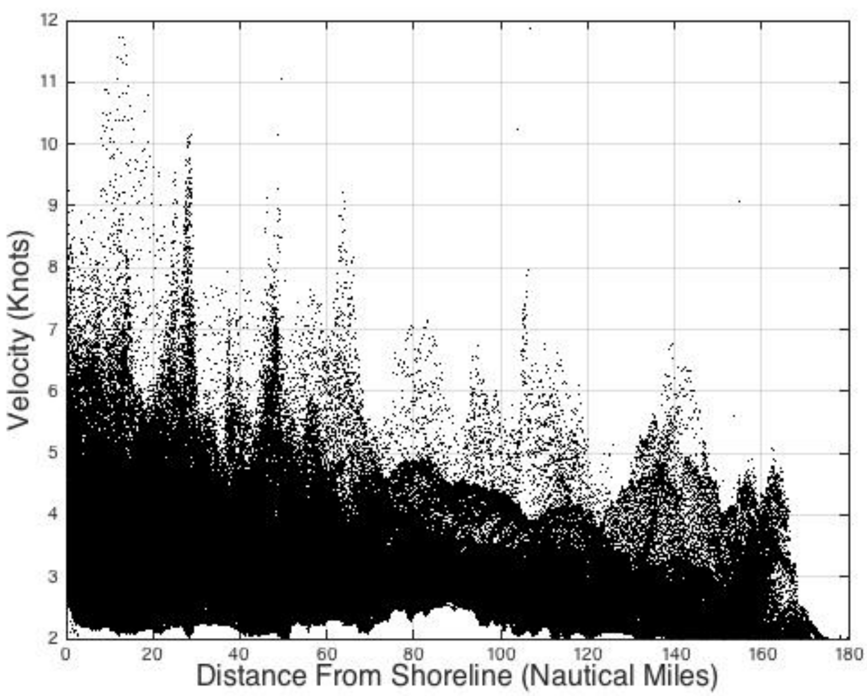

Figure 3. Maximum occurring velocity at each grid point vs an estimate of offshore distance. Ocean City, MD NGDC DEM (Tehranirad et al, 2014).

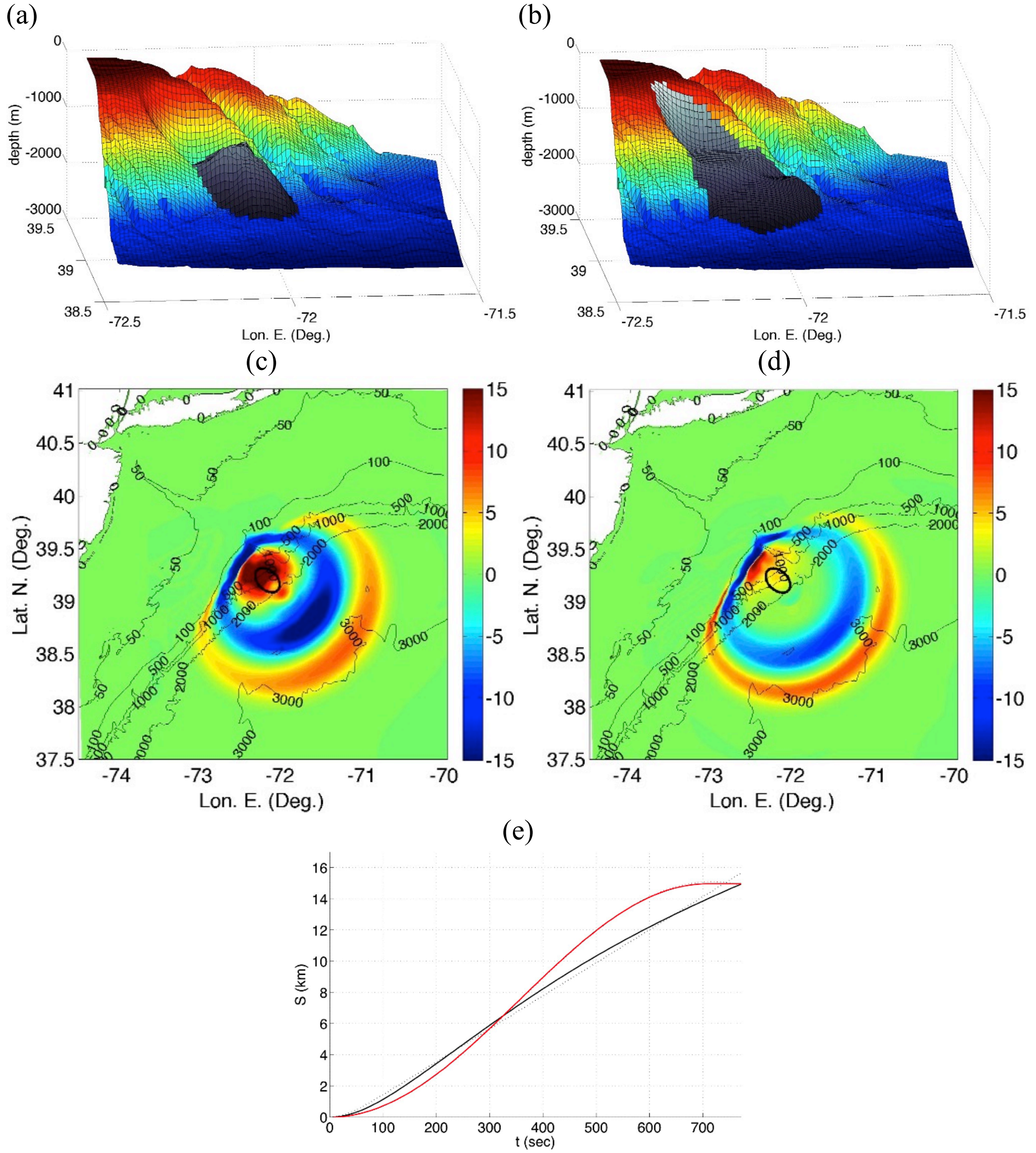

Figure 4. NHWAVE simulations of landslide tsunamis generated off of the Hudson River canyon by: (a,c) a rigid slump, modeled as a Currituck SMF proxy (Grilli et al., 2015a); (b,d) a deforming slide modeled as a dense fluid layer, with same initial geometry, location, volume, and runout at the time the slump stops moving (12 min), as the Currituck SMF proxy. Panels (a,b) show in gray the SMF locations after 13.3 min (to the left of the Hudson River canyon), and panels (c,d) show the surface waves generated after 13.3 min (the black ellipses mark the initial footprint of the SMFs). At this time, wave patterns are similar but waves have lower elevations in the deforming slide case;black ellipses mark the initial footprint of each SMF. (e) solid curves are center of mass motions of (red) slump and (black) slide, with dash curves being curve fits of theoretical laws of motion.

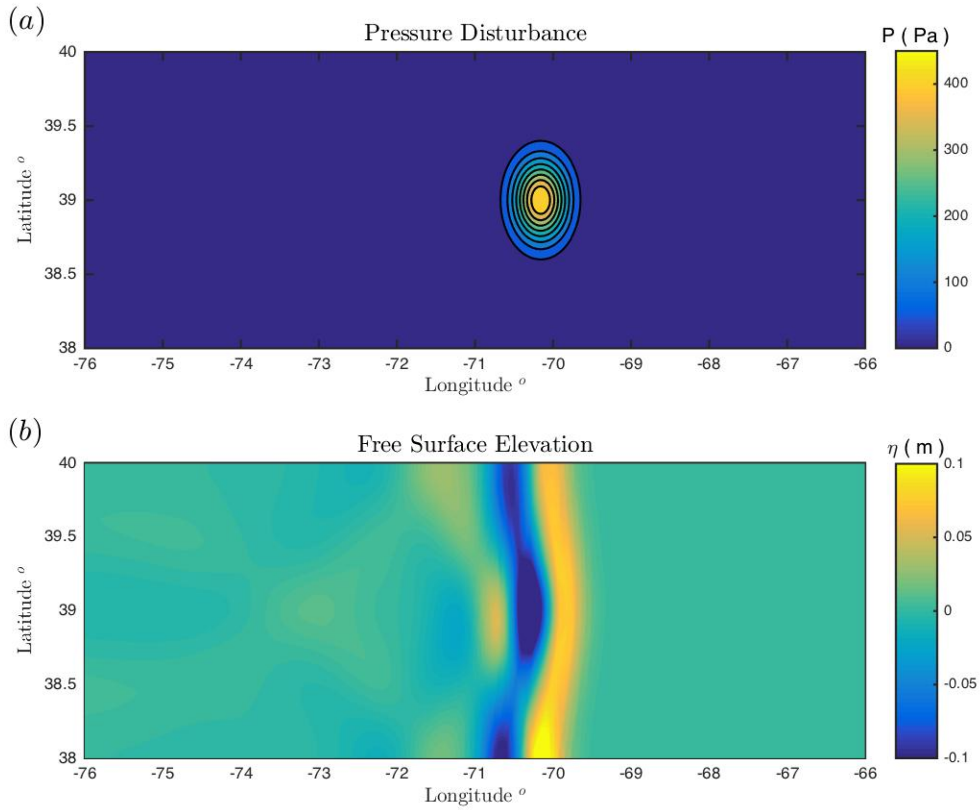

Figure 5: An idealized meteotsunami example. A Gaussian pressure distribution with major and minor axes = 30 km and central pressure deficit of 450 Pa translates at speed 20m/s over a water body of constant depth 40m. (top) pressure field. (bottom) Surface wave pattern computed by Boussinesq model FUNWAVE. Wave is evolving in a channel bounded by sidewalls at constant latitudes. Distortion in waveform is due to the N-S variation across the grid.

BIOGRAPHICAL SKETCH

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A. Professional Preparation

Brown University	Engineering	Sc. B., 1975
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University of Delaware	Civil Engineering	Ph. D., 1983

B. Appointments

Edward C. Davis Professor of Civil Engineering, University of Delaware, 2003 to present.
Professor, Department of Civil and Environmental Engineering, University of Delaware, 1994 to 2003.
Joint appointment in College of Earth, Ocean and the Environment, 1994 to present.
Visiting Professor, Grupo de Dinamica de Flujos Ambientales, Universidad de Granada, 2010, 2012.
Associate Professor, Dept. of Civil and Environmental Engineering, University of Delaware, 1989 to 1994.
Associate Professor, Dept. of Coastal and Oceanographic Engineering, University of Florida, 1988 to 1989.
Assistant Professor, Dept. of Coastal and Oceanographic Engineering, University of Florida, 1984 to 1988.
Assistant Professor, Marine Sciences Research Center, SUNY Stony Brook, 1983 to 1984.

C. Products

1. Schnyder, J. S. D., Eberli, G. P., Kirby, J. T., Shi, F., Tehranirad, B., Mulder, T., Ducassou, E., Hebbeln, D. and Wintersteller, P., 2016, "Paleo-tsunamis caused by submarine slope failures along western Great Bahama Bank", *Scientific Reports (NPG)*, submitted.
2. Kirby, J. T., 2016, "Boussinesq models and their application to coastal processes across a wide range of scales", *Journal of Waterway, Port, Coastal and Ocean Engineering*, in press.
3. Kirby, J. T., Shi, F., Nicolsky, D. and Misra, S., 2016, "The 27 April 1975 Kitimat, British Columbia submarine landslide tsunami: A comparison of modeling approaches", *Landslides*, doi:10.1007/s10346-016-0682-x.
4. Abdolali, A., Cecioni, C., Bellotti, G. and Kirby, J. T., 2015, "Hydro-acoustic and tsunami waves generated by the 2012 Haida Gwaii earthquake: modeling and in-situ measurements", *Journal of Geophysical Research: Oceans*, **120**, 958-971,
5. doi:10.1002/2014JC010385 Tehranirad, B., Harris, J. C., Grilli, A. R., Grilli, S. T., Abadie, S., Kirby, J. T. and Shi, F., 2015, "Far-field tsunami hazard on the western European and US east coast from a large scale flank collapse of the Cumbre Vieja volcano, La Palma", *Pure and Applied Geophysics,* **172**, 3589-3616, doi:10.1007/s00024-015-1135-5 .
6. Ma, G., Kirby, J. T., Hsu, T.-J. and Shi, F., 2015, "A two-layer granular landslide model for tsunami wave generation: Theory and computation", *Ocean Modelling* **93**, 40-55, doi:10.1016/j.ocemod.2015.07.012
7. Abdolali, A., Kirby, J. T. and Bellotti, G., 2015, "Depth-integrated equation for hydro-acoustic waves with bottom damping", *Journal of Fluid Mechanics*, **766**, R1, doi:10.1017/jfm.2015.37 .
8. Grilli, S. T., O'Reilly, C., Harris, J. C., Tajalli Bakhsh, T., Tehranirad, B., Banihashemi, S., Kirby, J. T., Baxter, C. D. P., Eggeling, T., Ma, G. and Shi, F., 2015, "Modeling of SMF tsunami hazard along the upper U. S. East Coast: Detailed impact around Ocean City, MD", *Nat. Haz.*, doi: 10.1007/s11069-014-1522-8.
9. Tappin, D. R., Grilli, S. T., Harris, J. C., Geller, R. J., Masterlark, T., Kirby, J. T., Shi, F., Ma, G., Thingbaijam, K. K. S. and Mai, P. M., 2014, "Did a submarine landslide contribute to the 2011 Tohoku tsunami?", *Marine Geology*, **357**, 344-361.
10. .Kirby, J. T., Shi, F., Tehranirad, B., Harris, J. C. and Grilli, S. T., 2013, "Dispersive tsunami waves in the ocean: model equations and sensitivity to dispersion and Coriolis effects", *Ocean Modelling*, **62**, 39-55.
11. .Grilli, S. T., Harris, J. C., Tajalibakhsh, T., Masterlark, T. L., Kyriakopoulus, C., Kirby, J. T. and Shi, F., 2013, "Numerical simulation of the 2011 Tohoku tsunami based on a new transient FEM co-seismic source", *Pure and Applied Geophysics*, **170**, 1333-1359.
12. Ma, G., Kirby, J. T. and Shi, F., 2013, "Numerical simulation of tsunami waves generated by deformable submarine landslides", *Ocean Modelling*, **69**, 146-165.
13. Ma, G., Shi, F. and Kirby, J. T., 2012, "Shock-capturing non-hydrostatic model for fully dispersive surface wave processes", *Ocean Modelling*, **43-44**, 22-35.

14. 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.
15. Grilli, S. T., Dubosq, S., Pophet, N., Perignon, Y., Kirby, J. T. and Shi, F., 2010, "Numerical simulation of co-seismic tsunami impact on the North Shore of Puerto Rico and far-field impact on the US East Coast: a first-order hazard analysis", *Natural Hazards and Earth Systems Science*, **10**, 2109-2125.
16. Waythomas, C. F., Watts, P., Shi, F. and Kirby, J. T., 2009, "Pacific basin tsunami hazards associate with mass flows in the Aleutian Arc of Alaska", *Quaternary Science Reviews*, **28**, 1006-1019.
17. Long, W., Kirby, J. T. and Shao, Z., 2008, "A numerical scheme for morphological bed level calculations", *Coastal Engineering*, **55**, 167-180.
18. Grilli, S. T., Ioualalen, M., Asavanant, J., Shi, F., Kirby, J. T. and Watts, P., 2007, "Source constraints and model simulation of the December 26, 2004 Indian Ocean tsunami", *Journal of Waterway, Port, Coastal and Ocean Engineering*, **133**, 414-428.
19. Ioualalen, M., J. A. Asavanant, N. Kaewbanjak, N., Grilli, S. T., Kirby, J. T. and Watts, P., 2007, "Modeling of the 26th December 2004 Indian Ocean tsunami: Case study of impact in Thailand", *Journal of Geophysical Research*, **112**, C07024, doi:10.1029/2006JC003850.
20. Day, S. J., Watts, P., Grilli, S. T. and Kirby, J. T., 2005, "Mechanical models of the 1975 Kalapana, Hawaii earthquake and tsunami", *Marine Geology*, **215**, 59-92.

D. Synergistic Activities

1. Editorial service including Associate Editor, Journal of Engineering Mechanics (1994-1995), Editor, Journal of Waterway, Port, Coastal and Ocean Engineering (1996-2000), Editor, Journal of Geophysical Research – Oceans (2003-2006) and Editor-in-Chief, Journal of Geophysical Research – Oceans (2006-2009).
2. Member, Coordinating Committee and Mapping and Modeling Subcommittee of the National Tsunami Hazard Mitigation Program (2008-present).
3. Member, Board of Directors, American Institute of Physics (2011-2013).
4. Lead developer of a number of widely used public domain models for surface wave processes, including the surface wave transformation programs REF/DIF and FUNWAVE, the nearshore community model NearCoM for wave-driven circulation, and the recently developed surface and terrain following nonhydrostatic model NHWAVE.
5. Developer of course content for several University of Delaware graduate level courses including CIEG 672 Ocean wave mechanics, CIEG 872 Advanced ocean wave mechanics (textbook under development), CIEG 681 Ocean wave spectra (textbook under development), and CIEG 684 Introduction to nearshore modeling techniques (new course)

E. Collaborators and Other Affiliations

Present Collaborators
Chris Baxter (URI), Stephan Grilli (URI), Tom Hsu (UD), Fengyan Shi (UD), Chris Summerfield (UD), Tobias Kukulka (UD), Gangfeng Ma (ODU), Chris Chickadel (UW), W. Rockwell Geyer (WHOI), Merrick Haller (OSU), Jeffrey C. Harris (U. Rhode Island), James M. Kaihatu (Texas A&M), Jamie MacMahan (NPS), Tim Masterlark (ND School of Mines), Alex Sheremet (UF), Ad Reniers (Delft UT).

Ph.D. Thesis Advisor: Robert A. Dalrymple, Dept. of Civil Engineering, Johns Hopkins University.

Doctoral and Postdoctoral Advisees (41 total graduate advisees)
James Kaihatu (1994, Texas A&M), Changhoon Lee (1994, Sejong Univ.), Ge Wei (1997, unknown), H. Tuba Özkan-Haller (1997, Oregon St U), Mauricio Gobbi (1998, Fed. Univ. Parana), Arun Chawla (1999, NWS), Shubhra Misra (2005, Chevron), Wen Long (2006, U MD), Joseph Geiman (2011, Johns Hopkins ARL), Gangfeng Ma (2012, Old Dominion U), Morteza Derakhti (2016, U. Delaware), Zhifei Dong (expected 2016), Babak Tehranirad (expected 2016), Saeideh Banihashemi (expected 2017), Mithun Deb (expected 2019), Cheng Zhang (expected 2019),

Francis Ting (postdoc, 1989-1991), NDState U), Qin Chen (postdoc 1997-1999, LSU), Andrew Kennedy (postdoc, 1997-1999), Dongming Liu (postdoc, 2008-2009); Ali Abdolali (postdoc, 2015-); Morteza Derakhti (postdoc, 2016-)

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A. Professional Preparation :

M.S. (1980, Civil Engineering); Registered Professional Civil Engineer (1980); M.S. (1983, Physical Oceanography); Ph.D (1985, Ocean Engng.; advisor Prof. A. Lejeune), all from Univ. of Liège (Belgium) (all *summa cum laude*). Post-doctoral work (1985-87), Univ. of Liège (Belgium)

B. Permanent positions :

2011-present, *Professor* (joint appointment), U. of Rhode Island, Grad. School of Oceanography
2002-2008, *Chairman*, University of Rhode Island, Dept. of Ocean Engng.
1998-present, *Distinguished Professor*, University of Rhode Island, Dept. of Ocean Engng.
1996-1998, *Distinguished Assoc. Professor*, University of Rhode Island, Dept. of Ocean Engng.
1993-1996, *Associate Professor*, University of Rhode Island, Dept. of Ocean Engineering.
1991-1993, *Assistant Professor*, University of Rhode Island, Dept. of Ocean Engineering.
1987-1991, *Research Assistant Professor*, University of Delaware, Dept. of Civil Engineering.
1985-1987, *Research Associate* (F.N.R.S.), University of Liège (Belgium).

C. Visiting positions :

2007, 2014, *Research Director*, C.N.R.S., University of Toulon, LSEET, France (Spring 07, 14).
2005, *Invited Professor*, U. of Braunschweig, Institute for Civil Engng., Germany (January 05).
1999, *Visiting Senior Scientist*, University of Nice, Institut Nonlin´eaire, France (Spring 99).
1998-present, *Visiting/Invited Prof.*, Univ. of Toulon, LSEET Laboratory, France (1-3 m./year).
1996, *Visiting Professor*, University of Nantes, Ecole Centrale, France (January 06).
1991, *Visiting Scholar*, U. of Cantabria, Dept. of Water Science and Tech., Spain (April/June 91).

D. Selected Relevant Publications : (http://www.oce.uri.edu/ grilli/resume.html; h-index: 35)

1. Grilli, S.T. 1997 Fully Nonlinear Potential Flow Models used for Long Wave Runup Prediction. Chapter in *Long-Wave Runup Models,* (eds. H. Yeh, P. Liu, and C. Synolakis), pps. 116-180. World Scientific Publishing, Singapore.
2. Watts, P., Grilli, S. T., Kirby, J. T., Fryer, G. J. and Tappin, D. R., 2003. Landslide tsunami case studies using a Boussinesq model and a fully nonlinear tsunami generation model. *Nat. Haz. Earth Syst. Sciences*, **3**, 391-402, 2003.
3. Grilli, S.T. and P. Watts. 2005. Tsunami generation by submarine mass failure Part I : Modeling, experimental validation, and sensitivity analysis. *J. Waterway Port Coastal and Ocean Engng*., **131**(6), 283-297.
4. Watts, P., Grilli, S.T., Tappin D., and Fryer, G.J. 2005. Tsunami generation by submarine mass failure Part II : Predictive Equations and case studies. *J. Waterway Port Coastal and Ocean Engng*., **131**(6), 298-310.
5. Day, S. J., Watts, P., Grilli, S. T. and Kirby, J. T., 2005. Mechanical models of the 1975 Kalapana, Hawaii earthquake and tsunami. *Marine Geology*, **215**, 59-92.
6. Grilli, S.T., Ioualalen, M, Asavanant, J., Shi, F., Kirby, J. and Watts, P. (2007). Source Constraints and Model Simulation of the 12/26/04 Indian Ocean Tsunami. *J. Waterw. Port Coast. Ocean Engng.*, **133**(6), 414-428.
7. Ioualalen, M., Asavanant, J., Kaewbanjak, N., Grilli, S.T., Kirby, J.T. and P. Watts (2007). Modeling the 12/26/04 Indian Ocean tsunami: Case study of impact in Thailand. *J. Geoph. Res.*, **112**, C07024.
8. Tappin, D.R., Watts, P., Grilli, S.T. (2008). The Papua New Guinea tsunami of 1998: anatomy of a catastrophic event. *Natural Hazard and Earth System Sc.*, **8**, 243-266.
9. Grilli, S.T., Taylor, O.-D. S., Baxter, D.P. and S. Maretzki (2009). Probabilistic approach for determining submarine landslide tsunami hazard along the upper East Coast of the United States. *Marine Geology*, **264**(1-2), 74-97, doi:10.1016/j.margeo.2009.02.010.
10. Grilli, S.T., S. Dubosq, N. Pophet, Y. P´erignon, J.T. Kirby and F. Shi (2010). Numerical simulation and first-order hazard analysis of large co-seismic tsunamis generated in the Puerto Rico trench: near-field impact on the North shore of Puerto Rico and far-field impact on the US East Coast. *Natural Hazards and Earth System Sciences*, **10**, 2109-2125.
11. Abadie, S., Morichon, D., Grilli, S.T. and Glockner, S. 2010. Numerical simulation of waves generated by landslides using a multiple-fluid NS model. *Coast. Enging.* , **57**, 779-794, doi:10.1016/j.coastaleng.2010.03.003.
12. Abadie, S., J.C. Harris, S.T. Grilli and R. Fabre (2012). Numerical modeling of tsunami waves generated by the flank collapse of the Cumbre Vieja Volcano (La Palma, Canary Islands) : tsunami source and near field effects. *J. Geophys. Res.*, **117**, C05030.
13. Grilli, S.T., Harris, J.C., Tajali Bakhsh, T.S., Masterlark, T.L., Kyriakopoulos, C., Kirby, J.T. and and Shi, F. (2013). Numerical simulation of the 2011 Tohoku tsunami based on a new transient FEM co-seismic source: Comparison to far- and near-field observations. *Pure Appl. Geoph.*, **170**, 1333-1359, doi:10.1007/s00024-012-0528-y.

14. Kirby, J.T., Shi, F., Tehranirad, B., Harris, J.C. and Grilli, S.T (2013). Dispersive tsunami waves in the ocean: Model equations and sensitivity to dispersion and Coriolis effects. *Ocean Modell.*, **62**, 39-55, doi:10.1016/j.ocemod.2012.11.009.
16. Horrillo J., Grilli S.T., Nicolsky D., Roeber V., and J. Zhang (2014). Performance Benchmarking Tsunami Operational Models for NTHMP's' Inundation Mapping Activities. *Pure and Applied Geophysics*, **172**, 869-884, doi: 10.1007/s00024-014-0891-y.
17. Tappin D.R., Grilli S.T., Harris J.C., Geller R.J., Masterlark T., Kirby J.T., F. Shi, G. Ma, K.K.S. Thingbaijamg, and P.M. Maig (2014). Did a submarine landslide contribute to the 2011 Tohoku tsunami ?, *Marine Geology*, **357**, 344-361 doi: 10.1016/j.margeo.2014.09.043 (open access).
18. Grilli S.T., O'Reilly C., Harris J.C., Tajalli-Bakhsh T., Tehranirad B., Banihashemi S., Kirby J.T., Baxter C.D.P., Eggeling T., Ma G. and F. Shi (2015). Modeling of SMF tsunami hazard along the upper US East Coast: Detailed impact around Ocean City, MD. *Natural Hazards*, **76**(2), 705-746, doi: 10.1007/s11069-014-1522-8.
19. Tehranirad, B., Harris, J. C., Grilli, A. R., Grilli, S. T., Abadie, S., Kirby, J. T. and Shi, F. (2015) Far-field tsunami hazard on the western European and US east coast from a large scale flank collapse of the Cumbre Vieja volcano, La Palma. *Pure Appl.. Geophys.*, **172**(12), 3,589-3,616 doi:10.1007/s00024-015-1135-5.
20. Grilli, S.T., Grosdidier S. and C.-A. Guérin 2015. Tsunami detection by High Frequency Radar beyond the continental shelf. I. Algorithms and validation on idealized case studies. *Pure and Applied Geophysics*, 40pps., doi: 10.1007/s00024-015-1193-8 (published online 10/28/15).
21. Grilli, S.T., Grilli, A.R., Tehranirad, B. and J.T. Kirby 2015. Modeling tsunami sources and their propagation in the Atlantic Ocean for coastal tsunami hazard assessment and inundation mapping along the US East Coast. To appear in *Proc. 2015 COPRI Solutions to Coastal Disasters Conf*. (Boston, USA. 9/15), American Soc. Civil Eng., 12 pps.
22. Grilli, S.T., Grilli A.R., David, E. and C. Coulet 2016. Tsunami Hazard Assessment along the North Shore of Hispaniola from far- and near-field Atlantic sources. *Natural Hazards*, 1-34 pps. , doi: 10.1007/s11069-016-2218-z (published online 2/15/17)
23. Shelby, M., Grilli, S. T. and Grilli, A. R., 2016. Tsunami hazard assessment in the Hudson River Estuary based on dynamic tsunami-tide simulations. *Pure and Applied Geophysics*, 53 pps. (accepted with minor changes).

E. Synergistic Activities:
1. Various tsunami hazard assessment projects for critical coastal infrastructures (e.g., nuclear powerplants and maritime facilities). Proprietary studies.
2. Appointed member of the US *National Research Council Marine Board* (2010-), leader of sub-committee on critical coastal infrastructure resilience; East Coast co-representative on the US *National Tsunami Hazard Mitigation Program* mapping and modeling committee (2010-2013).

F. Current collaborators: Profs. J.T. Kirby, F. Shi (U.oD), Prof. G. Ma (Old Dom. U.), Prof. A. Grilli (URI), Profs. M. Benoit, O. Kimmoun (Univ. Marseilles, France); Profs. C.A. Guérin, F. Nougquier, M. Saillard and Ph. Fraunie (Univ. of Toulon, France); Prof. S. Abadie (Univ. of Pau et Pays de l'Adour, France); Prof. F. Dias (Ecole Normale Supérieure, Paris, France); Prof. T.L. Masterlark South Dakota School of Mines); Prof. D. Tappin (British Geological Survey, UK), Dr. S. Day (Imperial College, UK); Drs. C. Janssen, A. Banari, (Tech. U. Hamburg, Germany), Dr. J. Harris (Laboratoire St Venant, Chatou, france), Prof. Krafczyk (Tech. U.. Braunschweig, Germany).

G. Media outreach: Featured on local, national, and international media (TV, radio, newspaper science sections) regarding extreme waves and tsunamis (e.g., Discovery channel, PBS-National Geographics Intl., US Weather Channel, BBC-TV/radio, ABC/NBC, CNN International, History Channel, DE-NPR,. . .).

H. Thesis advisor and postgraduate-scholar sponsor: (past 8 years : 2 post-doc, 23 graduate students) : Taylor Asher (MS), Amir Banari (PhD, TU Hamburg); Benjamin Biausser (PhD; Technip, France), Myriam El Bettah (PhD), Kevyn Bollinger (MS), A. Bringer (MS); M. Buckley (MS; USGS), Sara Dubosq (PhD, U. Toulon, France), Yann Drouin (MS; Ecole Centrale, Nantes, France), Francois Enet (PhD, URI; Alkyon Inc., Holland), Christophe Fochesato (PhD; Ecole Normale Supérieure, France), Nate Greene (MS, URI; Raytheon, RI), Richard Gilbert (MS; McLaren Inc., NY), Etienne Guerber (PhD; EDF, France); Philippe Guyenne (PhD; U. of Delaware), Christian Janssen (PhD and postdoc; TU Hamburg); Jeff Harris (PhD and postdoc; Laboratoire St Venant, Paris), Y. Mauzole (MS); J. Montgommery (MS); Yves Pérignon (MS; ECN, Nantes, France), Chris O'Reilly (current PhD student, URI and Navatek Ltd.), M. Shelby (current MS student, URI), O. Taylor (MS); T. Tajelli-Baksch (PhD; ASA-RPS Ltd).

I. Professional Societies : AGU, ASCE, ISOPE, MTS; 7 scient. awards in Belgium, France and US

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A. Professional Preparation

Wuhan University of Science and Technology, Physics, Sc. B., 1984
Ocean University of Qingdao, Physical Oceanography, Sc. M., 1991
Ocean University of Qingdao, Environmental and Physical Oceanography, Ph. D., 1995
University of Delaware, Center for Applied Coastal Research, Postdoc, 1999-2003

C. Appointments

Research Associate Professor, Department of Civil and Environmental Engineering & Center for Applied Coastal Research, University of Delaware, 2012 - present
Research Assistant Professor, Department of Civil and Environmental Engineering & Center for Applied Coastal Research, University of Delaware, 2007 - 2012
Associate Scientist, Center for Applied Coastal Research, University of Delaware, 2004 – 2007
Associate Professor, Institute of Estuarine and Coastal Research, East China Normal University, 1997 – 1998

E. Visiting positions:

ONR Summer Faculty, Naval Research Lab, Stennis Space Center, MS, Jun-Aug, 2014.

F. Publications

(i) Five most closely related to the proposed project

- Ma, G., Kirby, J. T., Hsu, T.-J. and Shi, F., 2015, "A two-layer granular landslide model for tsunami wave generation: Theory and computation", *Ocean Modelling*, 93. 40-55.
- Kirby, J. T., Shi, F. Harris, J. C., and Grilli, S. T., 2013, "Dispersive tsunami waves in the ocean: model equations and sensitivity to dispersion and Coriolis effects", *Ocean Modeling* , 62, 39-55.
- Ma, G., Kirby, J. T. and Shi, F., 2013, ``Numerical simulation of tsunami waves generated by deformable submarine landslides", *Ocean Modelling*, 69, 146-165.
- 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.
- Ma, G., Shi, F. and Kirby, J. T., 2012, "Shock-capturing non-hydrostatic model for fully dispersive surface wave processes", *Ocean Modelling*, 43-44, 22-35.

(ii) Five other recent publications

- Shi, J., Shi, F., Kirby, J. T. Gu, G. and Ma, G., 2015, ``Pressure decimation and interpolation (PDI) method for a baroclinic non-hydrostatic model", *Ocean Modelling*, 96, 265-279.
- Wu, G., Shi, F., Kirby, J. T., Mieras, R., Liang, B., Li, H. and Shi, J., 2016, "A pre-storage, subgrid model for simulating flooding and draining processes in salt marshes", *Coastal Engineering*, 108, 65-78.
- Tehranirad, B., Harris, J. C., Grilli, A. R., Grilli, S. T., Abadie, S., Kirby, J. T. and Shi, F., 2015, "Far-field tsunami hazard on the western European and US east coast from a large scale flank collapse of the Cumbre Vieja volcano, La Palma", *Pure and Applied Geophysics*, DOI 10.1007/s00024-015-1135-5.
- Chen, J., Hsu, T., Shi, F., Raubenbeimer, B., and Elgar, S., 2015, ``Hydrodynamic and sediment transport modeling of New River Inlet (NC) under the interaction of tides and waves", *J. Geophy. Res.* , DOI: 10.1002/2014JC010425
- Shi, F., Vittori, G. and Kirby, J. T., 2015, ``Concurrent correction method for modeling morphological response to dredging an offshore sandpit", *Coastal Engineering* , 97,1-10.

D. Synergistic Activities

Convener and chair of session of nearshore processes at AGU 2008 Fall Meeting
Session chair of 32nd international conference of coastal engineering, 2010
Editorial board of the scientific world journal - oceanography

G. Collaborators and Other Affiliations

(i) Collaborators

P. Barnard (USGS), Chris Chickadel(UW), Gregor P Eberli (U. Miami), Steve Elgar(WHOI), Li Erikson(USGS), V. Farquharson (U. Washington), R. Geller (U. Tokyo), Stephan Grilli(URI), Merrick Haller(OSU), J. Hansen (USGS), Rob Holman (OSU), T.-J., Hsu (U. Delaware), T. Janssen(Theiss Research), J. Kirby (U. Delaware), Gangfeng, Ma (Old Dominion U.), T. Masterlark (U. Alabama), Jamie MacMahan(NPS), J/ Puleo (U. Delaware), Ad Reniers(UM), John Ramsy (Applied Coast.), B. Raubenbeimer (WHOI), Ad Reniers (U. Miami), D. Tappin (British Geological Survey), Audrey Sawyer(U. Kentucky), G. Vittori (U. of Genoa), Chris Waythomas(USGS)

(ii) Graduate and Postgraduate Advisees

Master graduate student: Yunfeng Chen (graduated 2010, Educational Testing Service, co-advise with Kirby)
PhD students: Jian Shi (CSC support), Guoxiang Wu (CSC support), Jialin Chen (co-advise with Hsu), Mohammad Keshtpoor (co-advise with Puleo)
Post-doc: Wenzhou Zhang (Xiamen University)

(iii) Ph.D. Thesis Advisor:

Shizuo Feng, Department of Physical Oceanography, Ocean University of Qingdao.

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Education

University of Delaware, USA, 2000, Ph.D. in Climatology
University of Liège, Belgium, 1984, M.S. in Oceanography
University of Liège, Belgium, 1983, B.S. in Geography and B.S. in Education (summa cum laude)

Experience

2014-present: Associate Research Professor, Department of Ocean Engineering (OCE), University of Rhode Island (URI)
2006–2014: Assistant Research Professor, OCE-URI
2004-2005: Research Scientist, OCE-URI.
2003-2005 : Independent Consultant in Environmental Engng., Narragansett, RI.
2002-2003 : Research Scientist, Applied Sciences Associates, Narragansett, RI.
2000-2002 : Post Doctoral researcher, OCE-URI.
1993-2000 : Independent Consultant, Narragansett, Rhode Island.
1988-1991 : Research Assistant in Climatology, University of Delaware.
1984-1987: Research/Teaching Assistant/Lecturer in regional planning. Department of Geography, University of Liège (Belgium).

Professional Societies/Honors

2010-2012: Appointed member of the National Research Council (NRC) “Marine and Hydrokinetic Energy Technology Assessment” committee, of the National Academies.
2010-: Member of the “American Geophysical Union”.
2007-: Member of the “International Society for Offshore and Polar Engineers”.
1992-98: Member of the “American Geographical Society”.
1988-1989 : Lefranc Foundation Travel/Research scholarship, University of Liège (Belgium).

Book

Marine and Hydrokinetic Energy Technology Assessment Committee, 2013. National Research Council. *An Evaluation of the U.S. Department of Energy's Marine and Hydrokinetic Resource Assessments*. Washington, DC: The National Academies Press, 154 pages, 978-0-309-26999-5, http://www.nap.edu/catalog.php?record_id=18278.

Selected Recent Journal and refereed Proceedings Articles

Shelby, M., Grilli, S. T. and Grilli, A. R., 2016. Tsunami hazard assessment in the Hudson River Estuary based on dynamic tsunami-tide simulations. *Pure and Applied Geophysics*, 53 pps. (accepted with minor changes).

Grilli, S.T., Grilli A.R., David, E. and C. Coulet 2016. Tsunami Hazard Assessment along the North Shore of Hispaniola from far- and near-field Atlantic sources. *Natural Hazards*, 1-34 pps. , doi: 10.1007/s11069-016-2218-z (published online 2/15/17)

Grilli, S.T., Grilli, A.R., Tehranirad, B. and J.T. Kirby 2015. Modeling tsunami sources and their propagation in the Atlantic Ocean for coastal tsunami hazard assessment and inundation mapping along the US East Coast. To appear in *Proc. 2015 COPRI Solutions to Coastal Disasters Conf*. (Boston, USA. September 9-11, 2015), American Soc. Civil Eng., 12 pps.

Tehranirad B., Harris J.C., Grilli A.R., Grilli S.T., Abadie S., Kirby J.T. and F. Shi, 2015. Far-field tsunami hazard in the north Atlantic basin from large scale flank collapses of the Cumbre Vieja volcano, La Palma. *Pure and Applied Geophysics*, **172**(12), 3,589-3,616 doi:10.1007/s00024-015-1135-5.

Grilli, A.R., Grilli S.T., David, E. and C. Coulet 2015. Modeling of tsunami propagation in the Atlantic Ocean Basin for tsunami hazard assessment along the North Shore of Hispaniola. To appear in *Proc.*

25th Offshore and Polar Engng. Conf. (ISOPE15, Kona, HI, USA. June 21-26, 2015). Intl. Society of Offshore and Polar Engng., 8 pps.

Grilli, A.R. and E.J. Shumchenia, 2014. Toward wind farm monitoring optimization: assessment of ecological zones from marine landscapes using machine learning algorithms. *Hydrobiologia*, 1-21, DOI 10.1007/s10750-014-2139-3 (published online 12/12/14).

Grilli, A.R. and M.L. Spaulding 2013. Offshore wind resource assessment in Rhode Island waters. *Wind Engineering,* **37**(6), 579-594, doi:10.1260/0309-524X.37.6.579.

O'Reilly C., Grilli A. and G. Potty 2013. Micrositing Optimization of the Block Island Wind Farm, RI, USA. In *Proc. Intl. Conf. Ocean, Offshore and Arctic Engineering* (OMAE 2013, Nantes 6/9-14/13), paper OMAE2013-10191, pp. V008T09A009; 9 pps., doi: 10.1115/ OMAE2013-10191.

Gemme, D.A., Bastien, S.P., Sepe R.B., Montgomery J., Grilli S.T. and Grilli A.R. 2013. Experimental Testing and Model Validation for Ocean Wave Energy Harvesting Buoys. In *Proc. IEEE Energy Conversion Congress and Exposition* (ECCE13, Denver CO, September, 2013), paper 1407, 337-343

Grilli, A.R., Lado, T., and M. Spaulding 2012. A protocol to include ecosystem services in a wind farm cost model. *J. Environmental Engineering* **139**(2), 176-186, doi:10.1061/(ASCE)EE. 1943-7870.0000599.

Grilli, A.R., Lado, T. and M.L Spaulding 2011. Ecosystem services typology: a wind farm siting tool. In *Proc. 21th Offshore and Polar Engng. Conf.* (ISOPE11, Maui, HI June 19-24, 2011), 525-532, Intl. Society of Offshore and Polar Engng.

Grilli, S.T., Grilli, A.R., Bastien, S.P., Sepe, Jr., R.B., and M.L. Spaulding 2011. Small Buoys for Energy Harvesting: Experimental and Numerical Modeling Studies. In *Proc. 21st Offshore and Polar Engng. Conf.* (ISOPE11, Maui, HI, USA, June 19-24, 2011), 598-605, Intl. Society of Offshore and Polar Engng.

Grilli, A.R., Spaulding, M.L. and C. Damon 2010. Methods for Wind Farm Siting Optimization: New England Case Study. In *Proc. 20th Offshore and Polar Engng. Conf.* (ISOPE10, Beijing, China, June 20-25, 2010), 727-734, Intl. Society of Offshore and Polar Engng.

Spaulding, M.L., Grilli, A.R., and C. Damon 2010. Application of technology development index and principal component analysis and cluster methods to ocean renewable energy facility siting. *J. Marine technology Soc.*, **44**(1), 8-23.

Bastien, S.P., Sepe, R.B., Grilli, A.R., Grilli S.T., and M.L. Spaulding 2009. Ocean Wave Energy Harvesting Buoy for Sensors. In *Proc. IEEE Energy Conversion Congress and Exposition* (ECCE09, San Jose CA, September, 2009), **3**,718-3,725, doi: 978-1-4244-2893-9/09/.

Selected Recent Research reports

Grilli A.R. and S.T. Grilli, 2013. Modeling of tsunami generation, propagation and regional impact along the U.S. East Coast from the Azores Convergence Zone. *Research Report no.* **CACR-13-04**. NTHMP Award, #NA10NWS4670010, US National Weather Service Program Office, 20 pp.

Grilli A.R. and S.T. Grilli, 2013. Far-Field tsunami impact on the U.S. East Coast from an extreme flank collapse of the Cumbre Vieja Volcano (Canary Island). *Research Report no.* **CACR-13-13**. NTHMP Award, #NA10NWS4670010, US National Weather Service Program Office, 13 pp.

Grilli A.R. and S.T. Grilli, 2013. Modeling of tsunami generation, propagation and regional impact along the upper U.S East coast from the Puerto Rico trench. *Research Report no.* **CACR-13-02**. NTHMP Award, #NA10NWS4670010, US National Weather Service Program Office, 18 pp.

Grilli S.T., Tajalli-Bakhsh, T.S., Grilli, A.R. and J. Harris 2012. Fine grid simulations of tsunami hazard along the Mozambique coast. *Technical Report for Phase III.* Ocean Engineering, University of Rhode Island, 52 pps.

Recent graduate student advisees

Olivier Taylor (MS), Chris O'Reilly (MS), Rebekka Gieschen (MS); Lauren Schambach (current MS student).