# NTHMP FY17 Grant Project Narrative

| Project Name/Title: | U. S. East Coast: Improvements to Source and Inundation Modeling Procedures and Results |
|---|---|
| **Project Dates:** | September 1, 2017 – August 31, 2019 |
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## Executive Summary


**(Provide overview of effort, include objectives and how those objectives will be achieved (10,000 characters or less):**

During **FY10-13**, we started analyzing tsunami hazard to develop inundation maps for the US East Coast (USEC). In the process, we simulated far-field co-seismic tsunami sources from the Puerto Rico Trench (PRT) and the Açores convergence zone (LSB), and a flank collapse of the Cumbre Vieja Volcano (CVV) (Grilli et al., 2010, 2015a; Abadie et al., 2012; Harris et al., 2012, Tehranirad et al., 2015a; Grilli and Grilli, 2013a,b,c). In parallel, we sited, parameterized, and modeled a few near-field SMFs as Currituck slide proxies represented as rigid slumps (Grilli et al., 2015b). This work led to developing first-generation tsunami inundation maps (maximum envelope) for a nearly continuous coastal region extending from Ocean City, MD (Tehranirad et al., 2014) to Cape Cod, MA, with less continuous coverage to the south including Virginia Beach, VA, Cape Hatteras, NC, Myrtle Beach, SC and Savannah, GA. Coverage excluded major bays or estuaries such as Chesapeake Bay, Delaware Bay, Hudson River, Long Island Sound and Narragansett Bay (see reports at http://www.udel.edu/kirby/nthmp/ nthmp_protect.html; Tehranirad et al, 2014, 2015c-k). The continuation of this inundation mapping work has led to a reasonably comprehensive coverage to date of tsunami impact along the USEC (Fig. 1), with the exception of Florida, where DEM and updated source information has only recently become available. Florida inundation mapping is being completed during the first half of 2017.

In **FY14**, we addressed several important issues as part of three tasks:

**(i)** We investigated 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 FY10-13 work, but these investigations did not take into account any potential effects of the tidal conditions. Here, we assessed whether a combined tide-tsunami scenario could potentially lead to more hazardous conditions than would be expected from linear superposition alone. We found that tidal effects in Chesapeake Bay, although causing measurable changes in the incoming tsunamis, did not cause a significant increase in runup and/or inundation (Tajalli Bakhsh et al., 2015); in the Hudson River estuary, 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., 2015, 2016). This will eventually impact the next generation of inundation maps.
**(ii)** The current USEC inundation maps include landslide tsunamis resulting from 4 Currituck SMF proxies, parameterized as rigid slumps (Fig. 3). Here, we started the process of refining these sources by: (1) including a broader set of SMF cases from the geological record, such as landslide sources in the West Bahamas Bank (Schnyder et al., 2016), (2) performing a broader range of inundation simulations for the CVV flank collapse, for smaller volumes than the extreme 450 $km^3$ slide volume used to date (Tehranirad et al., 2015a); this led to selecting a 80 $km^3$ for inundation mapping, and (3) examining the tendency of the wide EC continental shelf to provide a somewhat source-independent control on the longshore distribution of tsunami elevation; this analysis combined direct wave modeling and ray-tracing and showed 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., 2015a, 2016).
**(iii)** We started comparing 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 still working on development of a joint methodology.

In **FY15**, we worked on three main technical tasks:
**(i)** We started organizing a landslide tsunami model benchmarking and validation workshop, that was held Jan. 9-11, 2017 in Galveston, TX (http://www1.udel.edu/kirby/landslide/index.html). The outcomes are still being worked out but are expected to be a set of community accepted model benchmarking tests, a web-based documentation of workshop and related data, and recommendations for NTHMP-MMS as of acceptable landslide tsunami modeling methodology.
**(ii)** We continued our FY14 effort of 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. In doing so, we started revisiting the modeling of the 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., 2016); see example in Figs. 2 and 4 (this led to

the work reported in Grilli et al., 2016c). Applying deforming slide models however requires specifying realistic rheological and frictional properties, which must be informed by field data. We expect guidance from USGS (e.g., J. Chaytor) in this respect (see for instance Chaytor et al., 2014 for new SMF sources off of the Florida straight).
**(iii)** As there is a vast area of the coastline to cover, we continued the FY14 effort of assessing tsunami hazard for unmodeled East Coast sites. We collected additional FEMA flood maps and continued applying the testing method developed during FY14 to objectively compare the FEMA and NTHMP maps and infer information for the unmodeled areas.

In **FY16**, we are working on 4 technical tasks, which are partially completed or about to start, aimed at:
**(i)** assessing maritime hazard for the USEC in terms of tsunami currents, based on information stored during FY10-15 inundation studies.
**(ii)** presenting tsunami mapping results and products to state EMA managers
**(iii)** continuing to simulate SMF events with recently developed models for landslide tsunami generation, as described for FY15 above. Deforming slide simulations for the Currituck SMF proxy in the Hudson River Canyon (Area in Fig. 3) have been compared to earlier results based on rigid slumps (Grilli et al., 2016c), which showed that deforming slides, in general, cause less inundation than the rigid slumps; hence, the latter used so far in USEC inundation mapping are conservative. The siting and parameterization of additional selected SMFs will be based on the most recent field data, in collaboration with USGS, once they complete their analysis and disseminate results based on their cruise data.
**(iv)** developing a modeling methodology for hazard from meteo-tsunamis, or meteorologically forced surface wave patterns resulting from fast moving squall lines (Figs. 12-14). These have been shown to be important for the EC when considering events with a 100-200 year return period (Vilibic et al., 2014). This task also initiates work on estimating return periods of the various considered tsunami sources.

Starting work on some FY16 tasks has been delayed due to significant time spent by both PIs in preparing and running the Landslide Tsunami Model Benchmarking Workshop, held on Jan. 9-11, 2017. This workshop was very successful, with an attendance of about 30 participants, including key national and NTHMP players as well as many invited international experts (http://www.udel.edu/kirby/landslide/index.html). Fig. 2 illustrates one of the selected mandatory benchmarks (BM #4). All workshop results will be disseminated on the workshop webpage and in the form of proceedings and paper(s); this will be done as part of FY16 work and continue in FY17 proposed Task 1 (see below).

For **FY17**, we propose working on 2 technical tasks, with an additional Task 3 covering travel for CC member Kirby to NTHMP annual meeting and to MMS summer meeting; additionally the subawardee budget for tasks 1 and 2 covers travel of Grilli to meet Kirby either at his home institution or another venue to coordinate work on project tasks.

*Task 1* continues work on return periods of tsunami sources, which are important to EMA managers and other stakeholders. *Task 2* considers hazard from meteo-tsunamis, which have been shown to be important for the east coast, including collaboration with the group initiating a tsunami detection effort by HF radar on the USEC. The *2 proposed technical tasks* include:

Task 1: *Development of estimates of tsunami return periods*: Continue work initiated in FY16 on estimation of return periods of extreme tsunamis from various sources used in inundation mapping with emphasis on landslide and meteo-tsunamis.

Task 2: *Simulation and evaluation of meteo-tsunami hazard*: Simulation of propagation and coastal impact of meteo-tsunamis generated on the wide EC shelf, for representative events of 100-200 year return period.

As for FY10-FY16 work, tsunami modeling will be carried out with FUNWAVE-TVD, a 2D Boussinesq model, in Cartesian or spherical coordinates (Shi et al., 2012a; Kirby et al., 2013), and NHWAVE, a 3D, sigma-coordinate RANS non-hydrostatic model (Ma et al, 2012). FUNWAVE-TVD is used for tsunami propagation and inundation, and has been benchmarked for NTHMP inundation and current modeling. The model has recently been extended to include a sediment transport capability in order to analyze morphology adjustments during tsunami events (Tehranirad et al, 2015b, 2016a,b) as proposed in task 4. The pressure forcing mechanism required for meteo-tsunami simulations in Task 5.1 has also previously been implemented in the model, and a demonstration of the accuracy of the model in generating ship waves is discussed in the supporting document. NHWAVE is used to model landslide tsunami generation for various slide types and rheologies.

We stress that no new model development will be done in FY17 using NTHMP funding, particularly for SMF tsunamis, for which the PIs have an active NSF project (2015-2018) to "develop the next generation of landslide tsunami simulation models". The two tasks above are thus primarily intended to support the MMS outcome: "Tsunami hazard assessment that supports informed decision making in tsunami-threatened communities." Task 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 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 ".

## Background

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

In contrast to the long history of tsunami hazard assessment on the US West coast and Hawaii, tsunami hazard assessment along the 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 (such as the PRT, LSB and CVV sources used so far). Moreover, considerable geologic and some historical evidence (e.g., the 1929 Grand Bank landslide tsunami, the Currituck slide site off North Carolina and Virginia, the South New England slide complex, and the West Bahamas slide off of Florida) suggests that the most significant tsunami hazard in this region may arise from SMFs triggered on the continental slope by moderate seismic activity; such tsunamigenic landslides can potentially cause concentrated coastal damage affecting specific communities (Grilli et al., 2009, 2015b, 2016c; ten Brink et al., 2014).

The proposing team of Kirby and Shi (UD), and S. Grilli and A. Grilli (URI) has over 20 years of experience developing and applying tsunami generation and propagation models for various sources. Since FY10, they performed NTHMP-funded work aimed at developing tsunami inundation maps for the USEC. Work to date has been entirely on topics related to MMS strategies and outcomes. Specifically, we modeled inundation resulting from potential coseismic, SMF, and volcanic cone failure (Fig. 5), events in the Atlantic basin, in support of the goal of developing tsunami inundation maps for coastal communities along the USEC. FY10-12 work centered on development of an initial set of tsunami sources and high resolution mapping of priority DEMs from Ocean City, MD to Cape Cod, MA (Fig. 1). FY13 work modeled additional regions further 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. FY14-15 work continued the mapping effort, with the inclusion of extreme SMF proxy sources off the upper USEC (rigid slumps in 4 areas; Fig. 3). Additional work was also conducted to: (i) estimate tsunami inundation risk and magnitude in the not-yet-mapped areas based on FEMA storm inundation maps and an analysis of the effect of the continental shelf in determining tsunami wave height distribution; and (ii) 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. Ongoing work in FY16 re-evaluates SMF sources using more realistic rheologies and the impact this has on USEC tsunami risk. Fig. 4 illustrates such results, for the SMF proxy sited off of the Hudson River canyon, and confirms that tsunami inundation from a rigid slump is a worst case scenario, as compared to 3 moderately deforming slides of various rheology with identical volume and location. More work in this respect will be performed in FY16.

In this work, tsunami modeling was performed using state-of-the-art models that were benchmarked as part of NTHMP workshops (Tehranirad et al, 2011, 2012; Shi et al, 2012b) for use in NTHMP-sponsored work, including: (i) FUNWAVE-TVD, a Boussinesq long wave model used to model 2D (horizontal) tsunami propagation in Cartesian or spherical coordinates (Shi et al., 2012a; Kirby et al., 2013), and (ii) NHWAVE, a 3D sigma-coordinate RANS model (Ma et al, 2012) used to model tsunami generation from landslide sources (Ma et al., 2013, 2015; Kirby et al., 2016; Grilli et al., 2015b, 2016c). NHWAVE can be used to simulate landslide tsunami generation for slides represented as a dense viscous fluid (Figs. 2, 4), a granular flow, or a debris flow, as required to perform work proposed in Task 1. FUNWAVE-TVD was recently extended to include a sediment transport capability in order to analyze morphology adjustments during tsunami events (Tehranirad et al, 2015b, 2016a,b). The pressure forcing mechanism required for meteo-tsunami simulations in Task 2 has also previously been implemented in the model, and a demonstration of the accuracy of the model in generating ship waves is discussed in the supporting document (Figs. 12-14).

More specifically:

(1) NHWAVE models dispersive wave response to SMF or subaerial slide 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 dense viscous flows (Kirby et al, 2016; Grilli et al., 2016c) or granular debris flows (Ma et al, 2015). All three forms of the NHWAVE model were recently benchmarked as part of the NTHMP landslide tsunami model benchmarking workshop held in Galveston, TX, Jan. 9-11, 2017 (Fig. 2). The full reporting, additional analyses, and disseminations of results of this important workshop, based on earlier similar NTHMP workshops, could take up to 1-2 years.

(2) FUNWAVE and the basic version of NHWAVE are open source, publically available models, that 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. While we have mostly considered rigid SMFs in our inundation mapping work to date (Grilli et al., 2015a,b), which yield worst case scenario SMF tsunamis, during FY15-16 we started modeling deformable SMFs using the most recent versions of NHWAVE (Ma et al., 2013, 2015; Kirby et al., 2016). We started assembling a set of model results based on deforming slide calculations (Grilli et al., 2016c). We will be coordinating the siting and parametrization of additional selected SMFs and subaerial slides with USGS as soon as they have processed and distributed the necessary field data.

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.

**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 estimates of tsunami return periods**

This task continues an ongoing effort by considering additional types of tsunami sources, such as meteo-tsunamis.

**Task 2: Simulation and evaluation of meteo-tsunami hazard**

This task continues an ongoing effort by applying the modeling methodology being developed in FY16 to simulating the propagation and coastal impact of meteo-tsunamis generated on the wide EC shelf, for events of 100-200 year return period.

**Task 3: Travel to NTHMP meetings**

## 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 estimates of tsunami return periods.*

In this task, we will continue work on estimation of return periods of extreme tsunamis from various sources used in inundation mapping with emphasis on landslide and meteo-tsunamis.

This activity was initiated as part of FY16 work and involves a reevaluation of tsunami sources used for inundation mapping along the USEC, in terms of a recurrence period, which so far have been treated as "Probable Maximum Tsunami" (PMT) sources, and combined in inundation maps, without a consideration of their return period. While some of these sources may have a return period of a few hundreds to a thousand years (e.g., the seismic sources in Puerto Rico and in the Açores convergence zone), others may have much longer, but unknown, return periods (e.g., the nearshore submarine mass failures and volcanic collapse sources). Hence, the current inundation maps do not allow putting east coast tsunami risk in perspective with other more probable flood risks, such as from hurricanes with 100 or 500 year periods, which is a concern for EMA managers.

For this reason, it was proposed to *initiate this activity* during FY16 and first concentrate on landslide tsunamis from nearshore sources, which up to now have been assumed to represent the highest tsunami hazard along the USEC. Another reason was that new 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), which is not yet available from USGS. For submarine mass failures (SMFs), however, 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, once fully analyzed, can be used for estimating SMF tsunami return periods. On this basis, the study of SMF return periods initiated in FY16 is based on revisiting and improving the earlier Monte Carlo analysis of Grilli et al. (2009) for upper USEC landslide tsunami sources, using both the most recent field data, once made available by USGS, as well as our recent SMF tsunami generation models.

In FY17, we propose to continue the evaluation of the return periods of landslide tsunamis. We will evaluate the more recent landslide sources identified for the upper USEC in the "Southern New England slide complex", and for the southern USEC (e.g., West Bahamas Bank, Florida straight) (J. Chaytor; presentation at NTHMP landslide workshop, Jan., 2017).

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

1. "Develop new tsunami hazard products to assist the maritime community and meet emergency management and other NTHMP customer requirements"

| Date of expected completion | Describe what will be achieved (bullet/short form) |
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| August 31, 2019 | • Continue probabilistic analysis of east coast SMF events for new sources identified by USGS, based on updated information on shelf sediments and geotechnical properties in order to estimate the return period of these events<br>• Develop a methodology for evaluating the return period of mete-tsunamis |
| | Task 2 Total Cost: **$51,467** |

Task 2: *Simulation and evaluation of meteo-tsunami hazard*

In this task, we will simulate the propagation and coastal impact of meteo-tsunamis generated on the wide EC shelf, for events of 100-200 year return period.

Meteo-tsunamis, resulting from resonant forcing of surface waves by atmospheric pressure anomalies, represent a potential source of maritime hazard and shoreline inundation along the US East Coast, which is bordered by wide shallow shelves (Vilibic et al, 2014; Thomson et al., 2009). These events are being considered in East Coast work for the first time in FY16, with an eye towards assessment of the hazard associated with return periods of 100-200 years.

Meteo-tsunamis can be created by derechos, or fast-moving bands of severe thunderstorms, whose translation speeds can be near the long wave velocity on the shelf. In this case, energy is 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 meteo-tsunami which was apparently generated by a rapidly moving storm which tacked across New Jersey and moved directly offshore (Wertman et al., 2014). The resulting meteo-tsunami 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. (2014a,b) 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. One goal of this task will be to re-examine the 100-200 year return period analysis in light of hazard assessment on the U.S. East Coast.

In FY16 work, we are presently using the Boussinesq model FUNWAVE-TVD (Shi et al., 2012) extended to include the effect of an imposed atmospheric pressure forcing of arbitrary form in $(x,y,t)$, to begin the modeling of the generation, propagation, and coastal impact of extreme meteo-tsunamis (similar to or even slightly stronger than the 2013 event). Our focus is on the examination of the interaction between storm size, forward speed and track, and the resulting potential for meteo-tsunami wave generation. In our present work, we will assess the spatial distribution and variability of coastal impacts for conditions leading to large meteo-tsunami. The tsunami generation phase will be modeled using FUNWAVE-TVD, 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 6 for an idealized example). Meteo-tsunami 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,

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| 2014, 2015 a-k, for example). We 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 is 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.<br><br>The pressure forcing mechanism required for meteo-tsunami simulations is an operational component of the FUNWAVE-TVD model, and is presently also being used in a project funded by the US Army Corps of Engineers to model ship waves and associated shoreline impacts in harbors and navigation channels. A demonstration of the accuracy of the model in generating ship waves using a surface pressure is discussed in the supporting documentation. | |
| List all NTHMP Strategic Plan Outcome and Strategies that this task addresses.<br><br>"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<br><br>August 2019 | Describe what will be achieved (bullet/short form)<br><br>• Estimation of a meteo-tsunami climatology with return periods in the range of 100-200 years for east coast continental shelf.<br><br>• Model validation using observed results such as the 2013 event off of New Jersey. |
| | Task 5 Total Cost: **$62,030** |

Task 3: *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 and MMS technical meeting (Travel Category 1).

1. 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.

2. 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.

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

| Date of expected completion | Describe what will be achieved (bullet/short form) |
|---|---|
| August 2018 | Attendance of CC and MMS members at NTHMP meetings |
| | Task 3 Total Cost: **$6,792** |

## 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 |
|---|---|---|
| | | |
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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. Tsunami return periods | **8/19** | **$51,467** |
| 2. Simulation of meteo-tsunami | **8/19** | **$62,030** |
| 3. Travel to NTHMP meetings | **8/18** | **$6,792** |
| Total FY17 Grant Request | **-------------------** | **$120,290** |

**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


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## Supporting Information

(a) (b)

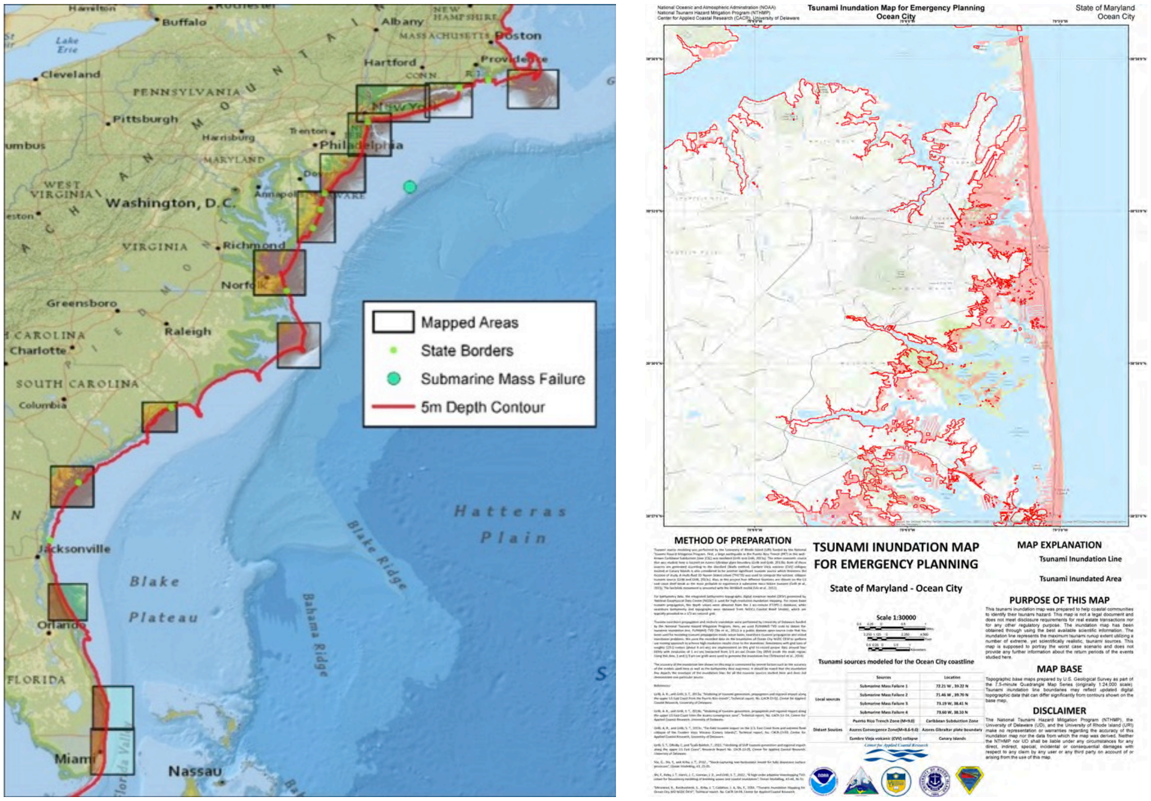



*Figure 1. (a) USEC regions covered by high resolution modeling (UPDATE) (Florida sites to be completed in FY15). (b) Example of completed inundation map for Ocean City, MD*

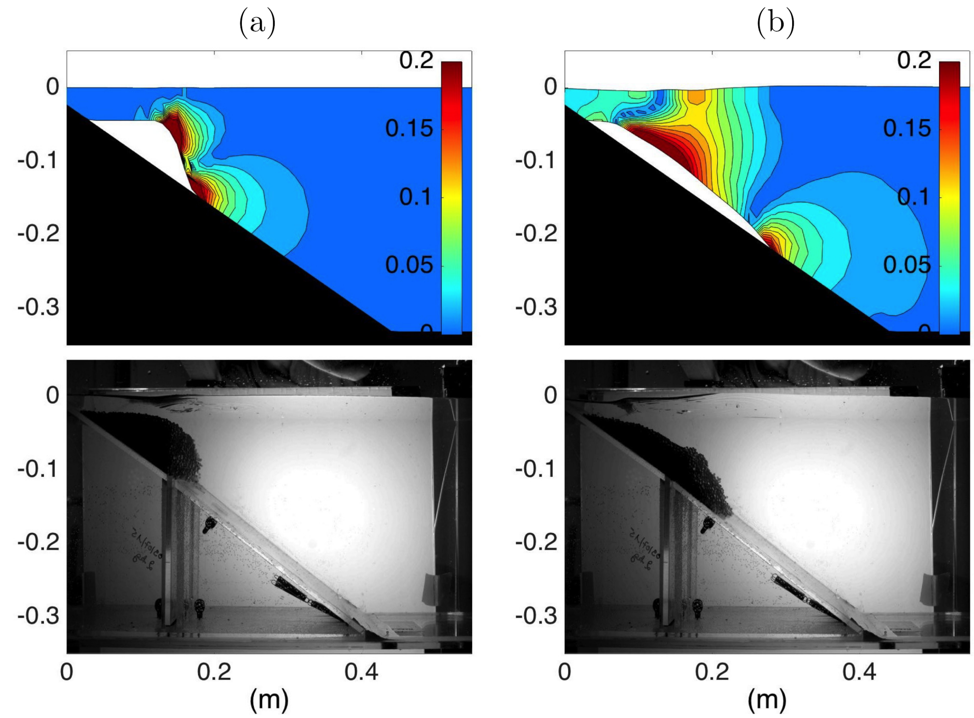



*Figure 2. Comparison of model simulations of deforming slide tsunami generation and glass bead experiments (see Grilli et al., 2016c). This was selected as Benchmark #4 of workshop (http://www1.udel.edu/kirby/landslide/index.html).*

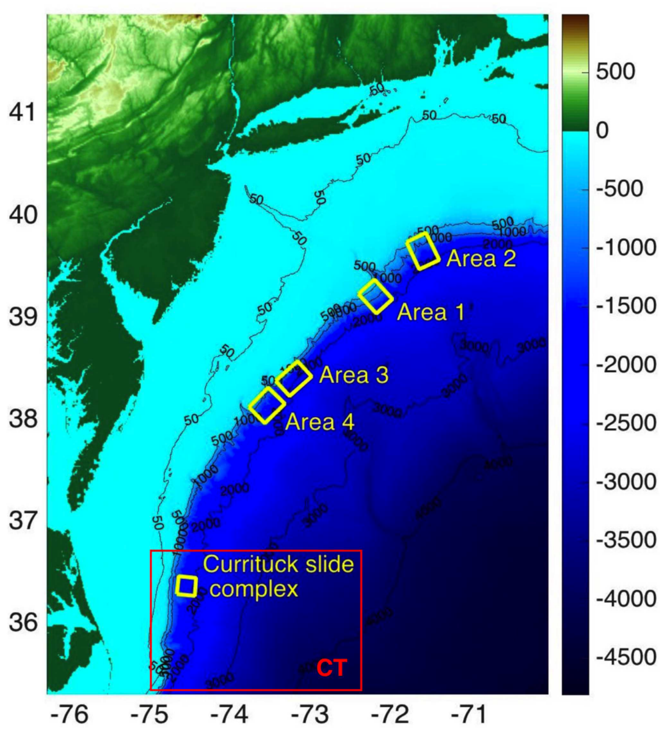



*Figure 3. Area of the Currituck slide complex (CT) and Areas 1-4 where Currituck Proxy SMFs were sited and modeled to perform NTHMP tsunami inundation mapping to date (Grilli et al., 2015b, 2016c)*

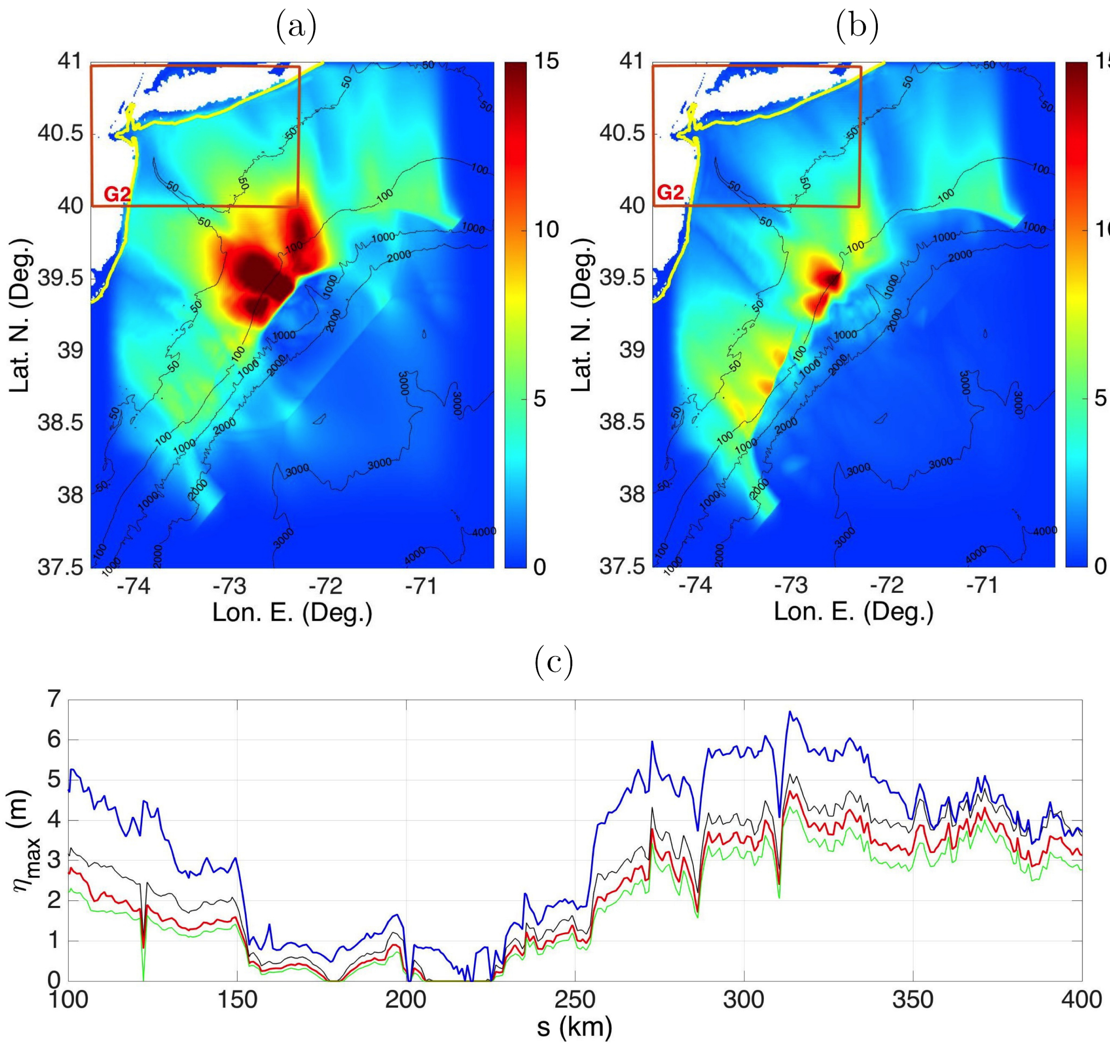
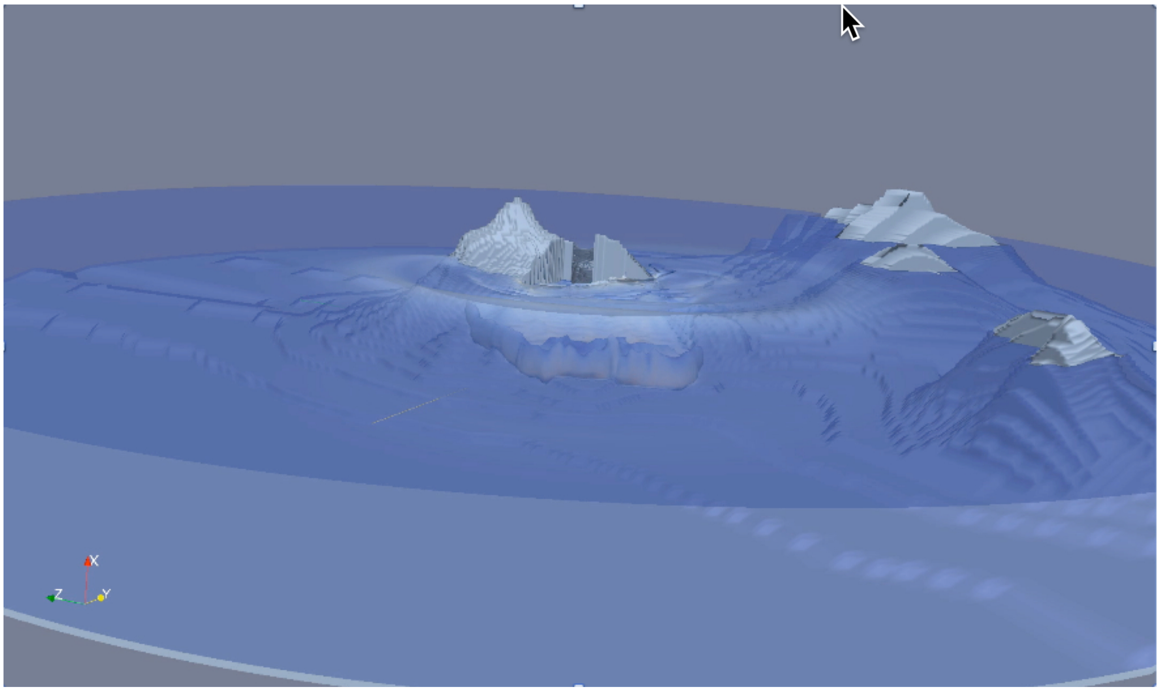



*Figure 4. Tsunami generation by a submarine mass failure in the Hudson River Canyon. Maximum surface elevation assuming a rigid slump (a) or a deforming slide (b) (Grilli et al., 2016c). Maximum tsunami elevation at the 5 m isobaths (yellow line in Figs. 4a,b) for the rigid slump (blue) and deforming slides of varying rheology (green, red, black)*

(a)



(b)

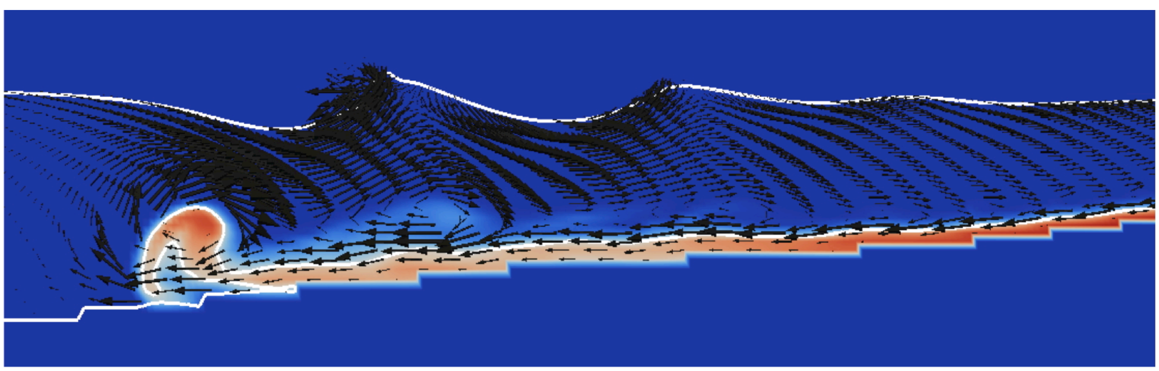


*Figure 5: Snapshot in Navier-Stoke simulations with model THETIS (Abadie et al., 2012) of the Cumbre Vieja Volcalo (La Palma) flank collapse/subaerial slide, for the most extreme 450 km$^3$ volume scenario. (a) View of 3D simulations with both surface wave generation(towards nearby Canary Islands) and underwater slide; (b) Cross-section in the main direction of wave generation (WSW) showing the generation of very large, nearly breaking waves (several 100 m high at this stage) and velocity vectors in both water and the dense fluid slide material.*

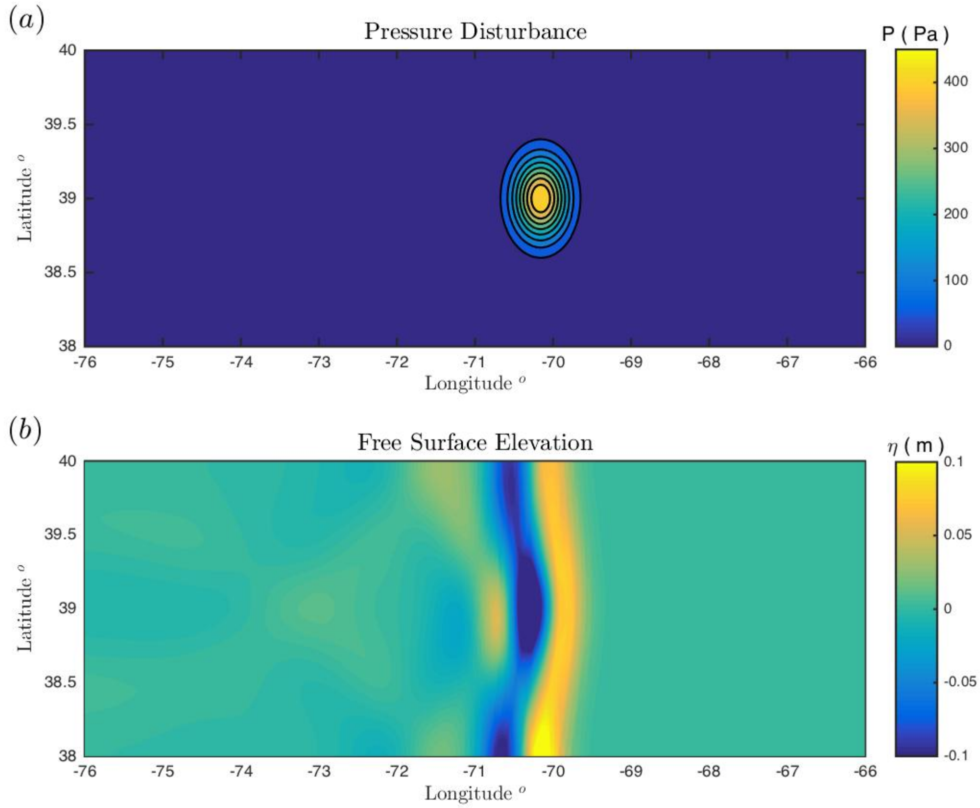



*Figure 6: An idealized meteotsunami example. A Gaussian pressure distribution with major and minor axes = 30 km and central pressure deficit of 450 Pa translates at speed 20m/s over a water body of constant depth 40m. (top) pressure field. (bottom) Surface wave pattern computed by Boussinesq model FUNWAVE. 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.*

## Surface wave response to atmospheric pressure forcing in Funwave-TVD

Surface forcing by variable atmospheric pressure has been implemented in FUNWAVE-TVD in connection with a U.S. Army Corps of Engineers-funded project associated with shoreline erosion caused by ship-waves. In the model, moving ship hulls are represented by imposed pressure anomalies of a given shape, amplitude and translational speed. The moving pressure distribution is applied on the free surface as a source term in the FUNWAVE momentum equations to simulate ship generated waves (e.g., Torsvik et al., 2008). The model has been tested using the laboratory experiment of Gourlay (2001), who investigated waves generated by a vessel traveling at a supercritical speed in a narrow channel.

The generation of large surface waves in response to a pressure impulse moving at or close to the critical speed for shallow water waves is strikingly close to the situation on the shelf, where meteo-tsunamis are generated by more general forms of atmospheric disturbance, also moving across the surface at the speed of free surface waves. It is thus of value to establish that FUNWAVE-TVD's response to such forcing, in the case of weakly dispersive wave propagation (as is characteristic of tsunami wave behavior on the shelf), is accurate. This is established here by comparing model results to experimental data for the case of a ship hull moving at critical speed in a shallow channel bounded by sidewalls (Gourlay, 2001). In this case, the ship forces the presence of an elevated shelf of water in front of the advancing hull, which then develops, through an undular bore-like process, into a train of advancing solitons or solitary waves. Figure 7 shows the modeled soliton generation with a fast moving pressure source (red curve). The model/data comparison in Figure 8 shows a good agreement between the model and measured data.

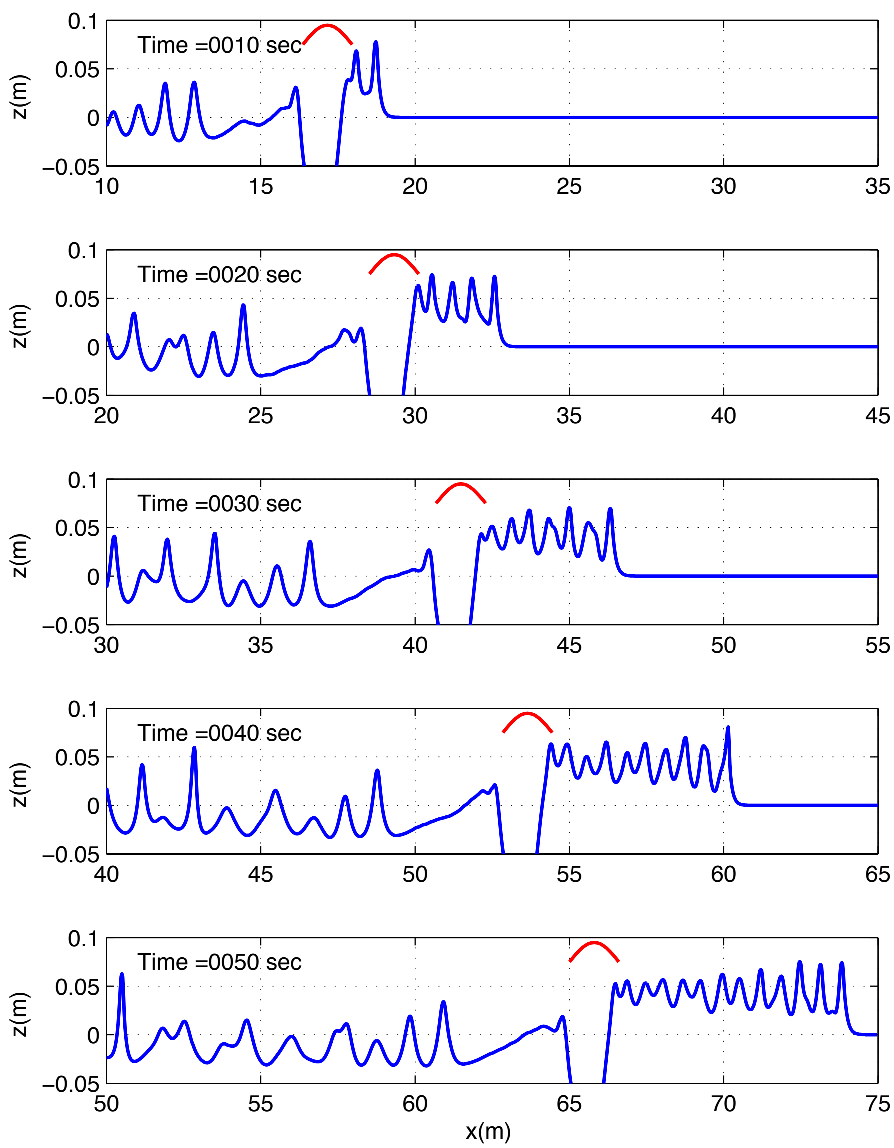


*Figure 7:. Snapshots of modeled surface elevations generated by a moving pressure source (Gourlay, 2001).*

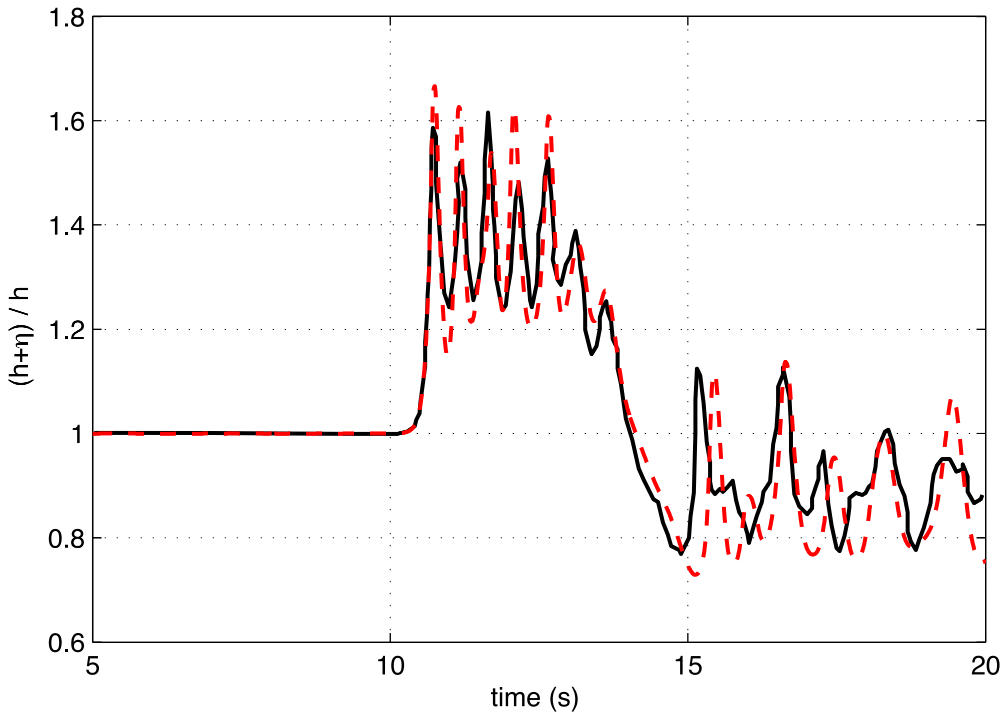



*Figure 8. Comparison of time series of total depth ($h + \eta$) normalized by still water depth h for model (red dashed line) and experiment data (black solid line, Gourlay, 2001).*

# BIOGRAPHICAL SKETCH

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## A. Professional Preparation

| | | |
|---|---|---|
| Brown University | Engineering | Sc. B., 1975 |
| Brown University | Engineering | Sc. M., 1976 |
| 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. Lynett, P. J., Gately, K., Wilson, R., Montoya, L., Arcas,D., Aytore, B., Bai, Y., Bricker, J. D., Castro, M. J., Cheung, K. F., David, C. G., Dogan, G. G., Escalante, C., González, F. I., González-Vida, J. M., Grilli, S. T., Heitmann, T. W., Horrillo, J., Kânoğlu, U., Kian, R., Kirby, J. T., Li, W., Macías, J., Nicolsky, D. J., Ortega, S., Pampell-Maniso, A., Park, Y. S., Roeber, V., Sharghivand, N., Shelby, M., Shi, F., Tehranirad, B., Tolkova, E., Thio, H. K., Velioğlu, D., Yalçıner, A. C., Yamazaki, Y., Zaytsev, A., Zhang, Y. J., 2016, "Inter-model analysis of tsunami-induced coastal currents", *Ocean Modelling*, under revision.
2. Grilli, S. T., Shelby, M., Kimmoun, O., Dupont, G., Nicolsky, D., Ma, G., Kirby, J. T. and Shi, F., 2017, "Modeling coastal tsunami hazard from submarine mass failures: effect of slide rheology, experimental validation, and case studies off the US East Coast", *Natural Hazards*, **86**, 353-391, doi:10.1007/s11069-016-2692-3.
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*, **13**, 1421-1434, doi:10.1007/s10346-016-0682-x.
4. Schnyder, J. S. D., Eberli, G. P., Kirby, J. T., Shi, F., Tehranirad, B., Mulder, T., Ducassou, E., Hebbeln, D. and Wintersteller, P., 2016, "Tsunamis caused by submarine slope failures along western Great Bahama Bank", *Scientific Reports (Nature),* **6**, 35925, doi:10.1038/srep35925.
5. 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*, **142**(6), 03116005, doi:10.1061/(ASCE)WW.1943-5460.0000350</a>.
6. Prestininzi, P., Abdolali, A., Montessori, A., Kirby, J. T. and La Rocca, M., 2016, "Lattice Boltzmann approach for hydro-acoustic waves generated by tsunamigenic sea bottom displacement", *Ocean Modelling*, **107**, 14-20, doi:10.1016/j.ocemod.2016.09.012.
7. Derakhti, M., Kirby, J. T., Shi, F. and Ma, G., 2016, "NHWAVE: Consistent boundary conditions and turbulence modeling", *Ocean Modelling*, 106, 121-130, doi:10.1016/j.ocemod.2016.09.002.
8. 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, doi:10.1002/2014JC010385
9. 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 .
10. 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 .

11. 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 .
12. 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", *Natural Hazards.*, **76**, 705-746, doi: 10.1007/s11069-014-1522-8.
13. 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.
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 Modelling*, **62**, 39-55.
15. 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", *Pure and Applied Geophysics*, **170**, 1333-1359.
16. Ma, G., Kirby, J. T. and Shi, F., 2013, "Numerical simulation of tsunami waves generated by deformable submarine landslides", *Ocean Modelling*, **69**, 146-165.
17. 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.
18. 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.
19. 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.

### 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. Co-convener, NTHMP Landslide Tsunami Workshop, Jan. 9-11, 2017.
4. Member, Board of Directors, American Institute of Physics (2011-2013).
5. 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, and the surface and terrain following nonhydrostatic model NHWAVE.
6. 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).

**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 (2016,xxx), Babak Tehranirad (2016, Moffatt-Nichol), 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, 2015-2016, NWS); Morteza Derakhti (postdoc, 2016)

**Biographical Sketch for Stephan Grilli**

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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 :** (https://personal.egr.uri.edu/grilli/resume.html; h-index: 38)

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., 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.
21. Grilli, S.T., Grosdidier S. and C.-A. Guérin (2016). Tsunami detection by High Frequency Radar beyond the continental shelf. I. Algorithms and validation on idealized case studies. *Pure and Applied Geophysics*, **173**(12), 3,895-3,934, doi: 10.1007/s00024-015-1193-8 (published online 10/28/15).
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. *Nat. Hazards*, **82**(2), 777-810, doi: 10.1007/s11069-016-2218-z
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 Appl. Geophysics*, **173**(12), 3,999-4,037, doi:10.1007/s00024-016-1315-y
24. Grilli, S.T., Shelby, M., Kimmoun, O., Dupont, G., Nicolsky, D., Ma, G., Kirby, J. and F. Shi (2016). Modeling coastal tsunami hazard from submarine mass failures: effect of slide rheology, experimental validation, and case studies off the US East coast. *Natural Hazards*, **86**, 353-391, doi:10.1007/s11069-016-2692-3

**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* (2010-2016), 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-).

**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, 25 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), M. Shelby (MS; NUWC, Newport), O. Taylor (MS); T. Tajelli-Baksch (PhD; ASA-RPS Ltd), Chris O'Reilly (current PhD student, URI and Navatek Ltd.), Amin Mivehchi (current PhD student, URI), Lauren Schambach (current PhD student, URI), Patrick Moran (current MS student, URI).

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

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## Education

| | | | |
|---|---|---|---|
| University of Liège, Belgium | Geography (*summa cum Laude*) | B.S | 1983 |
| University of Liège, Belgium | Education (*summa cum Laude*) | B.S | 1983 |
| University of Liège, Belgium | Oceanography | M.S. | 1984 |
| University of Delaware, USA | Climatology | Ph.D. | 2000 |

## Experience

| | |
|---|---|
| 2013-2015 | Associate Research Professor, Depart. Ocean Engng, University of Rhode Island |
| 2005-2012 | Assistant Research Professor, Depart. Ocean Engng, University of Rhode Island |
| 1993-2004 | Consultant for Applied Sciences Associates, Narragansett, Rhode Island. |

**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**

Spaulding, M.L., Grilli, A.R., Damon, C., Fugate, G., Oakley, B.A., Isaji T., Schambach, L., 2017. Application of state of art modeling techniques to predict flooding and waves for an exposed coastal area. *J. Marine Science and Engineering* (accepted, in press)

Spaulding, M.L., Grilli, A.R., Damon, C., Crean, T., Fugate, G., Oakley, B.A. and Stempel, P. 2016. STORMTOOLS: Coastal Environmental Risk Index (CERI). *J. Marine Science and Engineering*, *4*(3):54, doi:10.3390/jmse4030054

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*, **173**(12), 3,999-4,037, doi:10.1007/s00024-016-1315-y

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*, **82**(2), 777-810, doi: 10.1007/s11069-016-2218-z

Grilli S.T., M. Shelby, A.R. Grilli, C.-A. Guérin, Samuel Grosdidier and T. Lado Insua 2016. Algorithms for tsunami detection by High Frequency Radar : development and case studies for tsunami impact in British Columbia, Canada. In *Proc. 26th Offshore and Polar Engng. Conf.* (ISOPE16, Rodos, Greece. June 2016), Intl. Society of Offshore and Polar Engng., pps. 807-814

Schambach L., Grilli A.R., Hashemi M.H., King J. and S.T. Grilli 2016. Modeling the impact of historical storms on the Rhode Island shoreline. Presented at the *ASBPA 2016 National Coastal Conference* (Long Branch, NJ, 10/16).

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, 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.

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).

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**Recent graduate student advisees**

Taylor Asher (MS), Chris O'Reilly (MS), Rebekka Gieschen (MS); Lauren Schambach (MS); Gregory Wescott (MS).