NTHMP Grant Semi-Annual Progress Report

NOAA Grant Award Number:
Period of performance (start date to end date of entire grant): September 1, 2014 – August 31, 2015

Award reporting period (date range): February 1, 2015 – August 31, 2015

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Date of this report: October 5, 2015

Instructions: add rows to the table below as needed to complete reporting on all tasks awarded. Fill in all cells within the table. Make sure that task titles match the current Project Narrative for this grant.

Task #	Task title	Progress made during this reporting period	Challenges and successes	% of total task completed
1	*Tidal effects on tsunami inundation at estuarine and river entrances*	*A methodology was developed for performing dynamic simulations of tide and tsunamis with*		100%

		FUNWAVE-TVD, to estimate effects of tide elevation, current and phase on tsunami inundation, in estuaries subjected to significant tidal forcing. This method was applied to the Chesapeake Bay and Hudson River estuaries.		
2	*Refinement and extension of potential SMF sources and source modeling techniques for tsunami activity in the North Atlantic*	*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. This work has been reported at several conferences, and a journal paper is in preparation for submittal to Science.*	Work on south Florida inundation maps as part of this grant and FY13 funding was held up awaiting availability of NGDC DEM's for two areas in Florida. This work will be completed shortly. A list of mapping products which will result from this work is included below.	75%
3	*Examining the correspondence between tsunami and storm surge inundation estimates for use as the basis for mapping tsunami hazards in non-modeled U.S. East Coast areas*	*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*	Collaboration with Gulf of Mexico group established. Groups working on development of a joint methodology. An extensive ray tracing analysis has been conducted to examine the source-independent control on along-coast distribution of tsunami wave heights due to the	50% (100% of scope as established in this grant)

		in storm probability and shelf geometry that we are just developing an understanding of now. We are also examining 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. Preliminary results have been presented at or accepted for conferences	wide US East Coast shelf. A journal paper covering this work is in preparation	

During this reporting period, was any budget reprogramming required for this award? If so…

a. Date reprogramming approved by NWS Tsunami Program Office: some time after 11/2/2014
b. Date approved by NOAA Grants Office: 12/17/2014

c. Describe where funds were moved and why: Money was moved from student tuition category to cover the purchase a new PC needed to improve GIS capabilities for mapping, and to cover a portion of costs for a new computer node on UD cluster farber.hpc.udel.edu. (UD computer resources have otherwise been extensively used as a free standby resource for the duration of NTHMP activities – this is NTHMP's first contribution to supporting this resource.)

General comments from recipient about progress during this reporting period:

BACKGROUND

In contrast to the long history of tsunami hazard assessment on the US West coast and Hawaii, tsunami hazard assessment along the eastern US coastline 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 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.

In FY10-12, we have begun the process of hazard analysis and inundation map development for the U. S. East Coast. Simulating tsunami sources from the PRT, CVV and Azores-Gibraltar convergence zone, together with a number of relevant near-field SMF, we have concentrated on developing tsunami inundation maps for a nearly continuous coastal region located north of Ocean City, MD to Cape Cod, MA, plus Myrtle Beach, SC, including Long Island Sound but excluding major bays or estuaries such as Chesapeake Bay, Delaware Bay, the Hudson River and Narragansett Bay). FY13 work centered on continuing to develop inundation maps for the southern coastal areas along the US east coast, following the same methodology. While we were initially supposed to only model areas as far south as Georgia, after discussions with the NTHMP U.S. Gulf Coast group, we have extended the geographic range of our region of responsibility to also include the Atlantic coast of Florida, thus effectively placing the state of Florida in two different NTHMP regions. Our proposed new tasks in FY13 were inundation studies for Virginia Beach/Norfolk VA, Savannah GA, Jacksonville FL, Miami Beach FL and Palm Beach FL using existing source information as well as new sources developed for the West Bahama Banks. Similar to our earlier work during FY 10-12, modeling in this project is being carried out using a set of models developed at the University of Delaware, including FUNWAVE-TVD (a Boussinesq model for tsunami propagation and inundation simulations, in Cartesian or spherical coordinates, and NHWAVE, a RANS three-dimensional, sigma-coordinate model for simulating fully non-hydrostatic short wave response to large scale ground motion. FUNWAVE and NHWAVE are open source, publically available programs, which have been benchmarked according to NTHMP standards 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 in a series of nested grids of increasingly fine resolution. Both models deal with breaking dissipation via a TVD algorithm and also implement bottom friction. We use NHWAVE to compute the initial tsunami waves generated from SMF sources (both translational slides and rotational slumps), and, once the tsunamigenic part of the SMF is complete, we will continue simulating tsunami propagation in FUNWAVE. In addition to results needed to construct inundation maps, we are collecting information on flow fields and velocities in affected navigable inlets and harbor facilities that will be useful in future navigation hazard analysis.

New tasks covered by the present FY14 project include:

Task 1: Tidal effects on tsunami inundation at estuarine and river entrances.

Task 2: Refinement and extension of potential SMF sources and source modeling techniques for tsunami activity in the North Atlantic.

Task 3: Developing guidelines for tsunami hazard estimation in non-modeled U. S. East Coast areas.

ACCOMPLISHMENTS

The following section summarizes the status of accomplishments for each Objective and related Tasks funded under this grant award. Summary descriptions are organized according to the overall objectives of the NTHMP that reflects the Sub-Committee structure. The work is divided between the two participating institutions, with the University of Rhode Island working on source identification and tsunami generation and large scale/regional propagation modeling, and the University of Delaware working on tsunami nearshore propagation and inundation modeling and on developing the final inundation maps.

The method consisted in superimposing tide and tsunami forcing along the offshore boundary of a regional coastal grid. For deep enough waters, the elevation and current of both tide and tsunami can be linearly combined. Time series of all the relevant tsunamis are pre-computed along the grid boundary and similar time series are computed for the tidal signal (essentially the M2 signal here). Tidal components are obtained in deep water from one of the NOAA models and tide-only simulations are first run to verify that the expected tidal signal is simulated at the NOAA tide gages within the estuary.

Joint tide-tsunami simulations are then performed for different phases of the tide to identify conditions leading to a larger inundation within the estuary. Results of the combined signal are analyzed and compared to a simple linear superimposition of tsunami and tide simulations, that identify significant nonlinear interactions where currents are important. This work was completed. While dynamic tide effects do not significantly affect tsunami inundation computed for a static tide level in the Chesapeake Bay and the James River, dynamic tide effects lead to an increased flooding by 0.2-0.8 m in the Hudson River Estuary, depending on the case and location, as compared to simulations over a static tide level. Details can be found in the reports: Tajelli-Bakhsh et al (2015) and Shelby et al (2015).

ANTICIPATED OUTCOMES

Results for the additional mapping efforts described here will be presented in the form of technical reports for each NGDC DEM or similarly sized coastal region, and in the form of draft inundation maps for coastal communities within the DEM regions. Project results are displayed at the project website http://www.udel.edu/kirby/nthmp.html and will be displayed at the NTHMP website ws.weather.gov/nthmp/index.html as they are finalized.

Mapping products which will be completed in the near future include:

Daytona Beach
1- Palm Coast, FL
2- Flagler Beach, FL
3- Daytona Beach, FL
4- Port Orange, FL
5- Edgewater, FL

Palm Beach
1- Palm City, FL
2- Hobe Sound, FL
3- Jupiter, FL
4- North Palm Beach, FL
5- Palm Beach, FL
6- Boynton Beach, FL
7- Deerfield Beach, FL

Miami
1- Pompano, FL
2- Fort Lauderdale, FL
3- North Miami Beach, FL
4- Miami, FL
5- Kendall, FL

These represent the balance of maps developed under FY10-12, FY13 and FY14 funding, giving partial coverage of the entire US East Coast by first generation maps along with archived marine products for later use.

PUBLICATIONS AND REPORTS BASED ON FY14 WORK

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., 2014 "Modeling of SMF tsunami hazard along the upper U. S. East Coast: Detailed impact around Ocean City, MD", *Natural Hazards*, 76, 705-746.

Shelby, M., Grilli, S. T. and Grilli, A. R., 2015, "Dynamic tide-tsunami interaction in the Hudson River estuary", Research Report CACR-15-10, Center for Applied Coastal Research, Dept. of Civil and Environmental Engineering, University of Delaware.

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 CACR-15-09, Center for Applied Coastal Research, Dept. of Civil and Environmental Engineering, University of Delaware.

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*, published online 21 July, doi:10.1007/s00024-015-1135-5.

PRESENTATIONS RESULTING FROM FY14 WORK

Grilli, S.T., Grilli, A.R., Tehranirad, B. and Kirby, J. T., 2015. "Modeling tsunami sources and their propagation in the Atlantic Ocean for coastal tsunami hazard assessment and inundation mapping along the US East Coast", presented at the *Joint Coastal Structures/Solutions to Coastal Disasters Conference*, Boston, September 9-11.

Schnyder, J. S. D., Kirby, J. T., Shi, F., Tehranirad, B., Eberli, G. P., Mulder, T., Ducassou, E. and Principaud, M., 2013, "Potential for tsunami generation by submarine slope failures along the western Great Bahama Bank", *6th Int. Symp. on Submarine Mass Movements and their Consequences*, GEOMAR, Kiel, September 23-25.

Schnyder, J. S. D., Kirby, J. T., Shi, F., Tehranirad, B., Eberli, G. P., Mulder, T. and Ducassou, E., 2013, "Potential for tsunami generation along the western Great Bahama Bank by submarine slope failures", Abstract NH41A-1689, *AGU Fall Meeting*, San Francisco, December.

Schnyder, J. S. D., Eberli, G. P., Kirby, J. T., Shi, F., Tehranirad, B., Mulder, T., Ducassou, E., Hebbeln, D. and Wintersteller, P., 2015, "Tsunamis caused by submarine slope failures along Western Great Bahama Bank", in preparation for *Science*

Tehranirad, B., Kirby, J. T., Banihashemi, S., Grilli, S. T., Tajalli Bakhsh, T. and Shi, F., 2014, "Tsunami inundation mapping on the upper East Coast of the U.S.", presented at *Young Coastal Scientists and Engineers Conference - North America*, Newark, July.

Tehranirad, B., Kirby, J. T., Callahan, J., Shi, F., Banihashemi, S., Grilli, S. T., Grilli, A., Tajalli Bakhsh, T. and O'Reilly, C. 2014, "Tsunami inundation mapping for the upper East Coast of the United States", *AGU Fall Meeting*, Abstract NH12A-04, San Francisco, Dec. 15-19.

Tehranirad, B., 2015, "Effects of bathymetry on tsunami propagation on the US East Coast: Application of ray tracing to tsunamis", presented at *Young Coastal Scientists and Engineers Conference - North America*, Newark, July.

Tehranirad, B., Kirby, J. T., Shi, F. and Grilli, S. T., 2015, "Does morphological adjustment during tsunami inundation increase levels of hazard?", presented at *Coastal Structures & Solutions to Coastal Disasters Joint Conference*, COPRI/ASCE, Boston, Sept. 9-11.

Tehranirad, B., Kirby, J. T., Shi, F., Grilli, S. T. and Grilli, A. R., 2015, "Is continental shelf bathymetry the main control for tsunami inundation patterns on the US East Coast?", to be presented at the *Geological Society of America Meeting*, Baltimore, October.