2011 Japan Tsunami: Oceanography
US: 8 RAPID & Japan: 5 J-RAPID projects

Mori et al., 2011

Flow Dynamics/Morphological Impacts of March 11 Tohoku Tsunami, Japan

JAPAN: Takashi Oguchi, Yuichi S. Hayakawa, Hitoshi Saito, Akitoshi Kobayashi, Univ. Tokyo

Objective: Understand the catastrophic geomorphic effects of the March 11 Tohoku-Oki Tsunami on the Sanriku Coast, Japan, using 2-d Hydraulic Modeling and Terrestrial Laser Scanning
Flow Dynamics/Morphological Impacts of March 11 Tohoku Tsunami, Japan: **Key Findings**

- Distinctive Valley and Slope Morphologies are Generated by the Erosive Effects of Repeated, Century-Scale Tsunami Since Mid-Holocene Along the Sanriku Coast, Northeast Honshu, Japan.

- There is an apparent threshold effect whereby the energy expenditures by the incidence tsunami waves must be high enough to exceed resistance factors imposed by vegetation-stabilized regolith on hillsides. When the threshold is exceeded, on approximate century time scales, catastrophic erosion and deposition are generated in the local zone of tsunami impact.

Flow Dynamics/Morphological Impacts of March 11 Tohoku Tsunami, Japan

**Opportunities for Future Research**

**What new questions raised by these events require basic research?**

The newly discovered tsunami erosion effects are all remarkably similar to what is observed for catastrophic fluvial erosion in bedrock channels.

**What new data are available as a result of these events?**

Inverse hydraulic modeling associates the causative tsunami velocities and unit stream powers with the observed Tohoku-Oki tsunami erosion features.

**What unique aspects of these events require the development of a focused research program?**

The distinctive high-energy erosion/deposition features constitute definitive signs of the highest energy tsunami events. Their high potential for long-term preservation affords an opportunity to reconstruct the physics of those events through the application of hydraulic modeling codes.

**What are the important lessons from these larger than expected events for the U.S.?**

Preservation of distinctive tsunami erosion features in other high-energy tsunami settings, such as those landward of the Cascadia Subduction Zone, may afford an opportunity to estimate tsunami magnitudes via the inverse modeling noted above.
RAPID: Reconnaissance of the 11 March 2011 Tohoku, Japan Tsunami

J-RAPID: Investigation on the 2011 Tohoku earthquake tsunami propagation, nearshore effects and mitigation by coastal structures

US: Hermann M. Fritz¹, Harry Yeh², Costas E. Synolakis³, David A. Phillips⁵ (subaward),
¹Georgia Institute of Technology, ²Oregon State University, ³University of Southern California, ⁴HCMR, ⁵UNAVCO
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Objectives:
• Initial rapid survey to document perishable tsunami characteristics as part of Tohoku Earthquake Tsunami Joint Survey Group (~300 participants).
• Specifying the failure mechanisms of various coastal structures and proposing efficient countermeasures.
• Extract tsunami hydrographs and current velocities from eyewitness videos calibrated with detailed terrestrial LiDAR based topography.

Key Findings
• 2011 Tohoku tsunami characteristics
  Tsunami height and inundation distance measurements in joint database (TETJSG); Runup height distributions for several historical events and numerical simulations were compared.
• Coastal Structure Failure mechanisms
  Combined Field, laboratory and numerical studies on coastal seawall failure mechanisms and tsunami block and boulder transport.
• Tsunami Hydrograph and Current velocities
  Detailed LiDAR topography at several sites, eyewitness video analysis resulted in tsunami hydrograph and current velocity measurements (Fritz et al., 2012, GRL-special section, published)
Opportunities for Future Research

What new questions raised by these events require basic research?
- Historic tsunami runup distributions and potential submarine landslides
- Tsunami characteristics for various event types including tsunami earthquakes
- Effectiveness and failure of various coastal tsunami mitigation structures
- Tsunami flooding velocities, boulder transport and sediment deposit records

What new data are available as a result of these events?
- Intermediate water depth GPS-buoy tsunami wave profiles
- High-density tsunami characteristics database for 5 overlapping historic events
- High-density LiDAR coastal flood zone and damage topography
- Video-derived temporal and spatially resolved tsunami hydrograph and currents
- Post-tsunami coastal structures and tsunami forest performance and failure data

What unique aspects of these events require the development of a focused research program?
- Link between advanced inundation data modeling, sedimentology and boulders
- Construction mitigation standards for various coastal structures against tsunamis

What are the important lessons from these larger than expected events for the U.S.?
- Revaluation of tsunami flood zones, evacuation maps, expected impact on navigation and coastal structures in case of design exceedence.

Collaborative Research: The Japan March 11 2011 Earthquake, Tsunami Inundation and Initial Spread of Fukushima Dai-ichi Radionuclides on the Pacific Ocean: Model Assessment

Team:
- Changsheng Chen, Zhigang Lai, Huichan Lin
  University of Massachusetts-Dartmouth (UMASS-D), USA
- Robert Beardsley, Jian Lin, Rubao Ji
  Woods Hole Oceanographic Institution (WHOI), USA
- Jun Sasaki
  Yokohama National University, Japan

Objective:
Model assessment of March 11 initial M=9 and M=7.9 earthquakes, the resulting tsunami wave generation, propagation and coastal inundation along northern Honshu Island, and the initial pathways and changes in Cs-237 concentrations as the contaminated cooling waters enter the coastal waters at the Fukushima Daiichi nuclear facility and spread across the shelf to deeper water.
Key Findings

• Model-simulated tsunami height, shape of dikes and harbor in front of NNP structure, and surrounding topography combined to cause significant flooding of NNP from the back (land) side.

• Model-simulated distribution and dispersal of Cs-137 strongly dependent of grid resolution of the local NNP geometry.

Opportunities for Future Research

• What new questions raised by these events require basic research?
  1. Improve design of NNP sea wall/harbor to protect/reduce damage from future tsunamis.
  2. Nested model system can be used to simulate ocean response to past and potential (idealized?) earthquakes near Japan.
  3. Can tsunami warning system be improved using nested model approach?

• What new data are available as a result of these events?
  1. Hindcast of March 11 earthquake-tsunami simulation can be used to test new NNP site configuration, other coastal marine structures.

• What unique aspects of these events require the development of a focused research program?

• What are the important lessons from these larger than expected events for the U.S.?
  1. Add earthquake ocean bottom movement into Global FVCOM operation in order to drive operational inundation forecast model systems along US coast.
“RAPID - Offshore Impacts of the Tohoku-Oki Earthquake: Seafloor Deformation, Sedimentation, Erosion, Tsunamigenesis”

Marie-Helene Cormier (U. Missouri), Leonardo Seeber & Cecilia McHugh (Columbia U.)
Toshiya Fujiwara (JAMSTEC) & Kenji Hirata (Meteorological Research Institute – JMA)

- What are the impacts of the 2011 earthquake near the trench?
- How did it contribute to the building of the accretionary prism?
- Do sediments preserve evidence for similar prior earthquakes?

Key Findings

- The field component of this project has not yet started: American and Japanese co-PIs met twice but a cruise opportunity has not yet materialized. A proposal will be submitted this month for a joint research cruise.

- Expected findings:
  1) Confirm (or not) whether significant slip occurred in 2011 on the normal fault that occurs about 50 km landward of the trench axis.
  2) Document the sedimentary processes that accompanied the 2011 earthquake and quantify the approximate recurrence interval of similar large earthquakes from the sedimentary record.
Opportunities for Future Research

• What new questions raised by these events require basic research?
  What factors control a “rupture-to-the-toe” during megathrust event?

• What new data are available as a result of these events?
  Japanese scientists have collected a wealth of high quality, diverse data, and more continue to be collected. These should provide vastly more information that what was available from the 2004 Sumatra earthquake.

• What unique aspects of these events require the development of a focused research program?
  The great water depths at subduction trenches pose a technological challenge to the international community with regards to the collection of high-resolution marine geophysical / geological data.

• What are the important lessons from these larger than expected events for the U.S.?
  A megathrust earthquake similar to the 2011 Japan earthquake is expected to occur at the Cascadia Trench.

Project Description/Objective

– RAPID title
  Time Series Sampling for Radionuclide and Biogeochemical Fluxes at F1 Time-series Station, Offshore Fukushima Dai-ichi Nuclear Power Facility

– US Researchers
  German, C., Manganini, S., Buesseler, K.
  (Woods Hole Oceanographic Institution)

– International counterparts
  Honda, M. C., Kawakami, H., Kitamura, M.
  (Japan Agency for Marine-Earth Science and Technology)

– Objective of RAPID
  To verify vertical transport of Fukushima artificial radionuclides by settling particles in the western North Pacific

– Tactics
  Collection of time-series settling particles by sediment traps deployed at stations F1, S1 and K2 in the western North Pacific
Key Findings

Deployment of sediment traps

$$^{134}\text{Cs}$$ in settling particles at 4810 m of stations K2 and S1

Detection of $$^{134}\text{Cs}$$ from sample collected after 6 April (Detail is shown on poster.)

Broader Impacts

As learned in the aftermath of Chernobyl, establishing the distributions and activities of radionuclides present in the environment as soon as possible post-release is important to understanding the severity of the releases that have occurred, their implications for public health, and to establish “time zero” conditions against which the wider oceanographic community can subsequently track the fate of long-lived (conservative and bio-geochemically-active) radionuclides. In addition to the strong international (WHOI-JAMSTEC) collaboration that has already been developed for this project, we will strive to share all data (to be banked with BCO-DMO) and samples collected by this work with the wider national and international science community and public. But the single greatest contribution we anticipate will be to provide timely, quantitative data, from which well-informed policy decisions can subsequently be made.
Participation in Marine Geophysical Surveys of the Tohoku Quake Rupture Zone

- University of Hawai`i
  G. Moore, J. Barnes, B. Boston
- IFREE/JAMSTEC

Objective: Image the geologic structure of the Tohoku quake epicentral region

Key Findings

- Repeat bathymetry surveys show evidence for landslide at base of trench slope with accumulation of debris in the trench
  - Frontal region shifted 50 m seaward
  - Causes effective 10 m uplift to generate tsunami
- Seismic reflection images show potential propagation along a décollement interface at the base of the frontal accretionary prism
  - Co-seismic rupture may have propagated all the way to the trench
Opportunities for Future Research

• We need to determine whether or not the rupture propagated all the way to the trench
  • IODP drilling in April, 2012 will help
  • Future seismic/bathymetric surveys will be necessary

• The new bathymetry and seismic reflection data will allow much more precise measurements of possible fault slip after additional data processing

• An important lesson for the U.S. is that co-seismic slip may be able to propagate all the way to the trench axis
  • We need to evaluate whether this may mean that potential quakes in the Aleutian or Cascadia regions could result in larger tsunami events than previously thought