Accuracy and Variability in Tsunami-Induced Current Predictions

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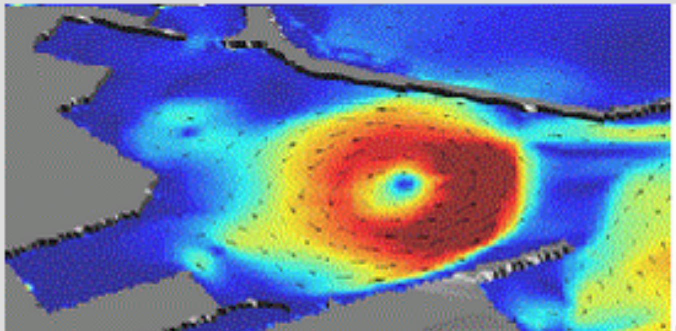
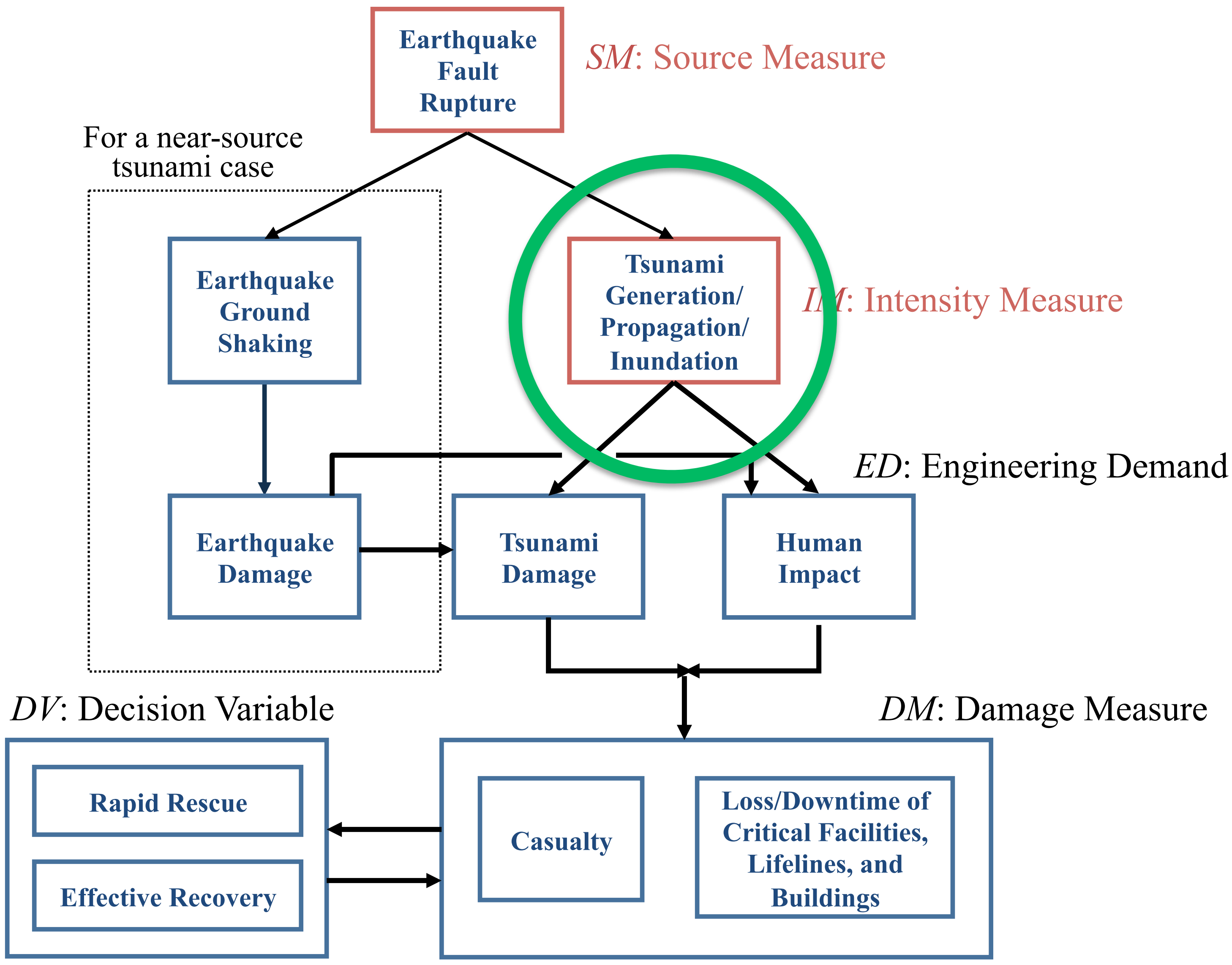



The March 2011 East Japan Tsunami: Onagawa

PEER Annual Meeting – Berkeley, CA

January 28-29, 2016

Performance Based Analysis for Tsunamis



- Examine model accuracy and inter-model variability for:
  - Coastal flows
    - Areas with eddies vs areas without eddies
    - Spatial averaging and ensembles
  - Overland flows
    - Flow depth vs speed
    - Statistical inter-model convergence
  - Point speed measurements useful for flow characterization?
  - Can we provide an expected model uncertainty?
  - Implications for load calculations

Inter-Model Comparison – Coastal Currents

JOURNAL OF GEOPHYSICAL RESEARCH: OCEANS, VOL. 118, 5703–5719, doi:10.1002/jgrc.20413, 2013

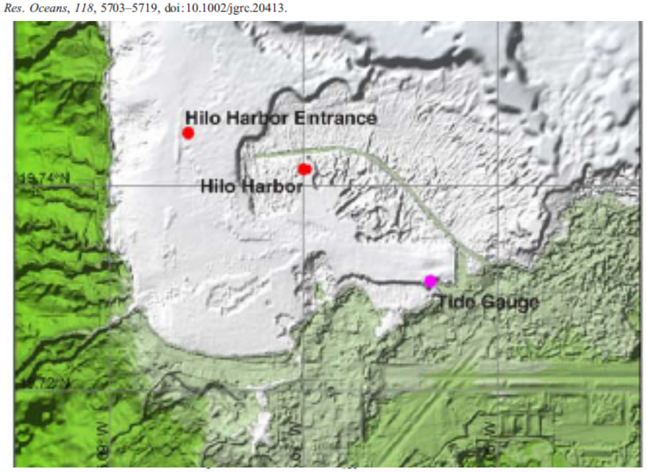
Surges around the Hawaiian Islands from the 2011 Tohoku Tsunami

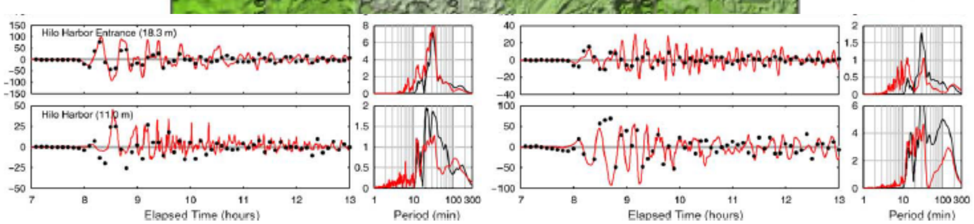
Kwok Fai Cheung,[1] Yefei Bai,[1] and Yoshiki Yamazaki[1]

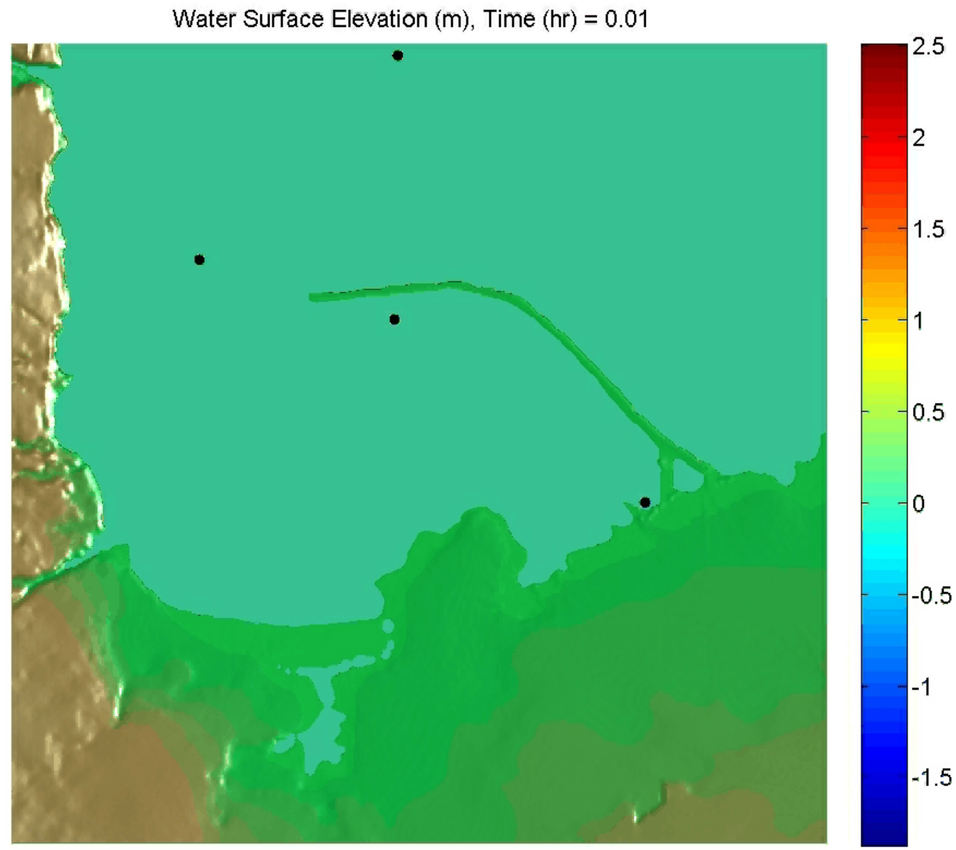
Received 6 June 2013; revised 19 August 2013; accepted 22 September 2013; published 22 October 2013.

[1] The 2011 Tohoku tsunami devastated the northeastern Japan coasts and caused localized damage to coastal infrastructure across the Pacific. The tsunami resulted in strong currents around the Hawaiian Islands that led to closure of harbors and marinas for up to 38 h after its arrival. We utilize a nonhydrostatic model to reconstruct the tsunami event from the seismic source for elucidation of the physical processes and inference of the coastal hazards. A number of tide gauges, bottom pressure sensors, and ADCPs provided point measurements for validation and assessment of the model results in Hawaii. Spectral analysis of the computed surface elevation and current reveals complex flow patterns due to multiscale resonance. Standing waves with 33–75 min period develop along the island chains, while oscillations of 27 min or shorter are primarily confined to an island or an island group with interconnected shelves. Standing edge waves with periods 16 min or shorter, which are able to form nodes on the reefs and inside harbors, are the main driving force of the observed coastal currents. Resonance and constructive interference of the oscillation modes provide an explanation of the impacts observed in Hawaii with implications for emergency management in Pacific island communities.

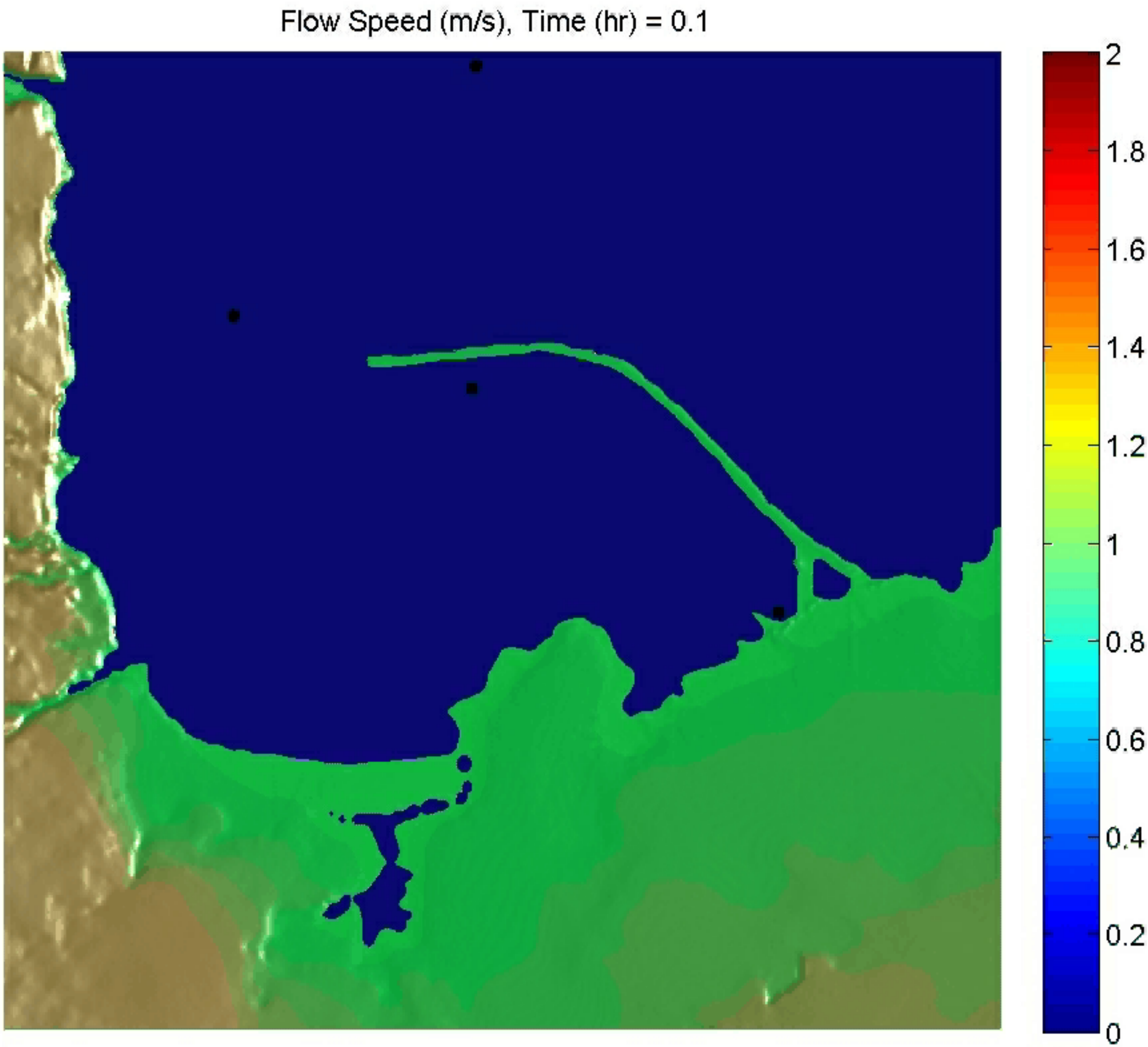
Citation: Cheung, K. F., Y. Bai, and Y. Yamazaki (2013), Surges around the Hawaiian Islands from the 2011 Tohoku Tsunami, *J. Geophys. Res. Oceans*, *118*, 5703–5719, doi:10.1002/jgrc.20413.



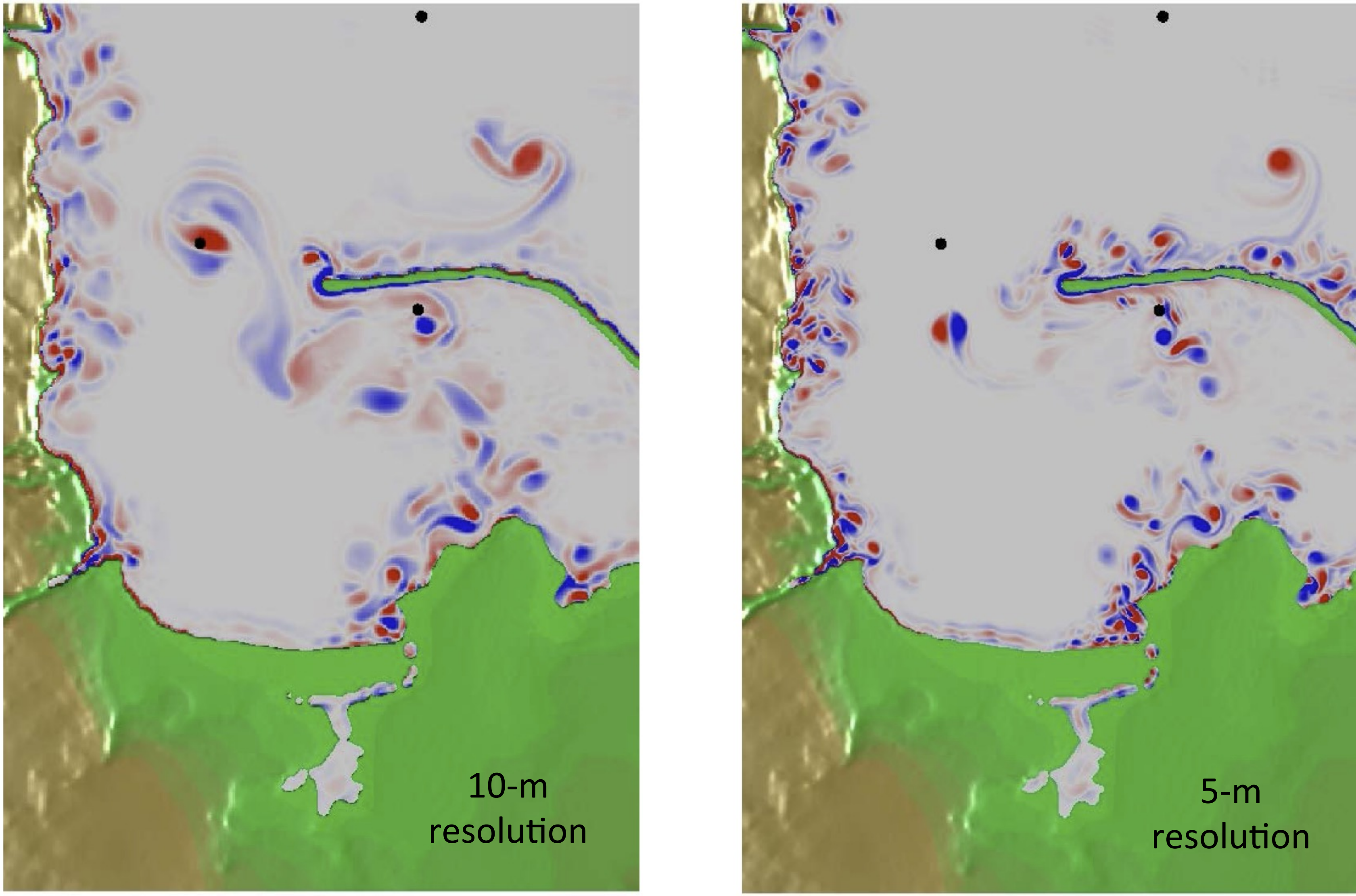




Inter-Model Comparison – Coastal Currents



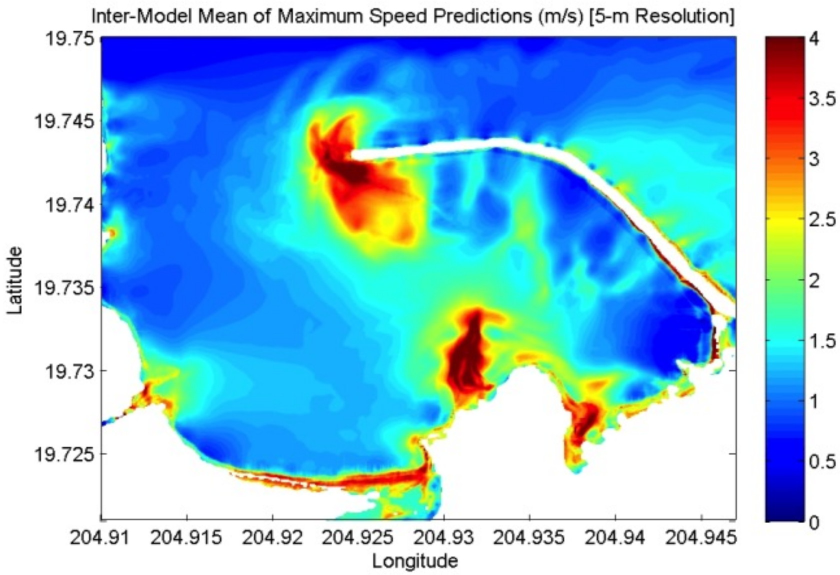
Inter-Model Comparison – Coastal Currents

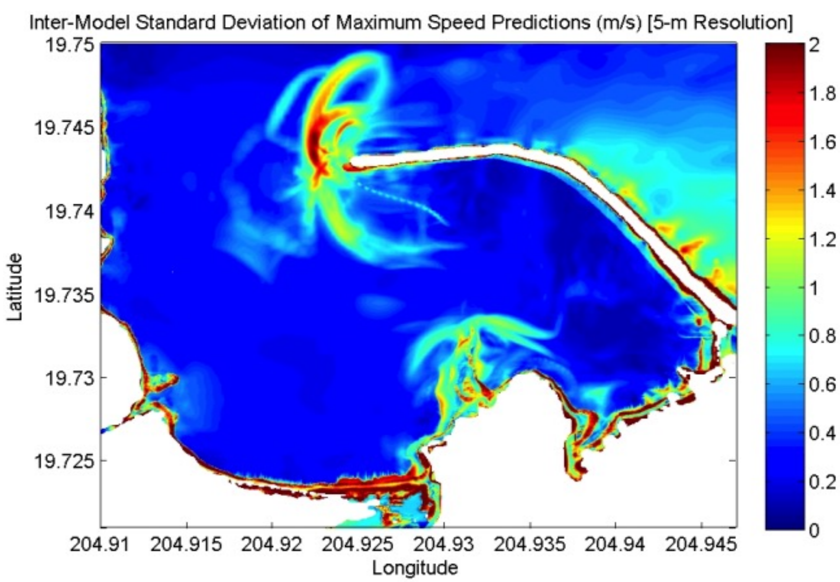


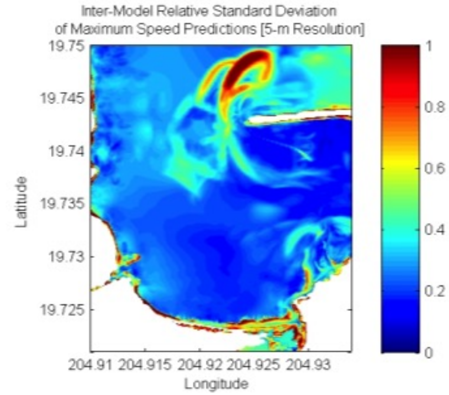
Images at the same physical time

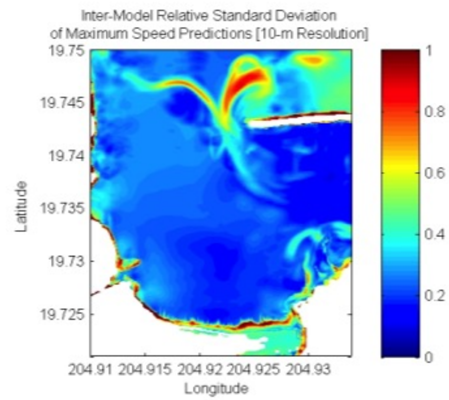
Inter-Model Comparison – Coastal Currents

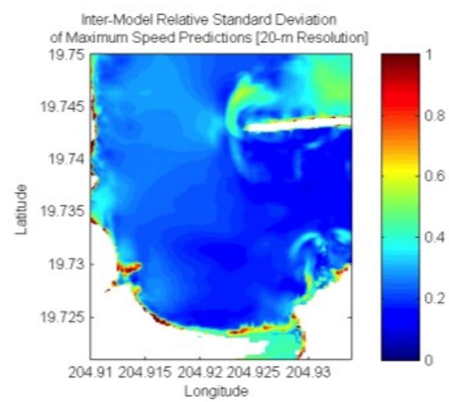
Largest inter-model differences are found in areas of eddies







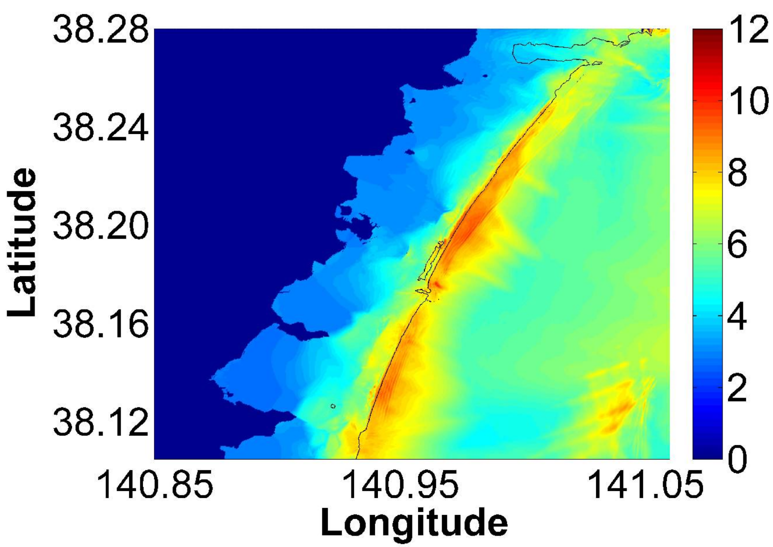


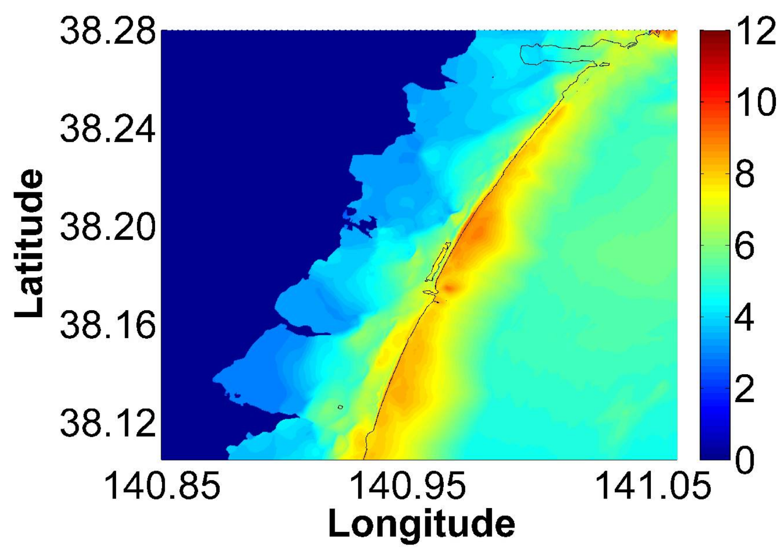


Predictions of eddy strength and path appears to be grid size dependent

Inter-Model Comparison – Overland Flow

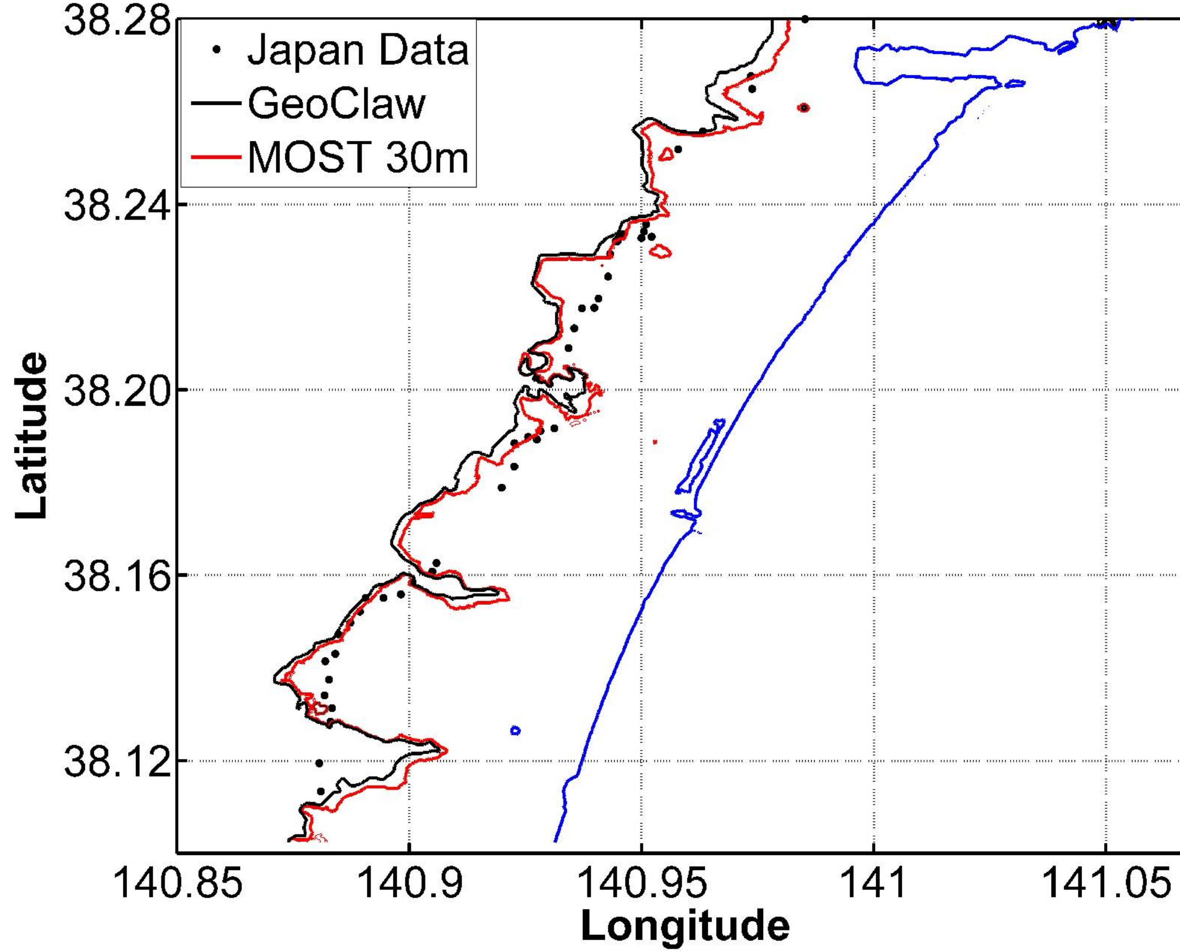
Inter-model comparison for flow over Sendai Plain during the 2011 Tsunami





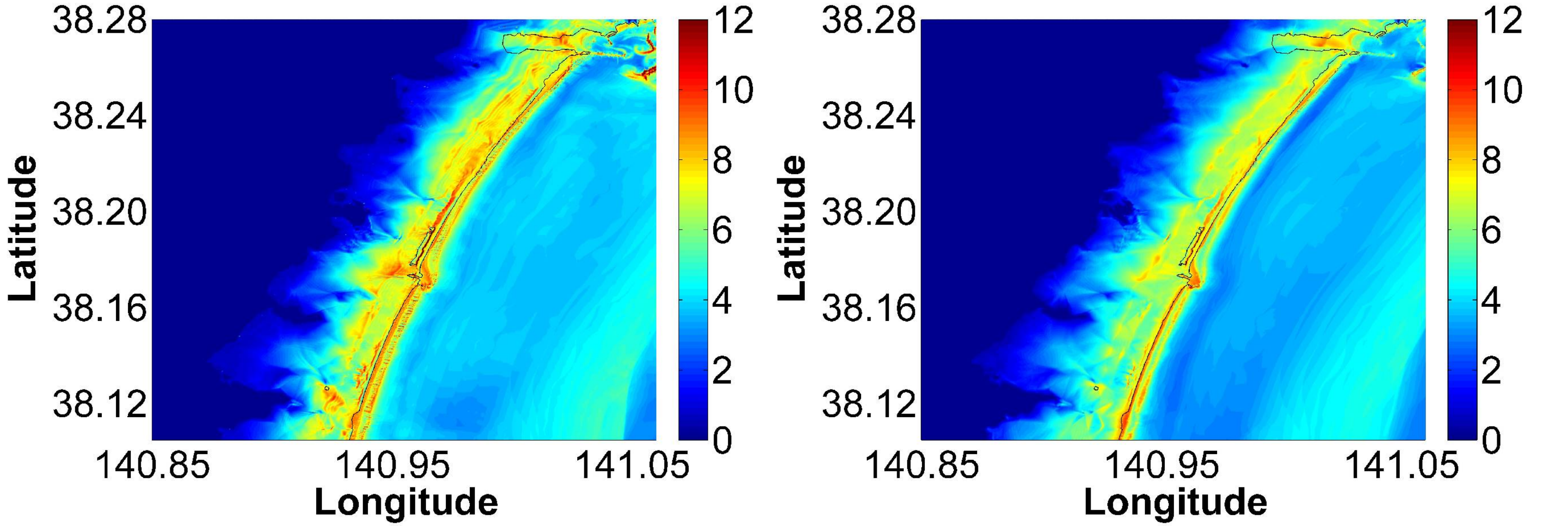
Maximum tsunami amplitudes (m) predicted by MOST (left panel) and GeoClaw (right panel) in the Sendai plain.

Inter-Model Comparison – Overland Flow



Models in close agreement with each other AND measured data for prediction of inundation limit

Inter-Model Comparison – Overland Flow

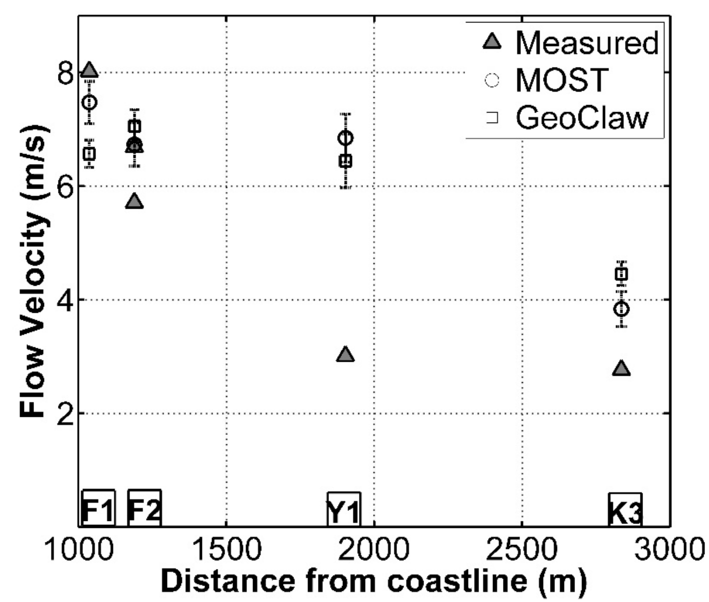


Maximum flow velocities predicted by MOST (left panel) and GeoClaw (right panel).

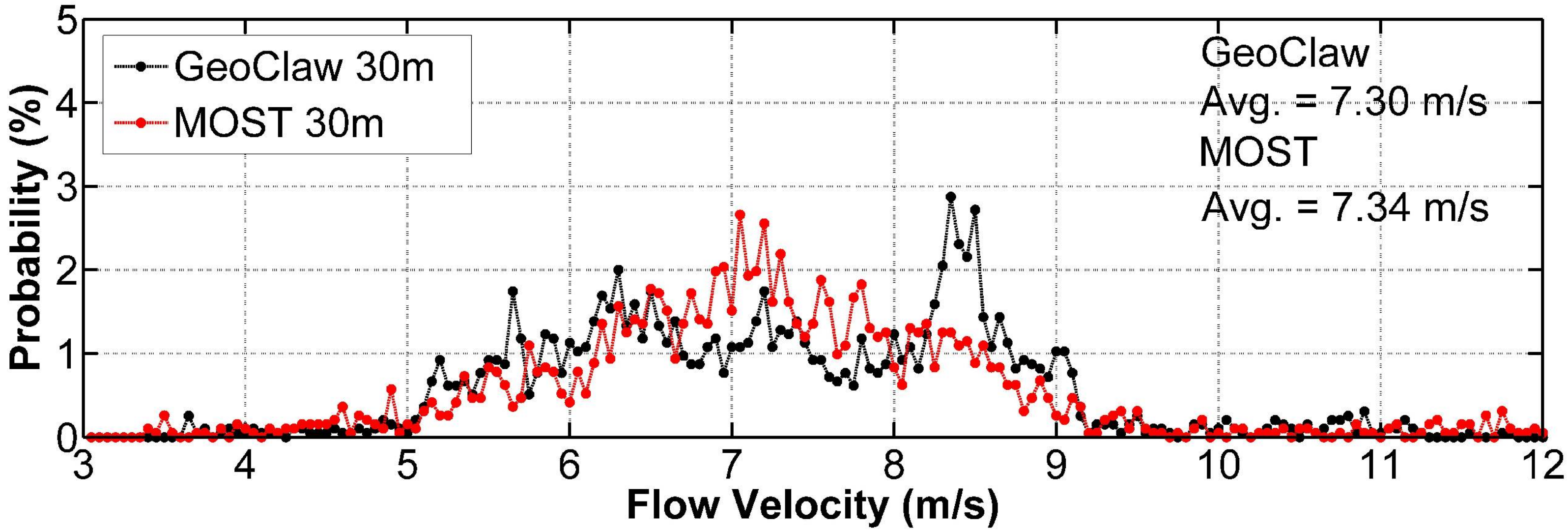
What about velocities???

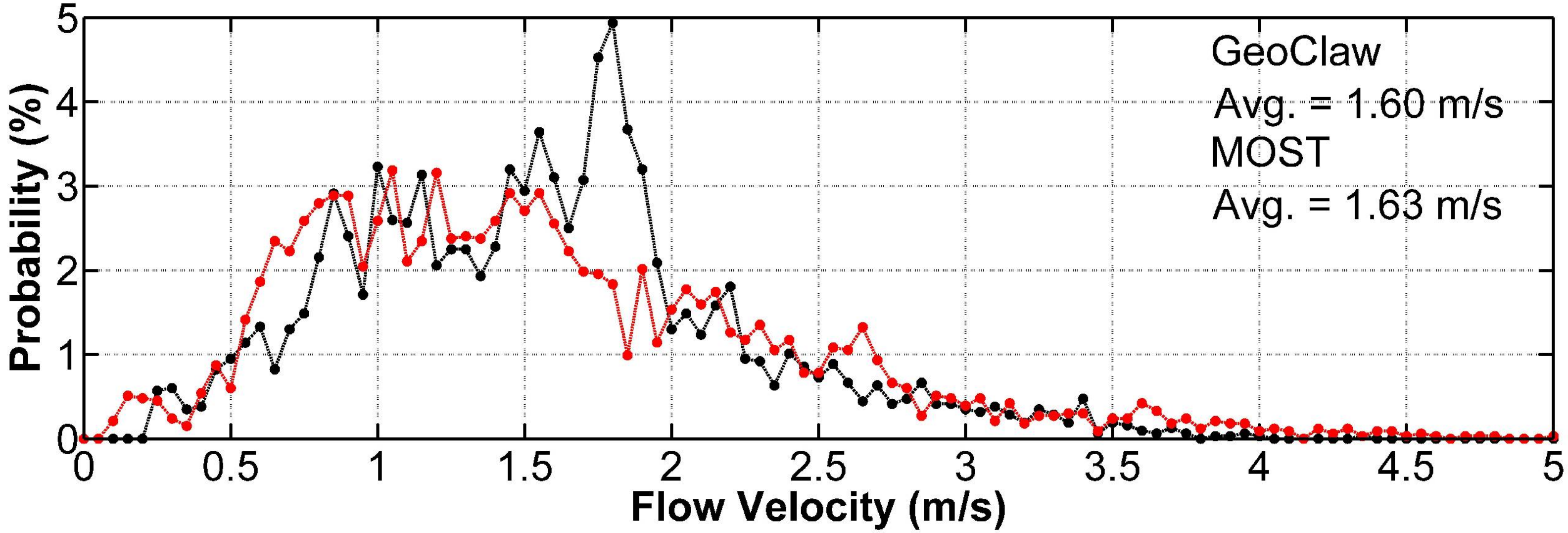
Local inter-model variability is large, mean relative difference onshore ~20% [5%-80%]

Measured data limited, accuracy similar to local inter-model



Inter-Model Comparison – Overland Flow





(top panel) Comparison between GeoClaw and MOST probability density functions of maximum shoreline flow velocities
(bottom panel) 1 meter depth maximum flow velocities at the Sendai plain.

Conclusions

- **Strong** inter-model convergence in ***local*** maximum speed predictions found in areas **not affected** by eddies (e.g. large areas characterized by smooth and regular bathymetry and topography) [inter-model standard deviations (2-20%)]
- **Weak** inter-model convergence in ***local*** maximum speed predictions found in areas **affected** by eddies (e.g. near coastal structures and most topography) [inter-model standard deviations (5-80%)]
- **Strong** inter-model convergence in ***spatially-averaged*** maximum speed predictions found in areas **affected** by eddies, with spatial-averaging lengthscale >=10*eddy lengthscale
- Evolution of eddies dependent on grid resolution, numerical model properties, boundary conditions, etc. (small perturbations can lead to large changes)
  - Significant "natural" or variability here, but lack of data makes quantification difficult
  - Model errors in similar range as inter-model variance
- Single scenario (or small set of scenarios) deterministic simulation of speeds in areas impacted by turbulent features (eddies, wakes, and jets) needs careful interpretation, subject to large uncertainty