## Simulating the M9 Sumatra-Andaman Earthquake and Tsunami Source

According to the Theory of Plate Tectonics, the Indo-Australia Plate and overriding Eurasia Plate are converging at a rate of about 6 cm/yr. Stresses caused by this convergence accumulate along the fault separating the plates until the stresses destabilize and rupture the fault. This relatively instantaneous fault-slip event is an earthquake. The M9 Sumatra-Andaman Earthquake of December 26, 2004 is one of the largest in recorded history as the event ruptured a 1200-kilometer-long and 150-km-wide portion of the boundary separating these plates. Although the M9 earthquake was destructive in itself, the seafloor deformation caused by it triggered a tsunami that was far more devastating.

While the colossal forces behind earthquakes are beyond our control, we can improve our understanding of them and attempt to minimize their impact on society. In the name of computational simplicity, the vast majority of geophysicists use simplified analytical solutions for inverse analyses of earthquake deformation, which poorly represent the complex structure of the deformational system. However, using ABAQUS it is possible to bypass these unrealistic simplifications and readily integrate the powerful capabilities of finite element models in inverse analyses. Such modeling provides the link between directly observable surface deformation and the inaccessible fault-slip, which is what we need to better understand.

ABAQUS is uniquely capable of simulating earthquake deformation for a three-dimensional problem domain having a distribution of material properties appropriate for a system of converging tectonic plates. The array of analysis and element types available in ABAQUS allows us to simulate the elastic response of the earthquake as well as the transient post-earthquake process with a single model. No other finite element package allows for seamless simulations of the earthquake and coupled post-earthquake processes. The preliminary results shown below are part of a project recently funded by the NASA New Investigator Program.

## This project used ABAQUS for

- Inverse models to estimate the fault-slip characteristics of the M9 Sumatra-Andaman earthquake based on observed GPS measurements.
- 2. Forward models, driven by the estimated fault-slip, to predict the seafloor deformation that will serve as the initial conditions for tsunami propagation and run-up models.

## **Author and Researcher**

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## **For More Information**

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The dark shaded region outlined in yellow is the surface projection of the plate boundary region that ruptured during the earthquake. Observed GPS measurements (red arrows) show the horizontal movement of the Eurasian Plate, with respect to the Indo-Australian Plate, as a result of the earthquake. Forward model predictions (yellow arrows) are extracted from an ABAQUS model loaded with the estimated fault-slip characteristics inverted from the GPS measurements.



The 3-D finite element model (FEM) configuration represents a novel attempt to honor the known structure of the converging tectonic plates. Modifications of this FEM configuration are used for both forward and inverse models of the M9 Sumatra-Andaman earthquake.



The realistic configuration of the ABAQUS model translates into reliable predictions of seafloor deformation, which in turn will generate more accurate models of tsunami behavior. Results of this project will provide insight into the entire earthquake-tsunami system and ultimately improve predictive capabilities for future events.