Constraining Models of Interacting Fault Systems in Active Tectonic Zones using Geodetic Imaging to Improve Hazard Analysis

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An estimated 283 million people are exposed to major earthquake risk, with numerous major population centers worldwide located in earthquake prone regions (**Figure 1**). Key challenges for Earth System Science include accurate, geographically detailed estimation of damage and risk resulting from disasters, realistic physical models to test hypotheses of real world phenomena, and an effective means to disseminate and deliver these results to both scientific and disaster response end-users.

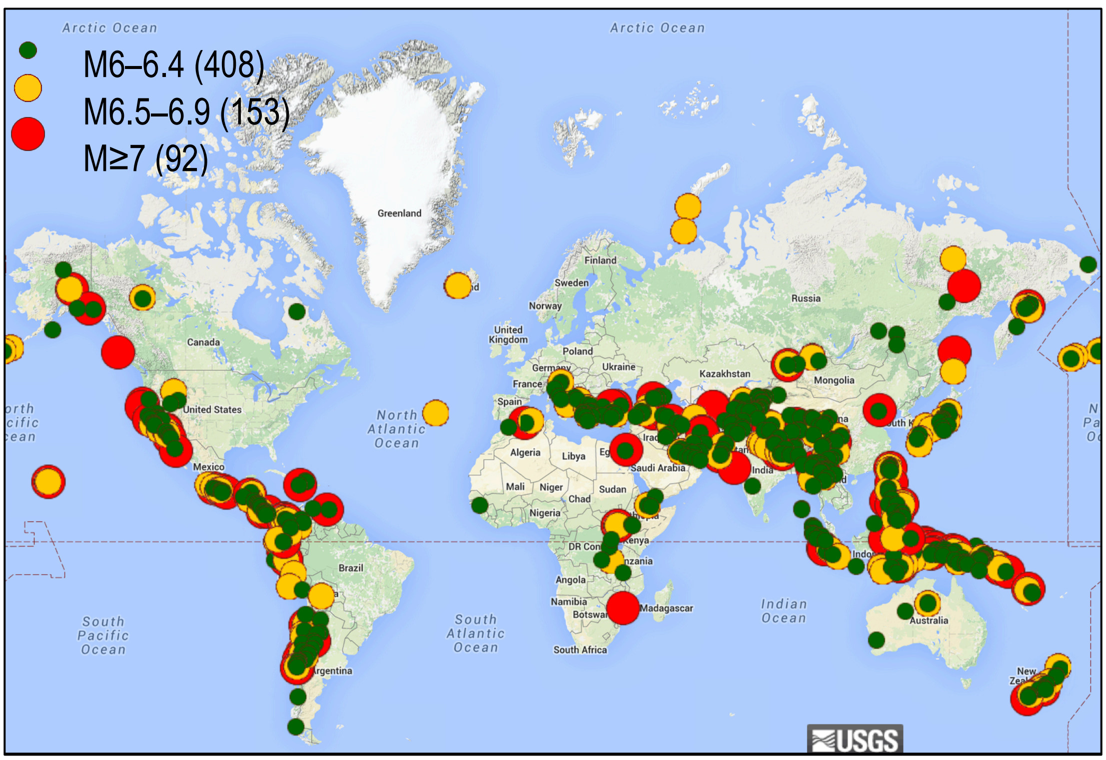

Figure 1. Land earthquakes ≥M6 1970 – present. Damaging earthquakes have occurred on every populated continent

These challenges are timely to address now because rapid delivery of information is critical for pre-event emergency planning and post-event recovery. Realistic physical models are a key contribution to our understanding of the underlying processes at hand. Identifying a clear path for delivering results, both scientific and applied, is critical to reaching the broadest user communities.

Space-based observations have been a fundamental tool for hazard research and disaster response for decades. From events such as earthquakes and tsunamis, floods, wildfires, storms and tornados, oil spills, drought, and many others, satellite observations have been used to aid in identifying emergent and cascading hazards, damage assessment and post-disaster recovery efforts.

The 2002 Solid Earth Science Working Group (SESWG) Report remains a leading guiding document for the community. One of the two 2002 SESWG Report Leading Solid Earth Questions is:

How is the Earth's surface being transformed and how can such information be used to predict future changes?

Two scientific questions from the report continue to drive earthquake hazard analysis:

1. *What is the nature of deformation at plate boundaries and what are the implications for earthquake hazards?*
2. *What are the dynamics of the mantle and crust and how does the Earth's surface respond?*

Earth Surface and Interior studies provide the basic understanding and data products needed to inform the assessment, mitigation, and forecasting of natural hazards, including phenomena such as earthquakes, tsunamis, landslides, and volcanic eruptions. In the case of earthquake hazard, realistic physical models will enable analysis of the behavior of complex fault systems by comparison of the results of these models with observed seismicity and geodetic imaging data from GPS and InSAR. The results will improve the utility of using combined models and data to estimate earthquake potential. Improved simulations will help characterize the deformation associated with earthquakes, and help assess and mitigate their associated hazard. Spaceborne observations provide data that are necessary to validate models, but also provide synoptic, time-critical situational awareness to responders and decision makers in a disaster.

New methods to advance research of geohazards using time-variable observations with a combination of computer simulations and geodetic observations for model validation are required to understand the complex nature of fault interaction and plate boundary deformation. These models help to enhance our understanding of the underlying processes and can further aid in developing observation strategies for upcoming satellite missions seeking to determine how faults interact.

Models will also help to characterize the behavior of fault systems and interactions that will enable improvements in hazard estimation. Validating the results against geodetic observations will allow us to better constrain the rheology and fault properties, which helps with the overall understanding of earthquake physics, fault interactions and earthquake hazard, preparedness and risk reduction (**Figure 2**).

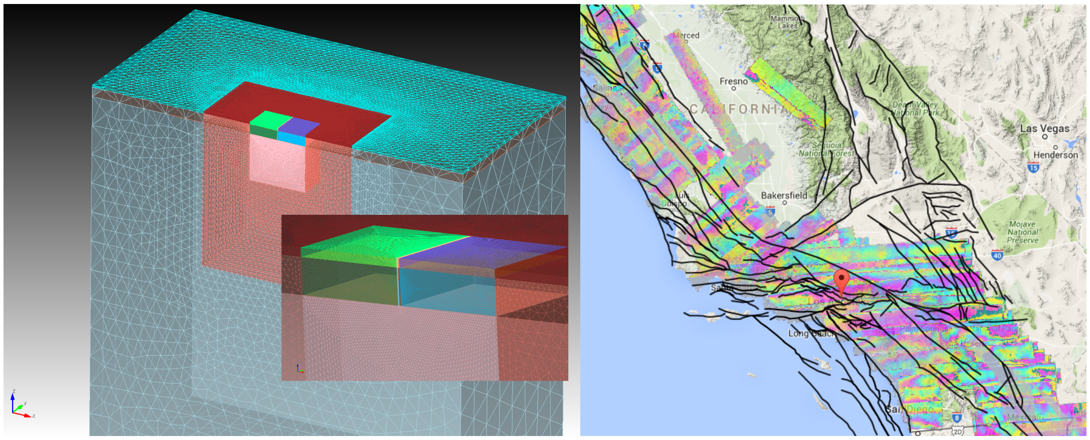

Figure 2 *Left:* Example benchmark validation fault model, 3D finite element mesh. Fault models can have variable material properties and fault zone slip and properties. The inset shows a zoomed-in view of the fault zone. Fault models can be increasingly complex, simulating tectonic regions such as the Los Angeles Basin or other well-known plate boundary zones. *Right:* Simulations are validated by observations of complex fault behavior, such as with UAVSAR in California.

Existing international programs provide reasonable capability to advance these challenges, but in order to make substantial improvements, dedicated US satellite resources should be committed to improve observations, both to enhance geohazard science and disaster response. The NASA-ISRO Synthetic Aperture Radar (NISAR) mission will provide unprecedented coverage for solid Earth hazards. Higher resolution imagery from airborne radar platforms would complement spaceborne radar observations, providing cross track swaths. Optical and topographic measurements would fill in details where radar measurements might decorrelate and where geomorphic features provide information about mechanical properties. Fused measurements would better constrain fault behavior and aid in response.

These particular challenges would focus on the Solid Earth community, but would have relevance to the Applications and Disaster Risk Reduction communities as well.