Use of QuakeSim and UAVSAR for Earthquake Damage Mitigation and Response

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Abstract – Spaceborne, airborne, and modeling and simulation techniques are being applied to earthquake risk assessment and response for mitigation from this natural disaster. QuakeSim is a web-based portal for modeling interseismic strain accumulation using paleoseismic and crustal deformation data. The models are used for understanding strain accumulation and release from earthquakes as well as stress transfer to neighboring faults. Simulations of the fault system can be used for understanding the likelihood and patterns of earthquakes as well as the likelihood of large aftershocks from events. UAVSAR is an airborne L-band InSAR system for collecting crustal deformation data. QuakeSim, UAVSAR, and DESDynI (following launch) can be used for monitoring earthquakes, the associated rupture and damage, and postseismic motions for prediction of aftershock locations.

Keywords: InSAR, earthquake, UAVSAR, QuakeSim, fault systems

1. INTRODUCTION

Remote sensing techniques for measuring crustal deformation are changing our understanding of earthquakes and are improving our ability to forecast the likelihood of these damaging events. These spaceborne technologies include Interferometric Synthetic Aperture Radar (InSAR) and Global Positioning System (GPS) neworks. GPS provides precise positions of GPS station from which velocities can be determined from position time series to 1 mm/yr. InSAR can be used to provide imagery of crustal deformation. UAVSAR, an airborne synthetic aperture radar platform also is used to measure crustal deformation.

The processes associated with earthquakes occur over a wide range of temporal and spatial scales, and express themselves as subtle deformations in the Earth's crust. Steady slip along a fault at depth in the crust can lead to sudden, major earthquakes and days of continuing slip. Present observational capabilities include sampling quickly varying surface change using in situ GPS methods, or observing fine spatial scale changes using interferometric synthetic aperture radar (InSAR). Both have drawbacks however, in that the GPS measurements occur over sparse networks, while spaceborne InSAR measurements are collected infrequently. UAVSAR measurements can be used to complement both the GPS and spaceborne InSAR, leading to a better understanding and assessment of the rate of slip and rebound surrounding a seismic event.

Measurement of crustal deformation provides information about strain accumulation and release associated with plate tectonics and earthquakes. Aseismic motions, which are not detectible with seismometers, can be measured, providing a more complete view of the full earthquake cycle. The Earth's crust and earthquake fault systems and their interactions are heterogeneous and complex. Realistic models of earthquake fault behavior and interactions can be carried out on high-performance computers.

1. QUAKESIM

QuakeSim is a project to develop a solid Earth science framework for modeling and understanding earthquake and tectonic processes. The multi-scale nature of earthquakes requires integrating many data types and models to fully simulate and understand the earthquake process. QuakeSim focuses on modeling the interseismic process through various boundary element, finite element, and analytic applications, which run on various platforms ranging from desktops to high-end computers, forming a compute cloud. Making these data available to modelers is leading to significant improvements in earthquake forecast quality and thereby mitigating the danger from this natural hazard.

QuakeSim has been developed with the goal of providing modeling infrastructure for surface deformation from an InSAR mission. It is relevant to the Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI) mission, mentioned numerous times in the Earth Science Decadal Survey. DESDynI consists of an L-band InSAR instrument and a multi-beam lidar instrument. The goal of DESDynI is to provide surface and ice sheet deformation for understanding natural hazards and climate and vegetation structure for ecosystem health. It is recommended in the first tier of missions with a 2011–2013 launch timeframe.

QuakeSim provides interoperability, incorporating legacy modeling software and data with new systems. QuakeSim integrates with the rupture and shaking modeling of the Southern California Earthquake Center. Other projects that have spun off of QuakeSim will also integrate with our project (e.g. Scripps GPS infrastructure, proposed decision support work). QuakeSim provides the tools to assimilate the multisensor data, model applications and pattern recognizers for extracting information from the disparate sources, and infrastructure for the expected deluge of data from DESDynI.

2. UAVSAR

UAVSAR is an L-band synthetic aperture radar (SAR) that is specifically designed to acquire airborne repeat track SAR data for differential interferometric measurements. It is reconfigurable and has polarimetric capabilities. We are focusing airborne surveys on

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the strike-slip faults of the San Francisco Bay Area, the thrust faults of the Transverse Ranges adjacent to the Los Angeles basin and the southern end of the San Andreas fault system.

Both northern and southern California are marked by frequent moderate and large earthquakes. The last great Earthquakes of northern and southern California occurred in 1906 and 1857 respectively. The magnitude of the 1906 San Francisco earthquake was 7.7 (Wald et al., 1993), while the 1857 earthquake was determined to be 7.9 (Stover and Coffman, 1993). However, both regions are actively deforming. We are carrying out UAVSAR flights of three regions: Northern California across the Bay Area, the front of the Transverse Ranges north of Los Angeles and the San Fernando Valley, and in the Southern California region west of the and spanning Salton Trough. Numerous moderate earthquakes have occurred in each of these regions.

Our goal is to quantify the rate of slip across the Bay Area (Northern California), the Transverse Ranges, and Southern California (Salton Trough region). The UAVSAR observations will establish a baseline of secular deformation and strain partitioning across the region. We will make multiple passes of each area in the week of observations each year, so that we will have multiple data sets taken at the same time. We will average the data to improve the overall noise performance, which should be better than sparse data acquired from space such as from ALOS PALSAR. Should an event occur, we will change our observing strategy to generate fine resolution, accurate observations of crustal deformation at hourly, daily, or weekly intervals.

3. CALIFORNIA SHAKEOUT

In November 2008, a massive earthquake drill, called The Great Southern California ShakeOut was staged. This simulation drew participation from all levels of the government as well as academic and private organizations. A magnitude 7.8 earthquake on the San Andreas fault running from the Salton Sea to north of Los Angeles was staged, and the impacts of the earthquake and responses were simulated. We participated in the exercise simulating UAVSAR flights and observations following the event.

Participation in the 2008 Los Angeles ShakeOut was useful for understanding the process for transferring information to emergency responders. We created a synthetic interferogram with displacements from the scenario M 7.8 earthquake on the San Andreas fault and transferred that information to responders at the California Office of Emergency Services through the US Geological Survey. Responders need to be better educated on the utility of InSAR for imaging earthquakes. Unwrapped interferograms and decorrelation maps would have greater utility than wrapped interferograms of the deformation. Detail is important for damaged regions.

3. CONCLUSIONS

Combining observations and techniques is improving our understanding of earthquake fault systems. We know from observations and models that earthquake faults behave as a system within a region. Slip on one fault affects the stress environment of surrounding faults, causing subsequent earthquakes to be advanced or delayed. The work carried out here helps lay the groundwork for handling the large data volumes expected from NASA's upcoming DESDynI InSAR/Lidar mission and develops the tools for maximizing the solid Earth science return for the mission.

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