The role of hydrology in an earthquake center

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California, like many other densely populated areas around the world, is impacted by both earthquake hazards and limited water resources. While the physical processes associated with these two challenges differ, there are overlaps in the effects on stress state within the subsurface, the tools used to describe and study them, and the types of response structure that they require. Below, we describe these three areas and the leading role that an earthquake center can play.

Stress state along faults and hydrological loading

Over the past decade, it has become increasingly clear that extraction of groundwater from subsurface aquifers can impact seismicity rates (e.g., Famiglietti et al., 2011; González et al., 2012; Amos et al., 2014; Argus et al., 2014; Borsa et al., 2014; Wetzler et al., 2019). Other key impacts on society include damage to infrastructure (roads, aqueducts, buildings) due to subsidence, depletion of water resources, and permanent reduction of the storage capacity of the aquifer. Much of this work has focused on characterizing the correlation between seismicity rates and groundwater depletion over timescales ranging from weeks to years. However, while numerical approaches for modeling of fluid flow within aquifers are fairly mature (e.g., MODFLOW, Harbaugh, 2005) and there has been rapid development of approaches for inferring characteristics of the aquifer from surface deformation data (e.g., Chaussard et al., 2017; Chen et al., 2017; Smith et al., 2017), further work is needed to modernize the treatment of how measurements of ground displacement from GPS or InSAR above aquifers can allow inference of changes in stress along adjacent faults and determination of whether faults are being brought closer or further from failure by hydrologic loading.

Data: Studying faults within the roiling sea of aquifer response

A related challenge involves efforts to use geodetic observations to constrain displacements associated with interseismic, postseismic or coseismic motion along faults, in the presence of seasonal hydrologic signals that may be many centimeters in amplitude (e.g., Murray and Lohman, 2018; Riel et al., 2018). Simply removing a best-fit annual and/or semiannual sinusoid is not sufficient, given the far more complex annual and multi-annual cycles that are known to characterize the hydrologic signals (e.g., Bennett, 2008). As the community seeks to understand small signals, as well as fine-scale variations of the larger ones, improved methods for separating hydrologic and tectonic signals will be required.

Community outreach and disaster response

One of the key contributions that SCEC has made is an expansion of the types, and improvement to the quality, of communication between scientists, engineers, the public, and decision-makers within communities and governmental organizations. The integration of student training into the research climate and annual meetings has greatly expanded the diversity and backgrounds of students who are then interested in studying earthquakes or computational geophysics. The public in California already has a high degree of engagement and interest in earthquake hazards. A similar degree of interest may also be present for hydrology, due to the constant threat of drought, fire and effects of climate change. Many of the techniques and skill sets that will be or have already been developed within an earthquake center would be applicable to hazards associated with droughts and hydrology as well.

Role of a center

SCEC provided many services to the earthquake science community. Future earthquake centers may hopefully also act in this role. A subset of roles relevant to hydrology are:

Data consolidation, leveraging of resources. In the SCEC era, researchers moved from PI-centric data models to free and open data access, helping spur innovation and intercomparison of results, as well as lowering the bar to entry for new researchers. The availability of data on groundwater resources is currently mixed, with some datasets being available through government agencies and their websites, and some key data requiring FOI requests or, worse, not being acquired at all. A center could serve as a platform for data requests, hosting, and interpretation, as well as for requests for funding to acquire new data as community needs are recognized.

Connections between scientific results and community/decision maker responses. SCEC has greatly improved communication between individual earthquake-related subdisciplines as well as researchers in civil engineering and community/government-led responders. This has occurred both through direct interactions with the people responsible for decisions in a crisis, as well as dissemination of education and outreach materials to the community. Similar efforts would be valuable in cases of drought response and water restrictions.

Facilitating advances in modeling. One of SCEC's greatest accomplishments has been how it has brought computational geophysicists together to intercompare codes and push for the advances required by other researchers in earthquake science. Particularly for some of the stress change questions described above, this same expertise could be very relevant to questions involving fault/groundwater load interactions.

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