The importance of expanding the Earthquake Center region to include the northern San Andreas fault system

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We suggest expanding the geographic scope of the future Earthquake Center to cover the northern San Andreas system up to the Mendocino Triple Junction. This will facilitate improved understanding of fault behaviors and earthquake hazards for large urban areas in California.

A greater diversity of fault behaviors

Including the major faults of northern and central California in the region of interest of the Earthquake Center would increase the diversity of investigated fault behaviors, leading to a more complete understanding of fault mechanics. In particular, slow-slip phenomena, which have been recognized as potential precursors of recent major ruptures [1-3], are well established north of the current SCEC natural laboratory. Several of these faults creep along significant portions of their lengths [4]. Long-term monitoring of this creep using 'alignment arrays' [5] and creepmeters [6] has shown a rich spectrum of time-dependent behavior in different locations, including continuous creep, episodic creep with different periodicities, and even left-lateral (retrograde) triggered slip. Laboratory friction experiments have shown some promise for identifying the lithological associations with creep, and thus for applying lessons learned to other regions [7]. The central San Andreas fault, which creeps at the surface, also sustains tectonic tremor and slow slip events at lower crustal depths [8,9]. The underlying geological conditions that facilitate tremor and slow slip are still not well understood; more focused investigation benefitting from excellent field access may illuminate the mechanism and produce results that may be more broadly applicable (e.g., to subduction zones).

The branching geometries of the major faults in the San Francisco Bay Area provide an excellent natural laboratory to study the physics of fault interactions and multi-segment ruptures. These junctures and the transitions from creeping to locked sections in the SAF system represent some of the most striking "earthquake gates" in the plate boundary zone. Inclusion of the youngest, most geometrically complex section of the SAF system just south of the Mendocino Triple Junction will enable research into the maturing of transform plate boundaries, and the influence of evolving fault-zone geometry on earthquake characteristics. Finally, studying potential interactions of the SAF system with the adjacent Cascadia subduction zone will provide new insights into stress evolution, triggering relationships and earthquake clustering over a wide range of spatial and temporal scales [10]

A wide array of secondary seismic and aseismic hazards

Past earthquakes in the San Francisco Bay Area have induced significant secondary hazards, such as widespread liquefaction and landsliding, region-wide. The last major event in the region, the 1989 M_w 6.9 Loma Prieta earthquake, had a short duration for its size and was located well to the south of the major populated areas. Despite these mitigating factors, the earthquake resulted in over 4000 landslides and caused significant building and infrastructure damage due to liquefaction over 100 km away from the epicenter [11]. Soil conditions in many parts of the Bay Area are conducive to liquefaction, with structures built on fill atop San Francisco Bay muds and old river channels particularly susceptible [12]. The current priorities of the Earthquake Center do not include a specific focus on the roles of such secondary effects in earthquake hazard and risk, yet they represent a significant amplifier to risk over the expected damage caused by strong shaking. In the recent Haywired scenario, simulating the effects of a magnitude 7 earthquake on the Hayward fault, the inclusion of liquefaction and landslide hazards increased the expected losses by over 16% over shaking alone [13]. Expanding the Earthquake Center to include the northern San Andreas system would draw a sharper focus on the need to investigate such phenomena, which also pose a threat to several areas of southern California, and provide a pathway to incorporating such expertise into future research.

Inclusion of the northern San Andreas system and its greater diversity of fault slip behaviors will also facilitate study of post-earthquake hazards. Several recent ruptures on partially creeping faults in northern and central California were followed by rapid shallow afterslip that in some cases equalled or exceeded the largest coseismic slip, such as the 2004 M 6.0 Parkfield [14] and 2014 M 6.1 South Napa [15] events. Ongoing postseismic slip represents a significant hazard in its own right, capable of repeatedly breaking fault-crossing infrastructure [16]. The Haywired scenario, focused on the partially creeping Hayward fault, explicitly included afterslip among the sources of potential infrastructure damage; an assessment of the likely damage to the East Bay water supply estimated that afterslip would be of equal importance to coseismic rupture [13].

A statewide Earthquake Center for investigating statewide earthquake risks

Expanding the geographical scope of the Earthquake Center will allow it to better serve the whole population of California. The greater San Francisco Bay Area is home to over 7 million people, and also to multiple dangerous active faults that have not hosted damaging earthquakes in living memory. The added research focus provided by an Earthquake Center, combined with the ongoing research by the USGS, CGS and other institutions will enhance our ability to investigate these faults in detail, and thus to forecast more accurately the seismic hazard and risk posed by them. A geographical expansion to the north would benefit all Californians, not just those living in northern or central California. Given the connected nature of the state's infrastructure lifelines, earthquake hazards that could be considered remote can have a strong impact on the population hundreds of miles away.

One example is the Sacramento-San Joaquin Delta. The water supply for over 25 million Californians (the majority living in southern California) and 4 million irrigated acres of farmland is transported through the Delta area. Damage to the Delta levee system, by seismic shaking, liquefaction or surface rupture, could imperil that water supply, with state- and nation-wide consequences. As much as 4 mm/yr of tectonic shortening may be localized within the Delta area [17] where there exist several identified blind fault structures [18]. Relatively little is known about the seismic potential of these faults, compared with the strike-slip faults to the west.

Uniting the coverage of UCERF, the Earthquake Center and community models

The Uniform California Earthquake Rupture Forecast (UCERF) is the premier study of statewide earthquake hazard in California, a report that is widely used by policy makers, utilities and industry to guide earthquake mitigation planning efforts and to assess seismic risk. The Earthquake Center has been a major contributor to UCERF, and the research underpinning it, over the past two decades [19,20]. There is, however, a mismatch between the coverage area of UCERF (which includes the whole San Andreas system), and the availability of community models developed within the Earthquake Center that provide input for UCERF calculations (which currently focus on southern California only). There will be synergistic and logistical benefits for aligning the areas of coverage of both entities.

A major activity within the last two iterations of the Earthquake Center (i.e. SCEC4 and SCEC5) has been the development of consensus community models for important hazard assessment inputs, such as fault geometries and slip rates, seismic velocities, the geodetic deformation field, and more. The level of detail is significantly higher in some of these community models than in the corresponding versions used in UCERF. By expanding Earthquake Center activities to include northern and central California, we could unify the methodologies, resolutions and applications of such community models to include the whole UCERF area, potentially leading to more accurate and detailed seismic hazard assessments.

Expanding and refreshing the researcher base of the Earthquake Center

While researchers and students from institutions outside of southern California have always been engaged in SCEC, an expansion of its geographical scope to include the full San Andreas plate boundary system will grow and diversify the Earthquake Center community. This will provide new intellectual stimulus, enrich the research enterprise and community engagement, and increase the impact of the collaboratory.

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