Draft Summary

Meeting Summary
National Earthquake Prediction Evaluation Council (NEPEC)
Wednesday and Thursday, September 10-11, 2008.
Hilton Palm Springs Resort, Palm Springs, CA

Attending:

NEPEC Members:
James Dieterich, University of California, Riverside (Chair)
David Applegate (Co-chair, by phone)
David Jackson, University of California, Los Angeles
Evelyn Roeloffs, USGS, Vancouver, WA
Barbara Romanowicz, University of California, Berkeley
Bruce Shaw, Columbia University
Wayne Thatcher, USGS, Menlo Park
Jeroen Tromp, California Institute of Technology
Robert Wesson, USGS Emeritus, Golden
{Members Arrowsmith, Ekstrom, Ellsworth and Zoback did not attend}

USGS Staff:
Mike Blanpied (NEPEC executive secretary)
Nick Beeler
Ned Field*
Jeanne Hardebeck*
Lucy Jones

* Invited speakers

Guests:
Jim Brune, University of Nevada, Reno
Tran Huynh, SCEC
Tom Jordan*, SCEC
Mike Reichle*, CGS, retired
David Rhodes, New Zealand
Danijel Schorlemmer*, SCEC
Terry Tullis*, Brown University

Ned Field — Earthquake Rupture Forecasts: UCERF wrap-up and looking forward.

Field described the products that accompanied the release of the Uniform California Earthquake Rupture Forecast version 2 (UCERF2), which, along with newly available Next-Generation Attenuation (NGA) relations, were used in calculations of time-independent hazard in the 2008 USGS National Seismic Hazard Maps (NSHM), and calculations of time-dependent hazard under consideration for rate adjustments by the California Earthquake Authority (CEA).

Field listed lessons learned during completion of the UCERF study. He explained that the UCERF model represents "best available science," but is extremely complex and unwieldy. A number of its features exist because they were inherited from earlier efforts, were required to match procedures used to build the NSHM, or are place-holders used with recognition that further research will lead to improved methods. He listed a number of potential improvements to the method that should motivate future work. These topics include an improved deformation model to underlie fault slip rates; a better basis for assigning the lower depth of seismogenic slip; an improved method for adjusting modeled long-term earthquake rates to better match recent seismicity rates; self-consistent renewal models that work for overlapping, multi-segment ruptures; and earthquake clustering. Field explained that the treatment of faults as segmented

entities is artificial and should be rethought. He contemplates a generalized inversion technique that would solve for the rate of all possible events, satisfying constraints of Gutenberg-Richter distribution, moment balancing, observed recurrence intervals, and the likelihood of rupture jumping between faults. Eventually, physics-based earthquake simulators may guide further improvements.

In discussion, Council members stressed the importance of earthquake rupture forecasts and hazard maps as flagship products, and that USGS must continue to push their improvement. Field noted that about three years exist before methods must be decided upon for the next round of seismic hazard maps, and Wesson urged USGS to take advantage of this luxury of time to encourage multiple, competing approaches, using the USGS grants program to encourage free thinking. Field urged aggressive development of physics-based simulators as an example of new approaches that push the envelope.

The conversation concluded with Applegate noting that the NEHRP strategic plan motivates the USGS Earthquake Hazard Program (EHP) to create a 5-year plan that aligns with its structure and goals. He welcomed NEPEC input on the level of priority this line of work represents.

Terry Tullis (Brown University) — SCEC activities

Tullis described the suite of work sponsored by the Southern California Earthquake Center (SCEC) under its Earthquake Forecasting and Prediction (EFP) focus group, which he leads. He showed a list of the SCEC-sponsored projects under EFP, work that includes development of physics-based earthquake simulators, tests of the "load-unload response ratio" (LURR) prediction method, creation of an earthquake forecast method tied to seasonal changes in seismicity, and development of testing procedures for alarm-based earthquake prediction algorithm. Discussion with the Council centered around the state of development of simulators, how they might be used to gain insight into the recurrence behavior of earthquakes, and how to test their performance.

Tom Jordan and Danijel Schorlemmer (USC) — CSEP

Schorlemmer and Jordan provided an update on development of the Collaboratory for the Study of Earthquake Predictability (CSEP), the CSEP testing center at USC, and testing centers under development abroad.

Danijel Schorlemmer (DS) of the Southern California Earthquake Center (SCEC) gave a presentation on the CSEP testing center and capabilities, including the center's suite of computers and interfaces. These include separate development, certification and testing platforms, plus a web server for results. When an algorithm is submitted for testing, the testing center freezes the submitted software for a month of certification before launching a test. The web presence includes main and regional web sites for public, plus a restricted test results site. CSEP testing centers have been erected in the US, Japan, New Zealand and the EU thus far, coordinated through the activities of international working groups for data, global testing, cyberinfrastructure, and testing. A suite of tests initiated under the Regional Earthquake Likelihood Models (RELM, a previous incarnation of CSEP) have reached a 2.5 year duration.

Those include 19 models on declustered seismicity. Other models are being developed and registered for testing at the CSEP testing centers. Tests include 5-year static forecasts for M≥5 earthquakes and shorter-term forecasts for M≥4 or M≥5 earthquakes, for which the forecasting code resides at the testing center and is run on a regular basis to update the forecast on the basis of accumulating catalog data.

SCEC developed the first testing center with support from the Keck Foundation, and had informed USGS for some time that federal funds would be sought to maintain the center once that initial development grant was exhausted, which will occur within months. The Council engaged Schorlemmer and Jordan in extensive discussion on a number of issues, including: the ability of CSEP's approach to testing to focus on higher earthquake magnitudes and alarm-style predictions on which NEPEC and CEPEC may be asked to comment; the benefits and possible shortcomings of the statistical tests employed by the testing centers; the status of research on electromagnetic earthquake precursors and whether CSEP should test predictions based on such data; extension of the CSEP approach to formally test a broader range of predictive products such as the National Seismic Hazard Maps and the UCERF; and the state of funding and support of the CSEP testing center at USC.

[*On the basis of these discussions, the NEPEC sent the USGS Director a letter of recommendations on CSEP and its link to USGS concerns, delivered on May 9, 2009*.]

Short science subjects

M8/MSc prediction algorithm: Dave Jackson summarized recent interactions with Vladimir Kosobokov regarding this ongoing global prospective test. The PI's are claiming a 98% prediction success rate, but it's not clear that that is relative to an appropriate null hypothesis. Jackson has been urging them to format the model in a way that can be tested by CSEP, but they appear unwilling to do that work. It was suggested that a graduate student might be tasked with that job, or that David Vere-Jones of New Zealand might be interested.

Reverse Detection of Precursors (RTP) method: Jackson briefly summarized the history of this method, which is promoted by Vladimir Keillis-Borok and Peter Shebalin. CEPEC has reviewed two predictions made via this method for earthquakes in southern California, neither time endorsing RTP as having demonstrated predictive power or more than a method being researched.

Parkfield velocity paper: Blanpied summarized a 2008 *Nature* paper by F. Niu, Paul Silver and others entitled, "Preseismic velocity changes observed from active source monitoring at the Parkfield SAFOD drill site. The authors described variations in seismic velocity measured between the pilot and main SAFOD boreholes. Two excursions in the time series began before two small earthquakes in the vicinity, leading to speculation that they might represent an earthquake precursor. Data will continue to be taken in order to further examine this correlation.

Xerasys: Blanpied reminded Council members of the history of prediction algorithms promoted by John Rundle (UC Davis) and colleagues, including the PI and RIPI algorithms that base predictions on decade-scale changes in earthquake rate. Neither CEPEC nor NEPEC has

reviewed the RIPI method, and Rundle has not been forthcoming with information about its performance. Rundle founded the University of California "Hazard Institute" with support of some UC administrators, but few of the university system's seismology faculty have been enthusiastic about participating. It was stated that the Hazards Institute is soliciting funds from the California Earthquake Authority.

Rundle is now associated with a new commercial enterprise called Xerasys. None of the meeting participants were familiar with the company or its products. The Xerasys web site states that it has released "XeraQuake, a web-based product that provides daily updates to earthquake risk for large metropolitan areas and customer-specified sets of securities in California, Mexico and the Pacific Northwest."

Jeanne Hardebeck (USGS Menlo Park) — AMR

Hardebeck summarized statistical tests that explored the viability of "accelerating moment release" (AMR) as an earthquake precursor. In a 2008 paper in *JGR*, Hardebeck and colleagues examined the AMR method as described in papers by David Bowman, Geoff King and others. Power-law curves are fitted to time-series plots of Benioff strain in a region surrounding a later mainshock; upward curvature is taken as evidence for accelerating moment release in the region. Hardebeck et al. concluded that much or all of the correlation between of AMR and mainshocks could be attributed to data-fitting. In discussion, Council members asked whether AMR was amenable to testing by CSEP. Hardebeck explained that several key tests involve comparisons between AMR performance on real and synthetic earthquake catalogs, so CSEP might need to implement synthetic catalogs as an input data source. It was noted that an ETAS model also displays accelerating earthquake rates, suggesting that AMR is dominated by earthquake clustering effects. Jackson noted that Bowman has been amenable to bringing AMR to CSEP, but has found it difficult to formulate the method for a prospective test.

Evelyn Roeloffs (USGS Cascades Volcano Observatory) — ETS Workshop

Roeloffs summarized results from a 40-scientist workshop on Episodic Tremor and Slow slip (ETS) held in Vancouver, BC in May, 2008. This workshop was encouraged by NEPEC and followed on discussions begun at their Portland meeting a year earlier. Progress has been rapid on accumulating observations of ETS and its relation to creep, passage of seismic waves, locations of moderate-magnitude seismicity, and other measurables. Models under development associate the occurrence of ETS with creation of fluids through dehydration, and work continues in precisely locating tremor relative to the lower edge of the locked portion of the subduction interface. A workshop report is being prepared for publication as a USGS Open-file report. (See detailed findings and recommendations in the report, now published and available online: *http://pubs.usgs.gov/of/2008/1343/.)*

Discussion centered around policy implications of ETS. Workshop participants varied in their opinions of the implications for slow slip events on subduction earthquake probabilities. Council members agreed that it was premature for government to release hazard warnings during slow slip events, given the small size and large uncertainty of calculated probability gains relative to

other time periods. Observations that would increase concern include a up-dip migration of tremor, suggesting failure of the locked patch.

Roeloffs said that the scientific community has been getting more organized in its conversation and interaction about ETS, with several published summaries, a special issue of JGR, and the launch of an EarthScope web site *http://www.earthscope.org/science/cascadia*.

Mike Reichle (CGS, retired) — California Earthquake Advisory Plan

Reichle, former California State Seismologist and CEPEC chair, delivered a summary of the California procedures for constructing and issuing advisories of increased earthquake danger. CEPEC, an expert committee that reports to the California Office of Emergency Services (OES), is responsible for evaluating evidence of increased earthquake threat and for drafting advisory statements for release by OES. Advisory statements give likelihood for earthquake occurrence in the following 3-5 days, and are sometimes released by OES to the media. At the conclusion of the time period, they are either extended or cancelled. CEPEC has considered drafting advisories 14 times, with a fraction of those actually completed and issued. Reichle noted that the process takes some time to complete, during which time the earthquake threat may have ebbed considerably. CEPEC has considered pre-drafting advisory statements in order to shorten the time needed to craft and submit an advisory during a time of increased concern, but this idea was shelved.

Evelyn Roeloffs — Earthquake Advisories: Issues for Discussion by NEPEC

Roeloffs presented information and recommendations for development of procedures for issuing earthquake alerts at times of increased threat. She explained that there is little experience with advisories in hazardous areas outside of California. Well-studied earthquake clustering statistics (e.g., work of Reasenberg and Jones) form the basis of formal advisories in California, but those statistics have not been developed elsewhere. She described several factors that suggest the need for work on this topic in the Cascadia region. Because the subduction earthquake cycle is poorly understood, it is not known what events may occur in advance of an M8 or M9 event. Possible scenarios include a change in nature of ETS, evolution in the nature of slow-slip earthquakes, subsidence, or moderate-magnitude earthquakes on the subduction interface. She advocates a dialog with emergency managers in the region to convey what forecast information may be available before an earthquake, to better understand the types of information that could be usefully conveyed, and about the types of actions that might be taken in response. This strategy corresponds to the sociological model of Miletti and others, in which effective hazard communication occurs through recognition of four essential "subsystems": Risk (the natural hazard), Detection (the observations, analysis and forecasts made by scientists), Management (interpretations and actions taken by governments and building owners) and Public Response (interpretations and responses by the affected citizenry). Coordination among the various science institutions is also needed in order that the scientific community can agree on messages and "speak with one voice" to emergency managers and the public. Useful lessons might come from the study of advisories issued during felt earthquake swarms (e.g., southern California and near Reno).

Roeloffs noted that time and resources will be needed to pursue these topics, but urged that USGS draft a plan of action that includes initiation of the dialogs described above, development of procedures for identifying seismic of geodetic events of possible concern, and deciding what entities in the Pacific Northwest would have the lead responsibility for communicating advisories. She identified first steps that include the study of clustering statistics outside California, and discussing the possible form and content of advisories, e.g., to include the message that a large earthquake is possible, information about the magnitudes and recurrence intervals employed in the NSHM earthquake occurrence model, likely effects of a mainshock, and reminders of appropriate activities to be taken by the public.

Executive session

Topics discussed in closed session included research underlying the UCERF and NSHMP products; scientific focus and support of CSEP; and Cascadia.