# USGS Strategy for Dynamic Earthquake Likelihood Forecasting

## (*the USGS approach to Operational Earthquake Forecasting*)

Michael L. Blanpied
USGS Earthquake Hazards Program
*mblanpied@usgs.gov*

For CSEP Workshop
September 6, 2014


# Is USGS providing operational forecasts?

- Reports of the Working Group on California Earthquake Probabilities (1988, ’90, ’99, ’03, ’08, ’13, ‘14).
- CISN publishes foreshock & aftershock forecasts after M≥5 earthquakes in California.
- STEP 24-hour PSH map of California.
- CEPEC reports to CalEMA (USGS members).
- *Ad hoc* formal and informal aftershock probabilities after major earthquakes, domestic and abroad.
  - Some based on clustering statistics.
  - Some based on time-dependent renewal models.
  - Some based on Coulomb stress calculations.

# Rationale for USGS Operational Forecasts

- USGS bears a responsibility to enhance public safety through effective forecasts, and is often asked for those forecasts.
- Vetted, approved methods exist for mainshock-aftershock sequences in California, where clustering statistics are known.
- We lack vetted methods for calculating dynamic forecasts…
  - outside of California and outside of the USA,`
  - during seismic swarms,
  - in areas subject to induced seismicity,
  - by methods other than earthquake clustering statistics.
- Current methods are not well tested.
- Current information products are not visible, effective, responsive to user needs, or consistent with the existing suite of USGS post-earthquake products.

# Goals of DELF Strategic Planning

- To develop and evolve a vision for DELF and the dissemination of related products, as an activity of the EHP & ANSS.
- Define user needs & uses for dynamic hazard & risk forecasts.
- Develop an integrated program that includes R&D and testing of forecast models, design and testing of needed products, and integration of methods into the operations of the ANSS.
- Define the roles of NEPEC, CEPEC, CSEP, SCEC and SAFRR.
- Improve estimates of changes in earthquake probability, hazard, and risk over relevant time periods.
- Extend capability broadly across the nation.
- Explore additional methods (e.g., geodesy, Coulomb stress).
- Define requirements for a structured multi-year effort:
  - Staffing and costs for all elements of effort.
  - Network requirements for seismic (and other?) input data.

# Strategic objectives

| | Research | Model Development | Model Evaluation | Product Design | Operationalization of Model & Product Dissemination | Assessment of Products |
|---|---|---|---|---|---|---|
| Activities | Conceive, develop and investigate approaches, develop algorithms to optimize OEF forecasts | Make OEF forecasting algorithms testable and usable, possibly with inclusion of real-time data | Test submitted algorithms to evaluate speed, skill and accuracy | Evaluate information products, develop explanatory materials | Use tested algorithms on real-time data, and produce products | Evaluate whether the products communicate the information as desired |
| Participants | Researchers from USGS, SCEC, academic community | WGCEP, NSHMP, CISN, ANSS network partners | USGS, CSEP, NEPEC, CEPEC | SAFRR, social scientists (inc. external) | CISN, ANSS network partners, NEIC, USGS Office of Communications | SAFRR, external experts |

# Status of DELF at USGS

- Strategic planning underway.
- Clustering statistics being developed outside of CA.
- Planning PNW coordination guideline document.
- UCERF3 dynamic forecast model under development.
- Powell Center approved and in development.
- SAFRR project helping to define user needs & strategies.
- Several staff attended an international workshop on OEF hosted by INGV, SCEC and RMS.
- Increasing needs in induced seismicity arena.
- Further detail needed on user needs, staffing needs, and network requirements.
- Management decisions needed on level of priority and effort to devote to DELF, and sources of support.
- SESAC review in June, 2014.

# Potential levels of effort in DELF

1. Status quo.
2. Increased capability:  vetted methods for forecasts across nation and globe, and beyond mainshock-aftershock.
3. Operational capabilities with improved network integration, and suite of information products.
4. Fully integrated systems for calculation and products within ANSS architecture.

# Potential levels of effort in DELF

1. ~~Status quo~~.
2. Increased capability: vetted methods for forecasts across nation and globe, and beyond mainshock-aftershock.
3. Operational capabilities with improved network integration, and suite of information products.
4. Fully integrated systems for calculation and products within ANSS architecture.

***SESAC approved general direction, suggested that initial 1-2 years focus on defining user needs to define requirements.***

# Key DELF R&D Goals

- Estimate time-dependent eq probabilities, hazard, and risk over relevant time and space windows.
- Expand suite of viable and tested forecasting models.
- Identify needed improvements in monitoring and analysis.
- Create a pathway for new methods can be coded and evaluated.
- Develop useful forecast products – one-time releases, real-time updates, user-customized products, etc.
- Formalize testing of both models and products.

# Proposed messaging strategy

## for emergency managers and other key decision-makers

Type of seismic activity

Probability of a damaging event

| | 1. Mainshock-aftershock sequence | 2. Swarms | 3. Special location (near a major fault) |
|---|---|---|---|
| Level A. Damaging earthquake very likely ≥50% | Mainshock>7<br>A damaging aftershock is likely | N/A | N/A |
| Level B. Damaging earthquake quite possible ≥10% | Mainshock≥6.5<br>Prob of a damaging aftershock >25% | A swarm with ≥2 M≥5 events.<br>Prob of a damaging earthquake >25% | Probability of a M≥7 earthquake is 5-25% |
| Level C. Damaging earthquake possible 1-10% | Mainshock≥5.5<br>Prob of a damaging aftershock 1-25% | A swarm with ≥2 M≥4.5 events.<br>Prob of a damaging earthquake 1-25% | Probability of a M≥7 earthquake is 1-5% |
| Level D. Damaging earthquake unlikely 0.1-1% | Mainshock≥4.5<br>Prob of a damaging aftershock 0.1-1% | A swarm with ≥2 M≥5 events.<br>Prob of a damaging earthquake 0.1-1% | Probability of a M≥7 earthquake is 0.1-1% |

# Coordinating Committee for OEF

- Michael Blanpied, Associate Earthquake Program Coordinator
- Lucy Jones, Science Advisor for Risk Reduction
- Andy Michael, Task leader for OEF in the Earthquake Processes, Probabilities and Occurrence Project
- Ned Field, Task leader for OEF in the National Seismic Hazard Maps Project
- Harley Benz, Lead for OEF at the NEIC
- Doug Given, Southern California Seismic Network
- David Oppenheimer, Northern California Seismic Network

# OEF Strategic R&D Highlights

- Year 1-2:
  - Create implementation plan, staffing requirements, funding model.
  - Define data requirements and work needed for initial products.
  - Incorporate OEF work as needed into cooperative agreements.
  - Complete UCERF3 short-term model; initiate product R&D, testing.
  - Begin analysis of clustering statistics outside California.
- Year 2-3:
  - Evaluate potential for geodetic-transient OEF in the PNW.
  - Evaluate methods for OEF during earthquake swarms.
- Year 4-5:
  - Evaluate potential of Coulomb-stress-based OEF.
  - Evaluate geodetic transients outside PNW.

# USGS-hosted discussion

## May 2, 2013, Seattle, Washington

- Co-scheduled with meetings of the National Earthquake Program Managers and the WSSPC.
- Two-hour early morning meeting.
- Invited:
  - Earthquake program managers, state geologists, and attending scientists from CA, OR, WA, BC, AK, HI.
  - Representatives of WSSPC and CREW.
  - Members of the NEPEC.
  - Key USGS and PNSN staff in UW.
- 24 participants, plus 9 by phone.

# USGS-hosted discussion

## May 2, 2013, Seattle, Washington

- Information users endorsed the idea of identifying and improving (where needed) key communication pathways, coordination across Cascadia, and risk messaging.
- Desire for a response coordination plan akin to volcano.
  - CREW volunteered to lead effort to create such a plan.
  - Dovetail with FEMA Cascadia response plan in development.
- Discussed a comm. strategy under development in SoCal.
  - Discrete “levels of concern” determined by scientists.
  - Pre-discussed message forms and pathways to key users.
  - Pre-considered actions by users.
- A brief summary has been prepared.