CSEP Workshop:
New Frontiers in Earthquake Forecasting

Convenors: Max Werner, Toño Bayona, Phil Maechling

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SCEC Annual Meeting, Palm Springs

Context

CSEP goals

- To accelerate rigorous research into the predictability of earthquakes via prospective testing
- To provide community-endorsed tools, concepts and methods for evaluating earthquake forecasts

CSEP Background

- Initiated as a SCEC special project with a Keck Foundation grant (PI Tom Jordan)
- First ever *prospective* community forecast 'experiment' in California initiated 2006
- **First phase of CSEP (2007 - 2018):**
  - 4 testing centers (servers + object-oriented Python) ran automated experiments: SCEC, ERI, GNS, ETH
  - 7 testing regions (California, Italy, Japan, NZ, globe, etc.); 400+ models/model versions
- **Second phase of CSEP (since 2019):**
  - Community-based open-source code development of Python toolkit pyCSEP
  - Papers include *reproducibility packages* (forecasts, code, results) stored on Zenodo/GitHub
  - 2019-2023 Bill Savran leads software developer at SCEC
  - The *Statewide* California Earthquake Center

Select CSEP Activities since 2022

pyCSEP :

- New features have been added to pyCSEP by an international community (Graham et al., SRL, 2024)
- Two tutorials held (1) online in fall 2023 and (2) at StatSei13 in Shenzhen in March 2024

New models:

- New statistical/ML models are being developed, e.g. neural point processes and Bayesian INLA models, which are flexible and fast, along with new (AI) ideas about benchmarking platforms

New regions: CSEP-CHINA developed a new testing region in the China Seismic Experiment Site (CSES)

Select Forecast Evaluations

- Are regional CSEP models more informative than the global GEAR1 model? (Bayona et al., 2023, TSR)
- 10-Year prospective evaluation in Italy (Iturrieta et al., 2024, SRL)
- Prospective testing of next-day forecast models in California (Bayona et al. 2024?)
- Comparison of ETAS and STEP using Voronoi residuals (Ward et al, 2025?)
- Comparing UCERF3-ETAS against CSEP models in California (Serafini et al., 2025?)
- …

Selection of CSEP Papers since 2022

- **pyCSEP: A python toolkit for earthquake forecast developers**
  1. Savran et al. (2022), Journal of Open-Source Software
  2. Savran et al. (2022), Seismological Research Letters

- **Published:**
  3. Bayona et al. (2022), GJI: Prospective evaluation of multiplicative hybrid forecast models in California
  4. Serafini et al. (2022), GJI: Ranking earthquake forecasts using proper scoring rules: binary events in a low probability environment
  5. Mancini et al. (2022), JGR: On the Use of High-Resolution and Deep-Learning Seismic Catalogs for Short-Term Earthquake Forecasts
  6. Bayliss et al. (2022), NHESS: Pseudo-prospective testing of 5-year earthquake forecasts for California using inlabru
  7. Asim et al. (2023), BSSA: Multi-resolution grids in earthquake forecasting: the Quadtree approach
  8. Bayona et al. (2023), TSR: Are regional earthquake models more informative than global models?
  9. Asim et al. (2023), GJI: Statistical power of spatial earthquake forecast tests
  10. Hermann & Marzocchi (2023), GJI: Maximizing the forecasting skill of an ensemble
  11. Iturrieta et al. (2024), SRL: Evaluation of a Decade-Long Prospective Earthquake Forecasting Experiment in Italy

- **In preparation:**
  12. Iturrieta et al. (in prep): Modernizing CSEP experiments: the floating testing center
  13. Bayona et al. (in prep): How reliable are tomorrow's earthquake probabilities?
  14. Serafini et al. (in prep): The CSEP Next-day California Forecast Benchmark:
  15. Stockman et al. (in review): EarthquakeNPP: A Benchmarking Platform for Earthquake Forecasting with Neural Point Processes

Intended Workshop Outcomes

- **Community engagement and exchange**
- **Shaping CSEP/SCEC priorities**
- **CSEP's role in testing AI-based forecasts and predictions**
- **Next steps for testing USGS and other operational earthquake forecasts**
- **Opportunities for the *Statewide* California Earthquake Center**

Agenda

Session 1: State of CSEP and OEF

8:15 How Reliable Are Tomorrow's Earthquake Probabilities? An Evaluation of Clustered Seismicity Models in California. Toño Bayona

8:30 The CSEP Next-Day California Benchmark: Tutorial & Preliminary Comparison with UCERF3-ETAS. Francesco Serafini

8:45 The CSEP-China Experiment at the China Seismic Exploration Site (CSES). Shengfeng Zhang/Angie Zhang

9:00 New Capabilities of the pyCSEP Toolkit for Earthquake Forecast Developers. Kenny Graham

9:15 Magnitude-Weighted Likelihood Scoring of Earthquake Forecasts. Rick Schoenberg

9:30 Comparative Evaluation of Earthquake Forecasts: Application to Italy. Jonas Brehmer

9:45 Discussion & Coffee Break

Session 2: New Frontiers

10:15 EarthquakeNPP: A Benchmarking Platform for Neural Point Processes. Sam Stockman

10:30 Perspectives on USGS Operational Earthquake Forecasting. Ned Field

10:45 Earthquake Forecasting and Low-Frequency Earthquakes. Gaspard Farge

11:00 Sustainable Computing for Earthquake Forecast Testing Centers. Phil Maechling

11:15 Demonstration of a User-Centered Interactive Viewer for Aftershock Forecast Maps

11:30 TBD/Discussion

12:00 Workshop adjourns