RELM

From the Testing Center of Regional Earthquake Likelihood Models (**RELM**) to the Collaboratory for the Study of Earthquake Predictability (**CSEP**)

SCEC

USGS science for a changing world

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What are the Goals of RELM?

- Develop a variety of viable, geophysically based earthquake-rupture forecast (ERF) models for the region.

- Examine and compare the implications of each model with respect to seismic hazard and loss estimate.

- Test these models for consistency with existing geophysical data (e.g., historical seismicity) and design and document conclusive tests

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What are the Goals of RELM?

- Develop a variety of viable, geophysically based earthquake-rupture forecast (ERF) models for the region.

  Large variety of models have been developed

- Examine and compare the implications of each model with respect to seismic hazard and loss estimate.

  OpenSHA

- Test these models for consistency with existing geophysical data (e.g., historical seismicity) and design and document conclusive tests

  Community-agreed testing procedure & Testing Center

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What are the Goals of RELM?

Why is testing so important?

- Evaluate potentially successful forecasts
  Detect overly enthusiastic claims

- Certification process for models (Documentation)

- Validation of models

- Estimation of comparative performance of models
  Avoid testing only against 'dumb' null hypotheses

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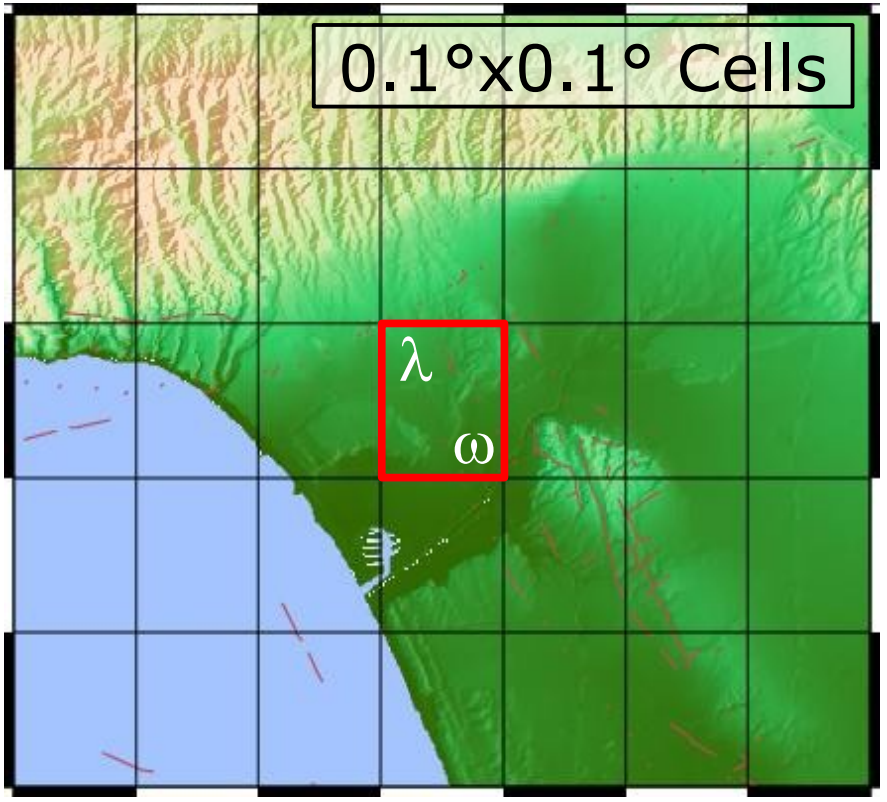
How do we Test?

The testing area is separated into cells (grid-based models)

A bin defines a volume (cell), magnitude range, and range of focal mechanism angles for which a forecast is issued

In each bin: **Expectation** λ
Observation ω



The default binning:

Lon/Lat	0.1°x0.1°
Depth	0-30km
Magnitude	0.1
Focal Mech.	None (30°)

Computing the **likelihood** as the Poissonian probability of making an observation given an expectation.

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What do we Test?

We apply 3 different tests:

L-Test
Examines the consistency of a model with the observation (in the likelihood space)

N-Test
Test if the number of observed events is in the range of the expectation of a model

R-Test
Compares 2 models by its log-likelihood-ratio. It estimates the differences in spatial performance.

In each test we compare observed values with the value obtained from catalogs simulated based on expectations of a model.

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Features of the Current RELM-Test

Test data-consistency and compare each model's performance

Parameter uncertainties
error distributions of location, magnitude, and FM angles

Independence probabilities (Declustering)
aftershock vs. main shock

Magnitude completeness windows
time and magnitude

Resolution independent
location, magnitude, focal mechanisms angles

Analysis of spatial and magnitude-range performance

Implementation

What does the testing implementation additionally include?

- Model definitions (Classes of models)

	5-year	**1-year**	**1-day**
Forecast duration	5 years	1 year	1 day
Aftershocks	yes/no	yes/no	yes
Magnitude range	5-9	5-9	4-9
Modeler provides	numbers	code	code
Revised data	no	yes	yes

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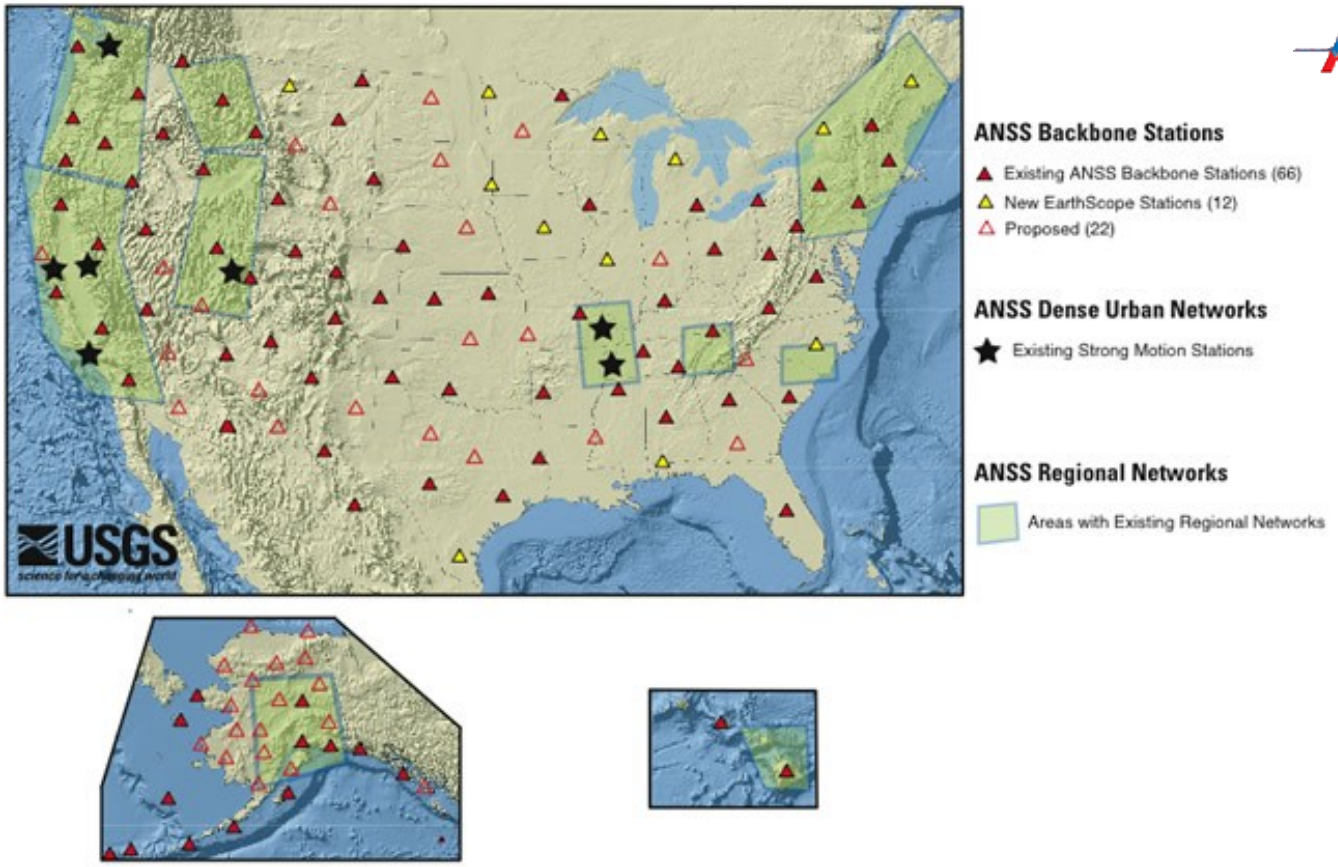
Implementation

What does the testing implementation additionally include?

- Model definitions
- Authorized data sources (Independent)
  Earthquake catalog



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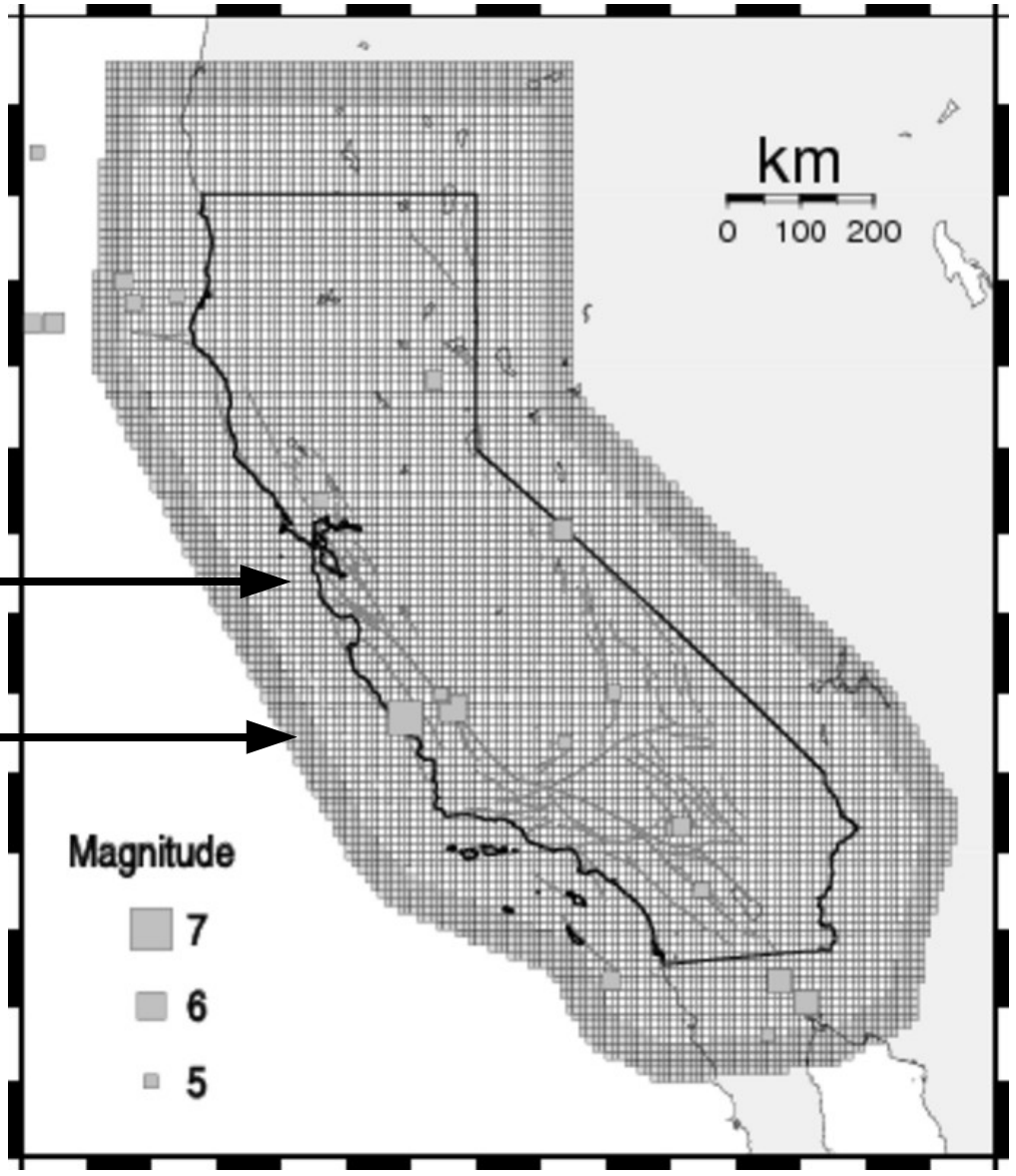
Implementation

What does the testing implementation additionally include?

- Model definitions
- Authorized data sources
- Definition of testing bins



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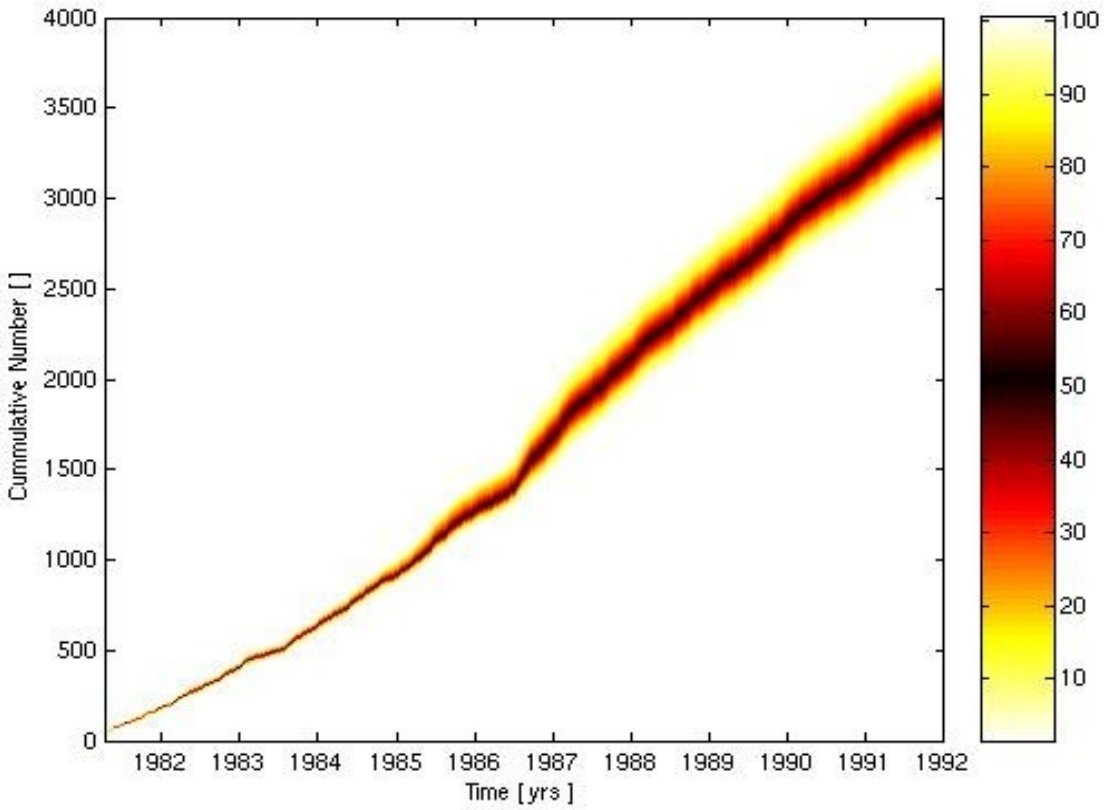
Implementation

What does the testing implementation additionally include?

- Model definitions
- Authorized data sources
- Definition of testing bins
- Declustering



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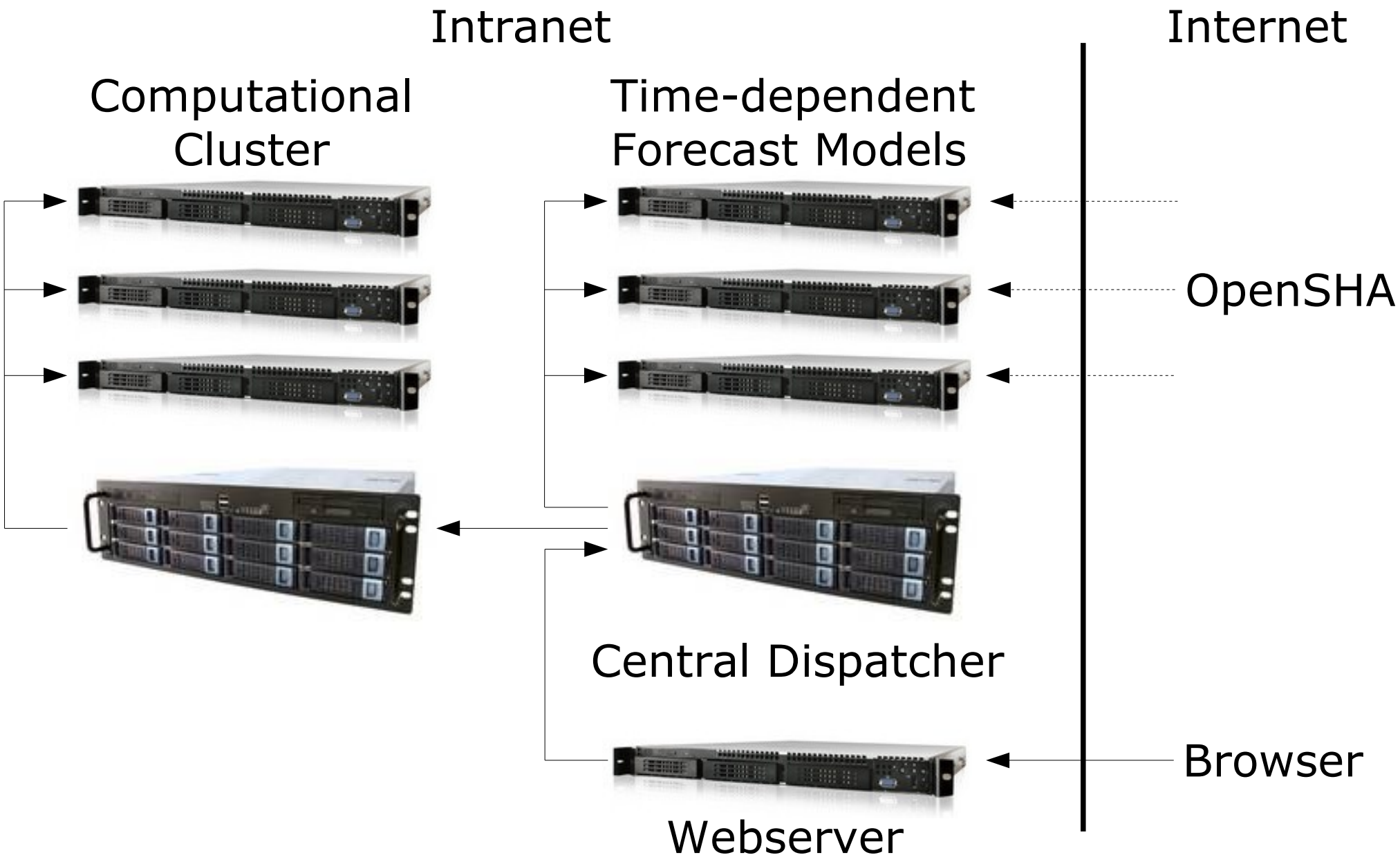
Testing Center Setup



Why a Testing Center?

A controlled environment for:

- Test multiple models against each other
- Re-run the tests with alternative options (different magnitude ranges)
- Re-run the tests in case of bugs in the testing procedure
- Document each models code and potential changes to it
- Track the modeler's additional data and deposit it
- 'Certify' all steps of testing

- Convince the public that nobody cheated!

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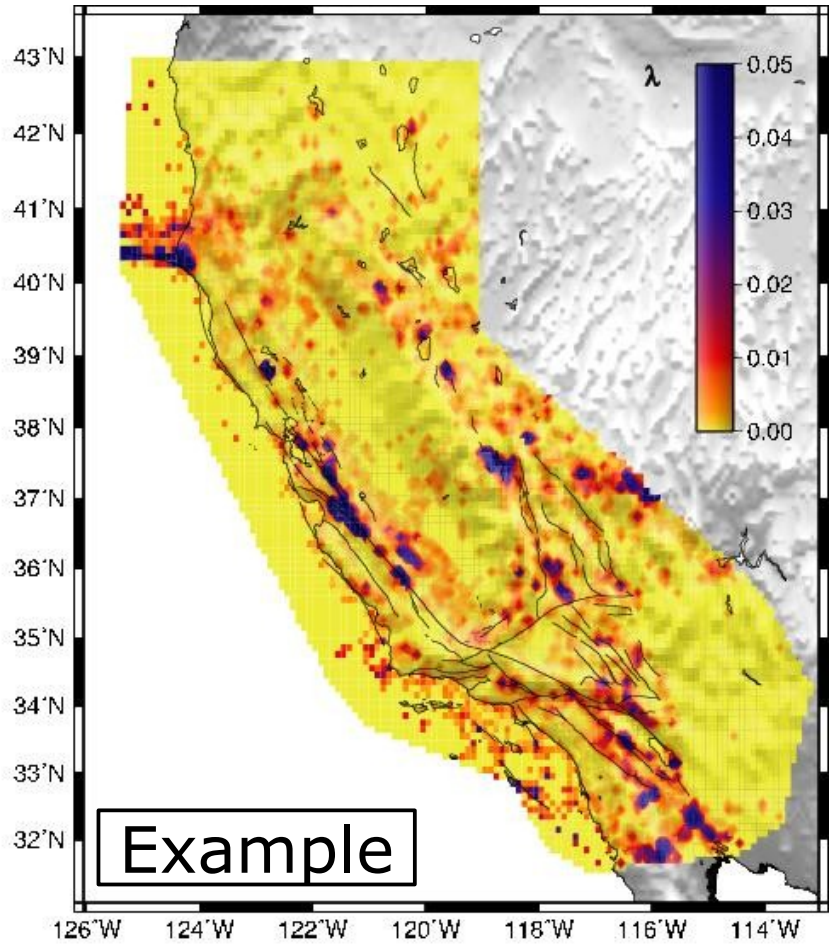
Submitted Models

17 5-year models have been submitted to the Testing Center



Bird & Liu
SHIFT (quasi-static Poissonian forecast, including aftershocks)

Ebel et al.
5-yr main shock+aftershock model
5-yr main shock model

Frankel
1996 National Hazard Model

Helmstetter, Kagan, Jackson
HKJ 2005 long-term model (De-clustered)
HKJ 2005 long-term model (Complete)

Holliday et al.
Pattern Informatics

Shen, Jackson, and Kagan
Geodetic De-clustered Forecast
Geodetic Complete Forecast

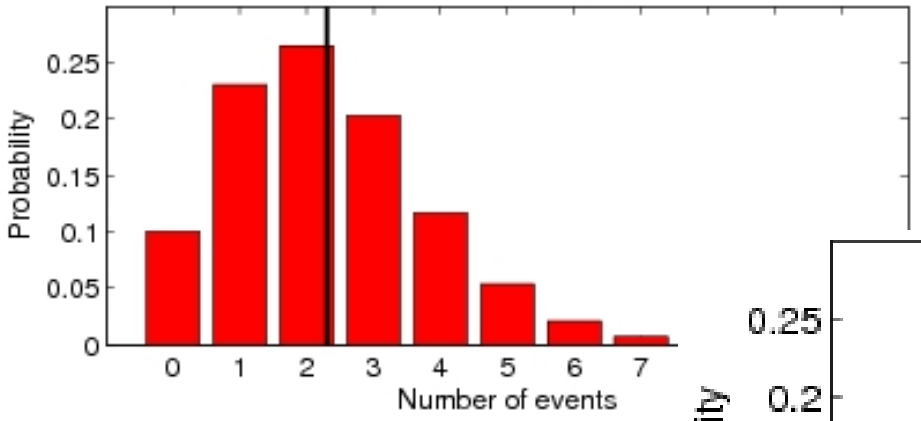
Ward
combo81
geodetic81
geodetic85
geologic81
seismic81
simulation

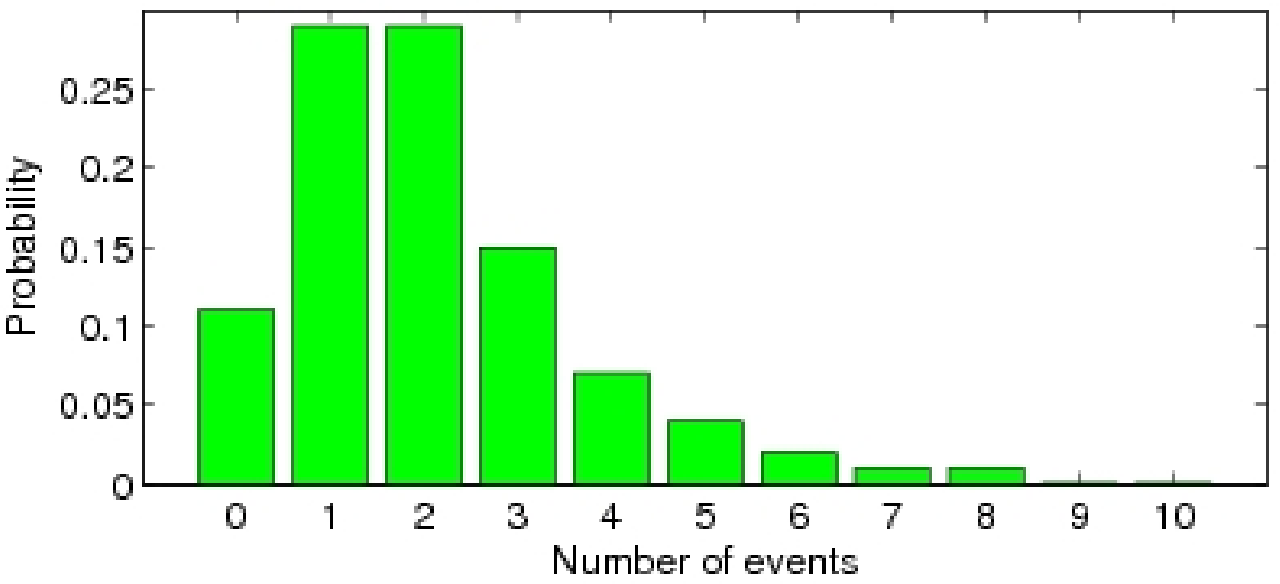
Wiemer & Schorlemmer
Asperity Likelihood Model

WG 2002
National Hazard Model

Extend RELM with:

- New probability distributions

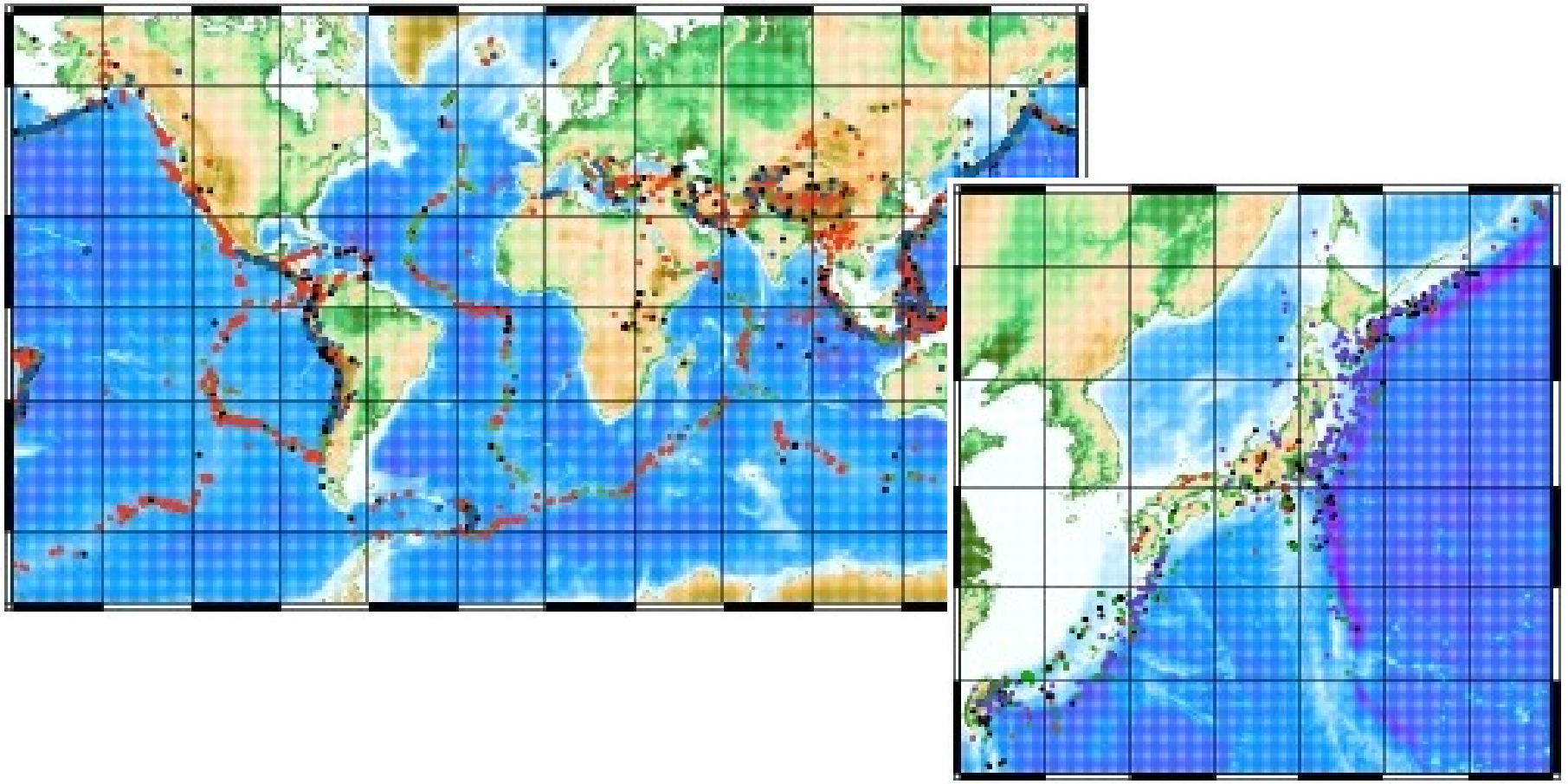




- New testing/scoring methods

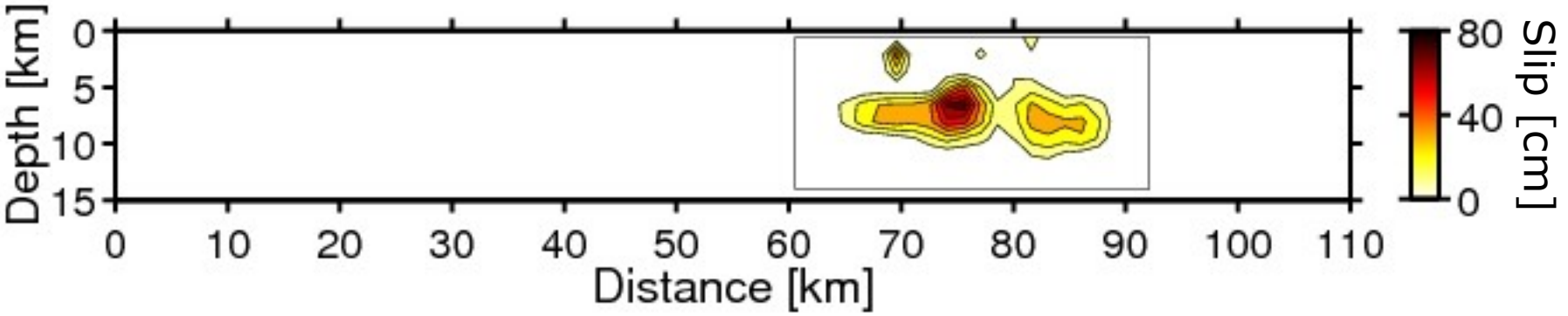
Extend RELM with:

- Expand the model space by
  - Including new areas



Extend RELM with:

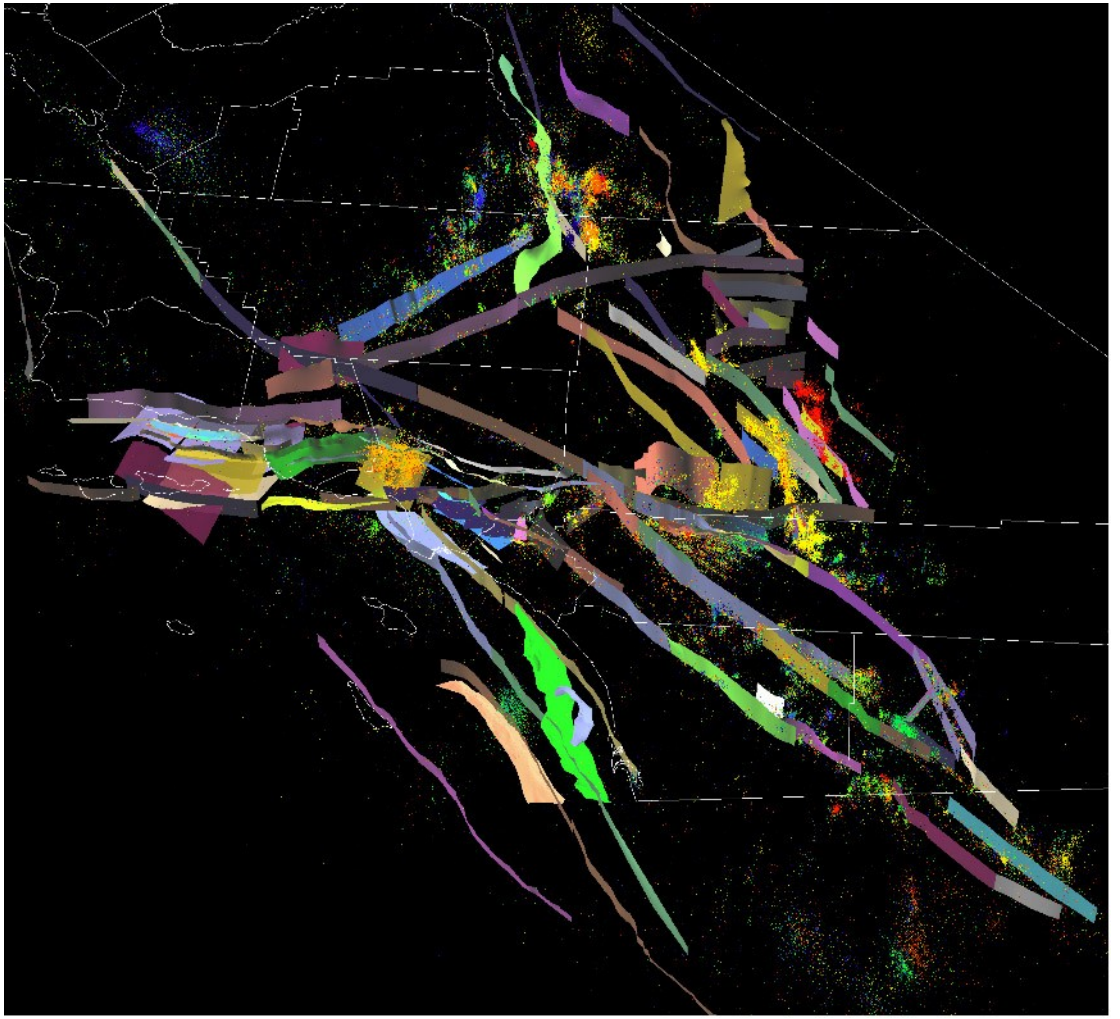
- Expand the model space by
  - Including new authorized data sources



Slip distribution of the 2004 Parkfield event
Courtesy of Chen Ji

Extend RELM with:

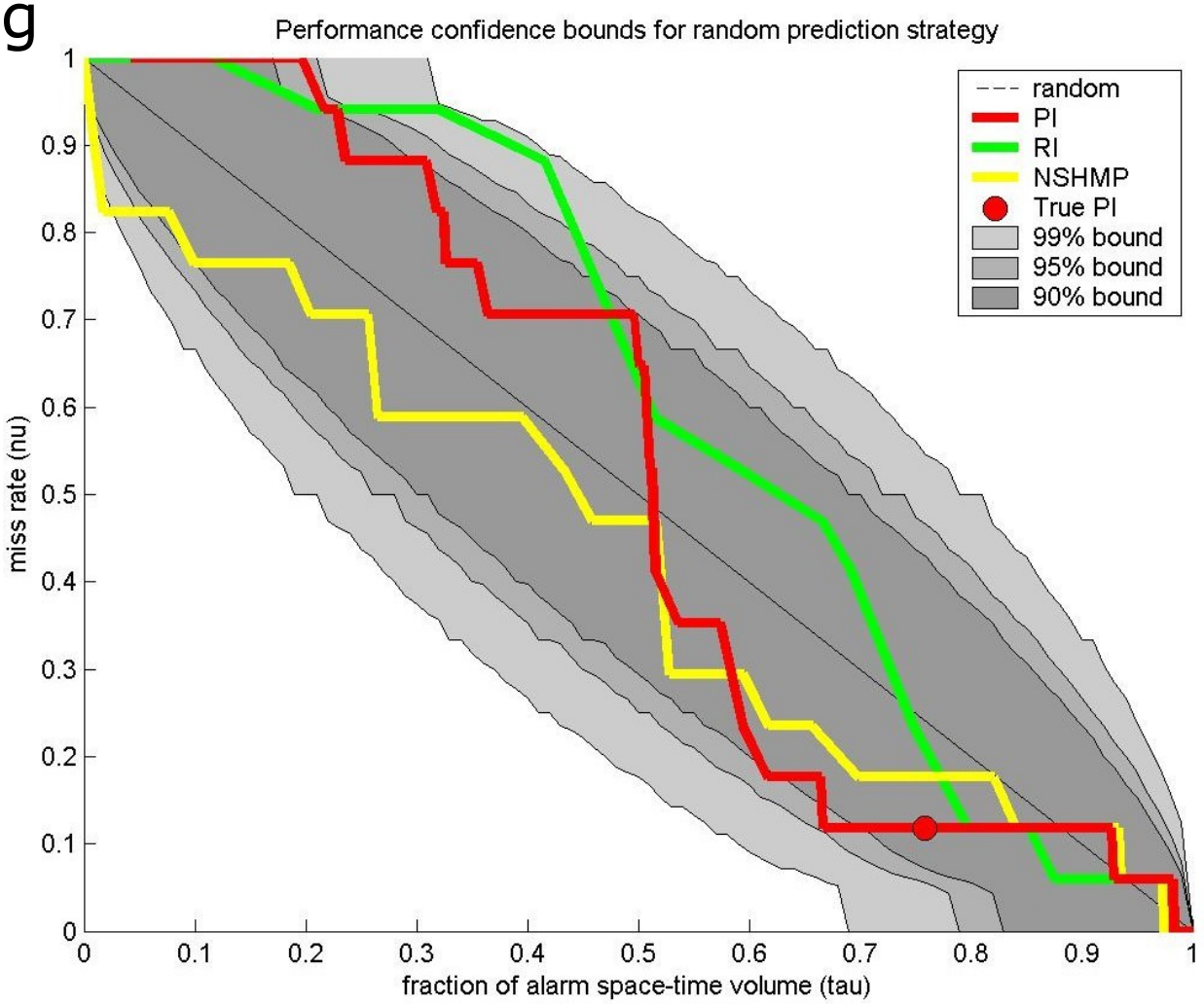
- Expand the model space by
  - Fault-based testing



SCEC Community Fault Model

Extend RELM with:

- Expand the model space by
  - Alarm-based testing



Courtesy of
J. Zechar & T. Jordan

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Summary

- RELM achieved most of its goals:
  Development of models
  OpenSHA
  Community-accepted testing is underway

- RELM established a new standard in rigorous testing of probabilistic earthquake forecasts (Testing Center)

- CSEP will extend RELM by:
  Expanding the model space
  Introducing new testing procedures
  Establishing a world-wide center for earthquake predictability research
  Reporting to governmental agencies (CEPEC, NEPEC)
  Outreach

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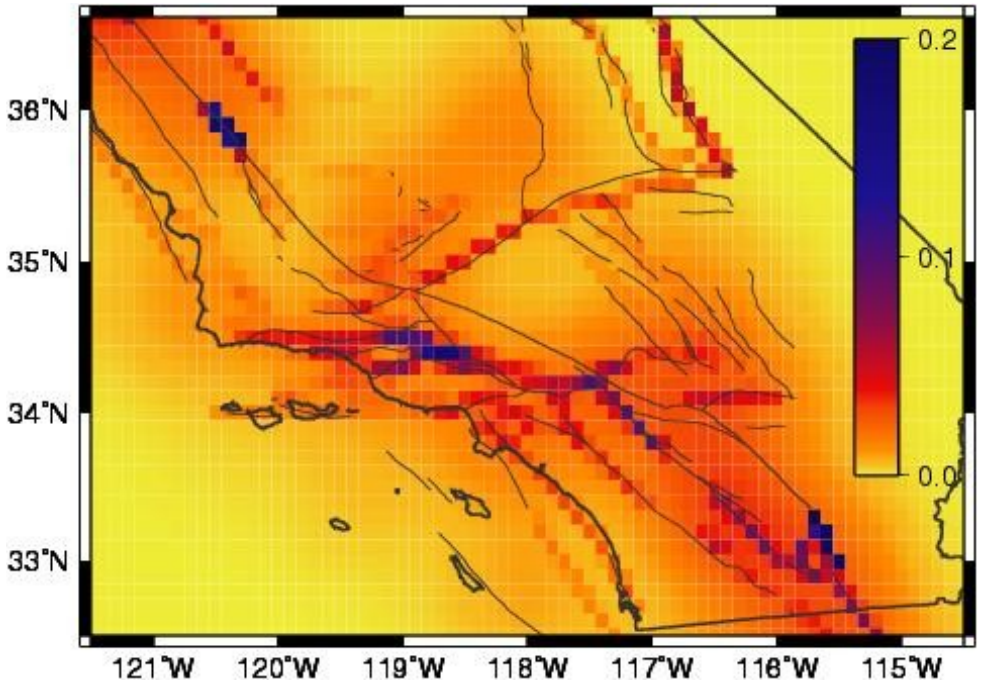
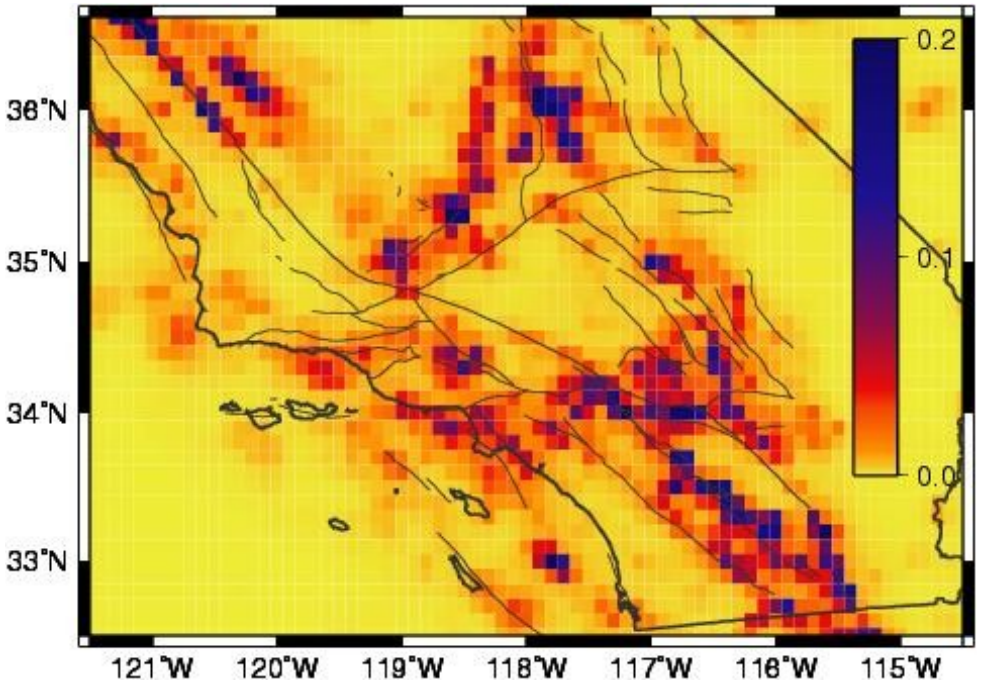
Example

20-year expectations for events of magnitude M ≥ 5



[*Frankel*, 1996]
(smoothed to grid)



[*Helmstetter*, submitted]

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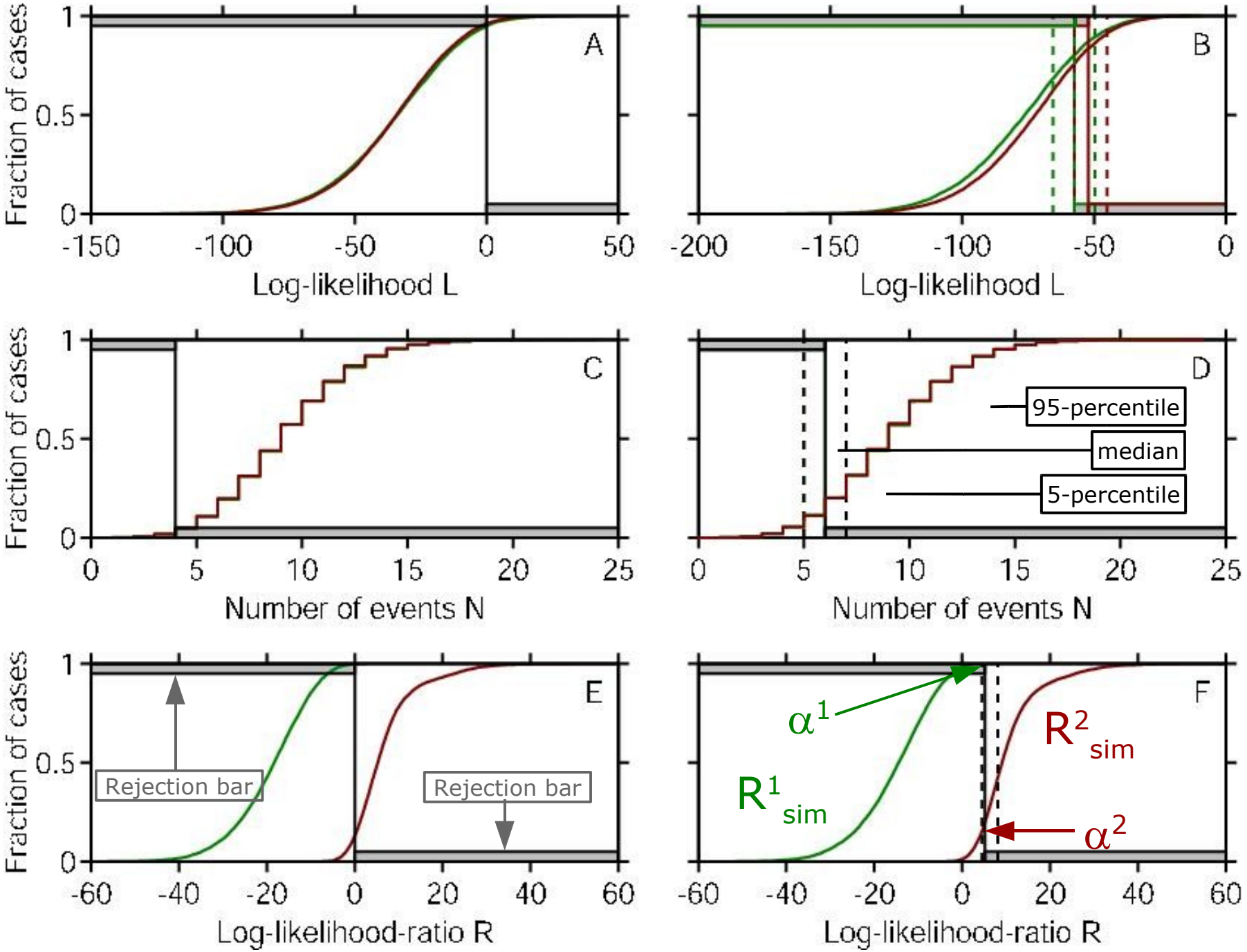
Example



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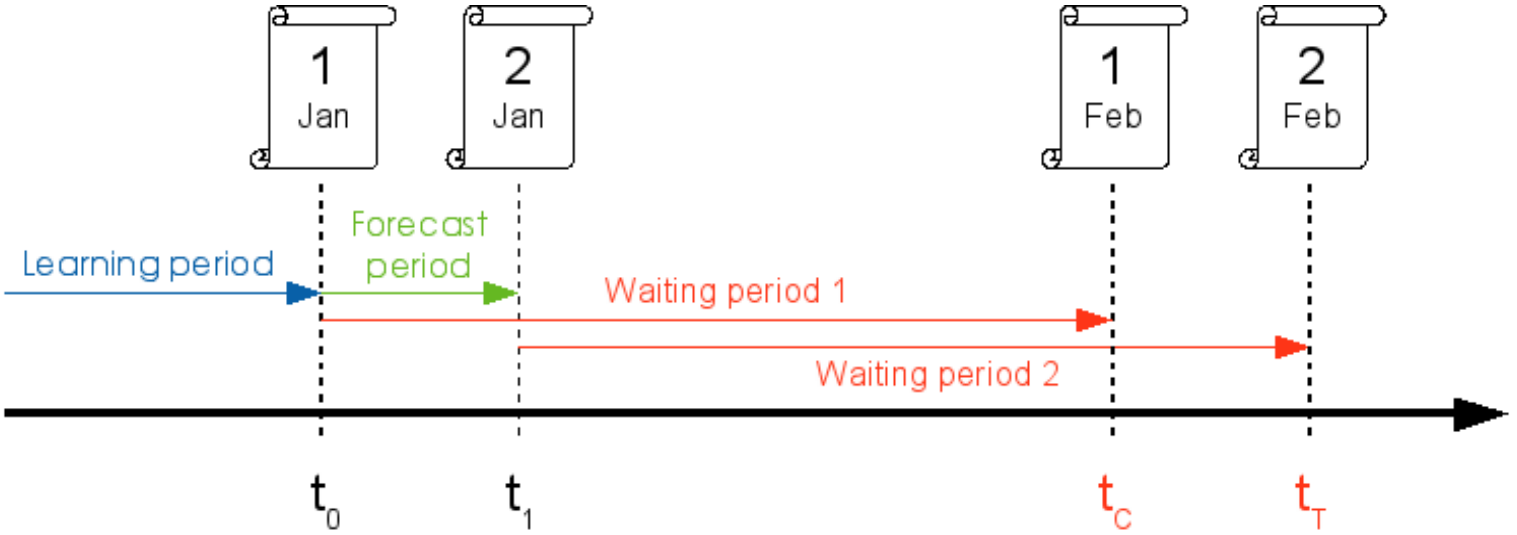
Time lines



Learning period

Non-authorized data can be deposited by the modeler.

Data gets a time-stamp for reproducibility results.

Waiting period 1

Time before the authorized catalog for t_0 can be provided.

t_c: Compute the forecasts.

Waiting period 2

Time before the authorized catalog for t_1 can be provided.

t_T: Perform the tests and compute the results.