Combining rate-based earthquake forecasting models with precursory information and with non-normalized models

P. Shebalin (1,2), C. Narteau (2), J. Zechar (3), and M. Holschneider (4)

(1) Institute of Earthquake Prediction Theory and Mathematical Geophysics, Moscow, 84/32 Profsouznaya, Moscow 117997, Russia.,
(2) Institut de Physique du Globe de Paris, Sorbonne Paris Citeì Univ Paris Diderot, UMR 7154 CNRS, 1 rue Jussieu, 75238 Paris, Cedex 05, France.,
(3) Institut f. Geophysik, NO H 61 Sonneggstrasse 5 8092 Zuřich, Switzerland.,
(4) Institute of Dynamics of Complex Systems (DYCOS), Universitat Potsdam, POB 601553, 14115 Potsdam, Germany.

Non-normalized models

Alarm function

$A(x,t)$

Examples: TIPs (binary or threshol-dependent), precursors (e.g. radon measurements, Vp/Vs values etc.), time-dependent measurement (tides, GPS-geodesy, sleep rates, any rate-based model), time-independent maps, space independent measurements (e.g. solar flares).

$$\nu(A_0) = 1 - \frac{\sum_{A(x,t)\geq A_0} \omega(x,t)}{\sum \omega(x,t)}$$

$$\lambda(x,t) = \sum_{M_1 < M \leq M_2} \lambda(x,M,t)$$

several magnitude ranges can be used

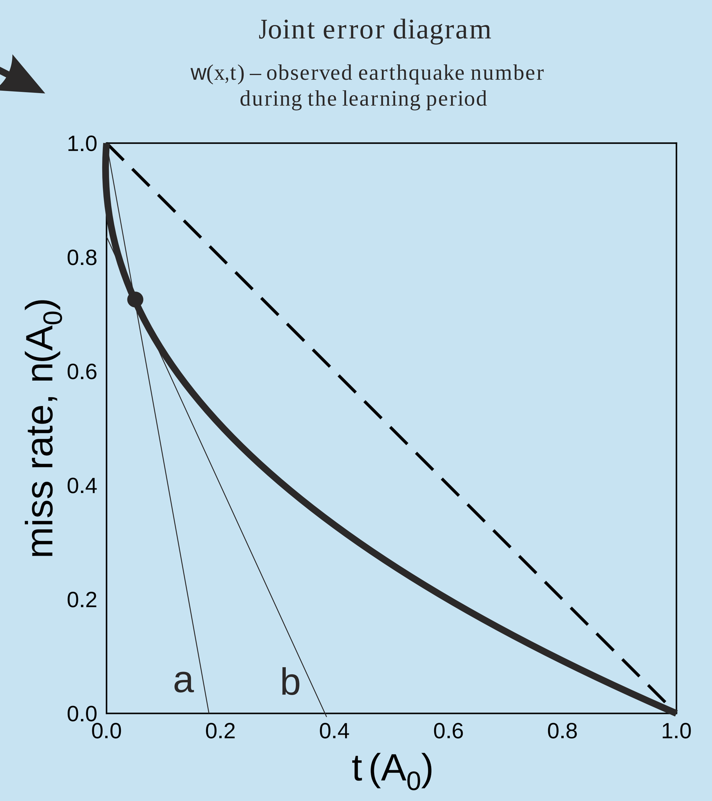
$$\tau(A_0) = \frac{\sum_{A(x,t)\geq A_0} \lambda(x,t)}{\sum \lambda(x,t)}$$

Rate-based models

Poisson rate of expected earthquakes

$\lambda(x,M,t)$

Examples: RELM/CSEP models, seismic hazard maps, time-dependent seismic hazard maps.



Aki's probability gain:

$$G(A_0) = \text{tg}\,\alpha = \frac{1-\nu(A_0)}{\tau(A_0)}$$

Differential probability gain (DPG):

$$g(A_0) = \text{tg}\,\beta = -\frac{\partial \nu(A_0)}{\partial \tau(A_0)}$$

the expected rate of eathquake should be:

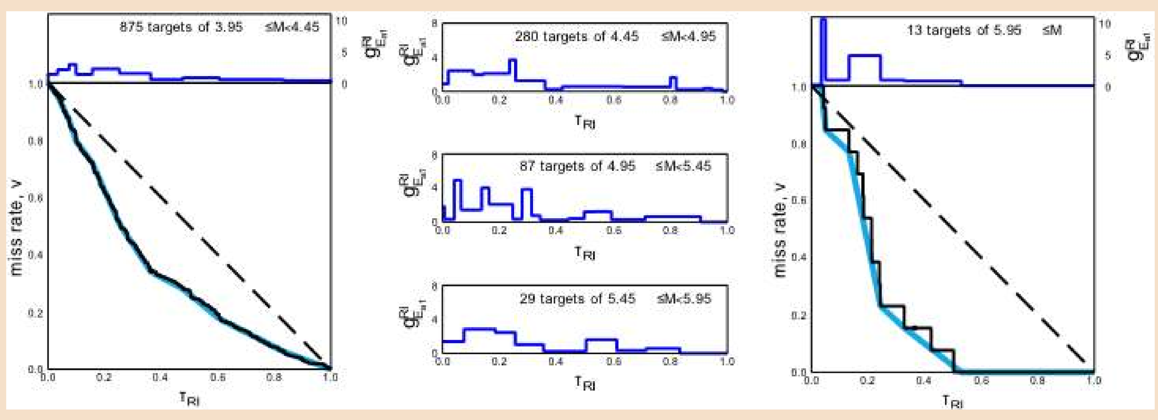
$g(A_0) > 1$ - increased
$g(A_0) < 1$ - decreased
$g(A_0) = 1$ - unchanged

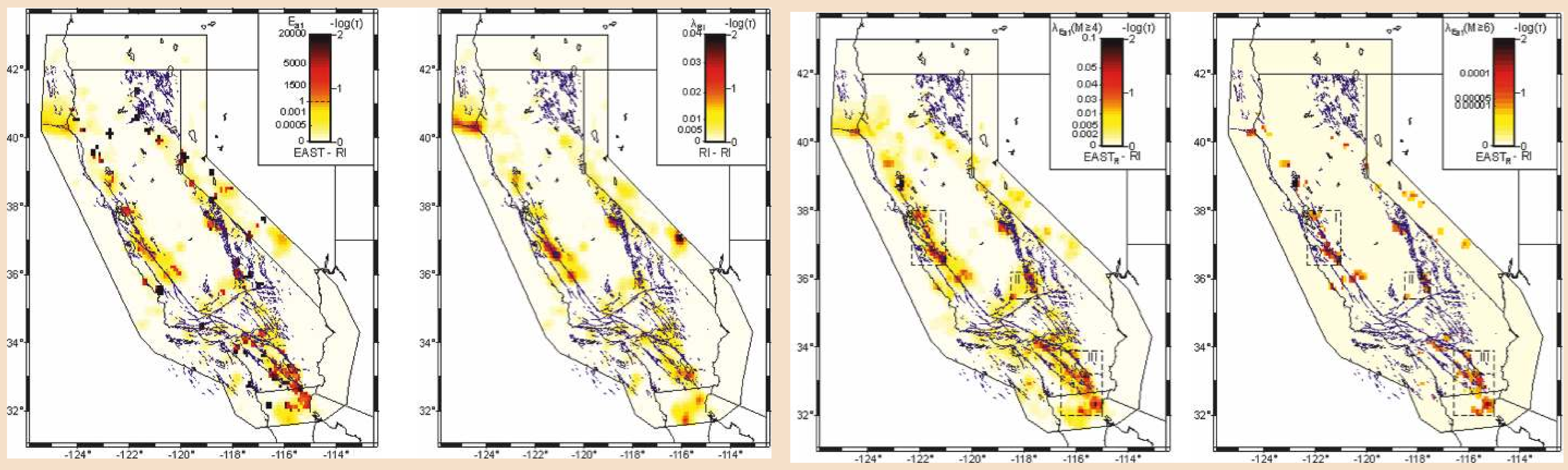
$$\lambda_{combined}(x,M,t) = g(A(x,t))\,\lambda(x,M,t) = A(x,t)^{\sim}\;\lambda(x,M,t)$$

Example 1:

alarm-based model -> rate-based model

EAST -> $EAST_R$



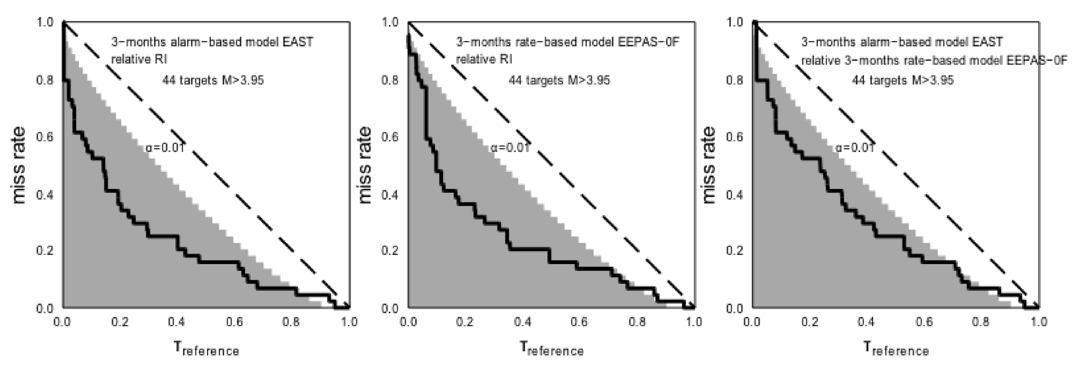


Example 2:

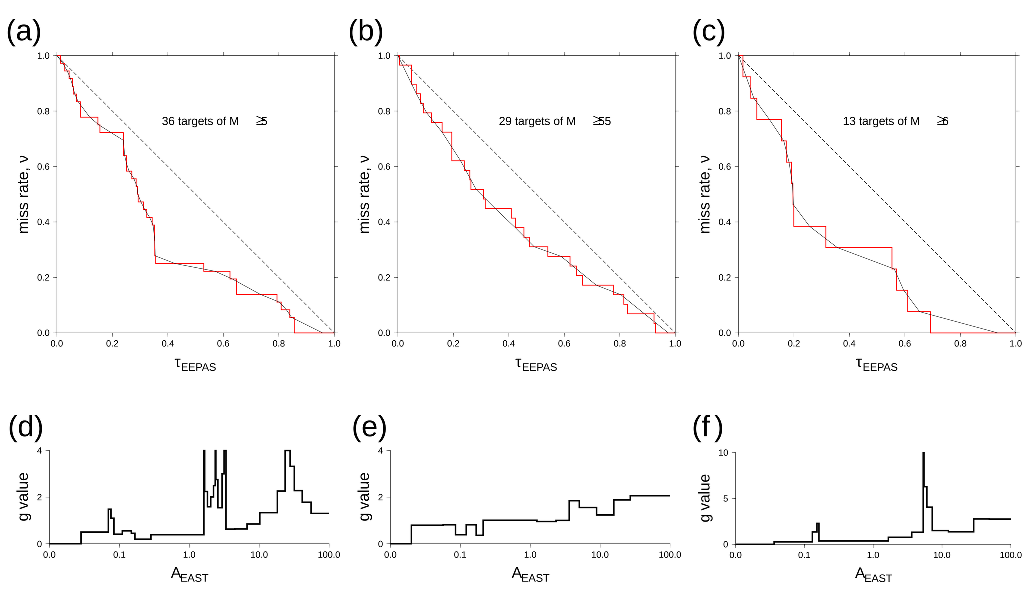
combining alarm-based model with rate-based model

EAST ~ EEPAS

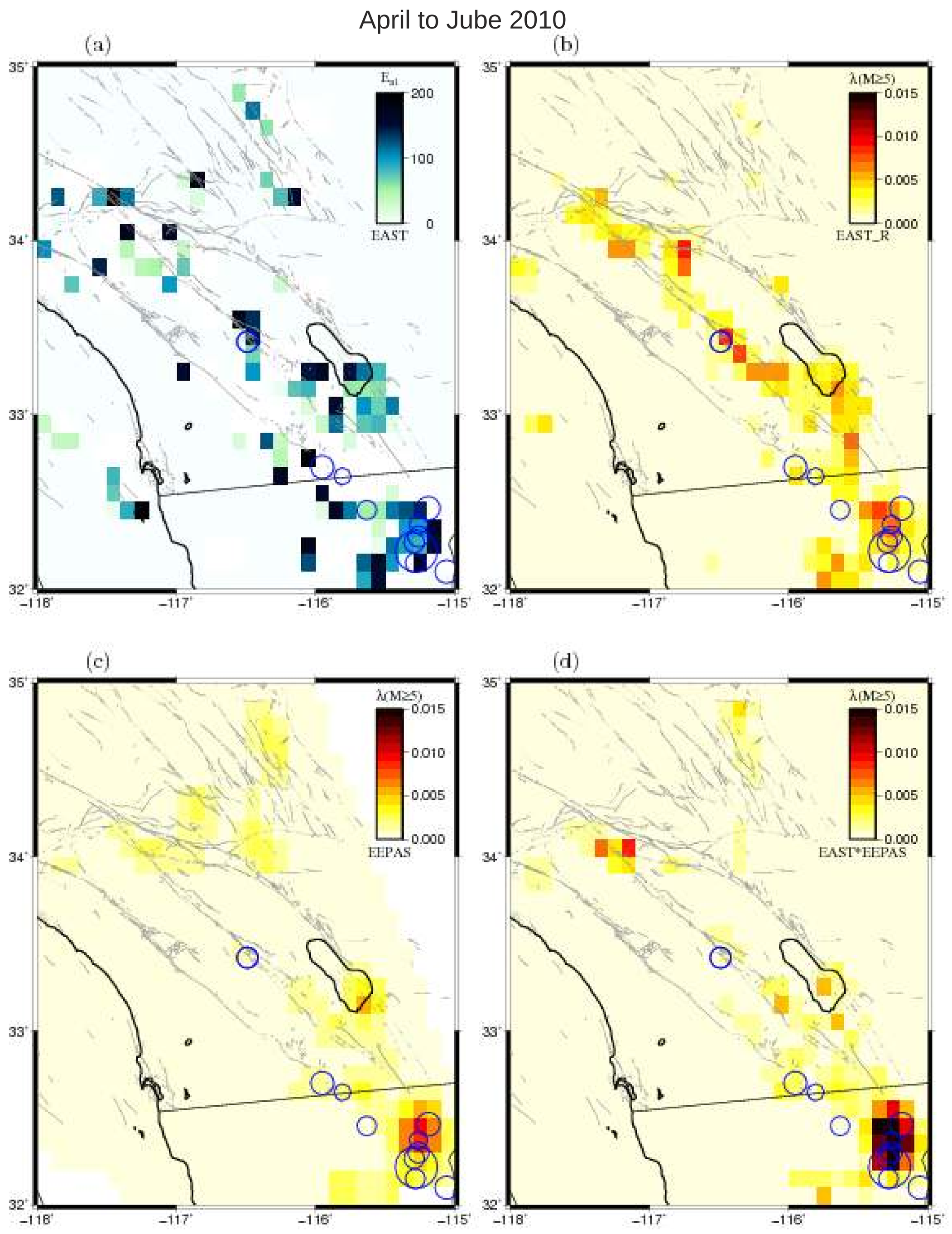
Why to combine: EAST and EEPAS relative Ri are inforamtive, but EAST relative EEPAS too



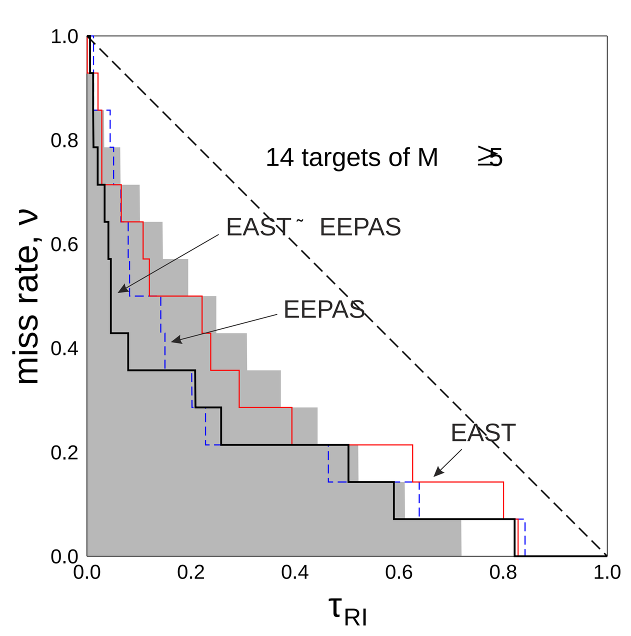
Determining $g(A_{EAST})$



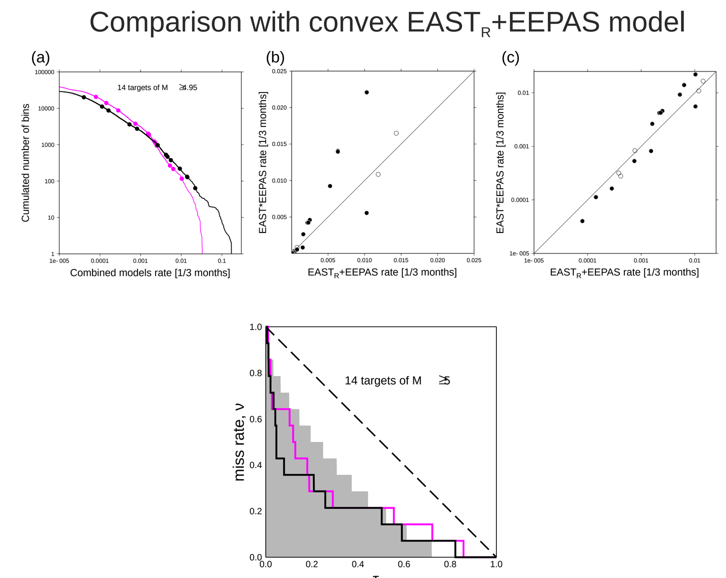
April to Jube 2010



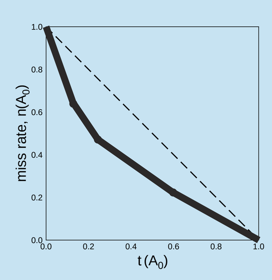
Testing period July 2009 to December 2012



Comparison with convex $EAST_R$+EEPAS model



Conservation rule



$$\Lambda_{combined} = \sum_{i=1}^{N} g_i \lambda_i = \Lambda \sum_{i=1}^{N} g_i (\tau_i - \tau_{i-1}) = \Lambda \sum_{i=1}^{N} \nu_i = \Lambda$$

The rule is strict in learning period, and approximate in real-time

Bibliography

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