Enhancing OPerational Earthquake foRecasting through innovative Approaches (OPERA)

Shlomo Havlin (Bar-Ilan University)

Yossi Ashkenazy (Ben-Gurion University)

and

Warner Marzocchi (Institute of Geophysics, Rome)

Collaboration with Rami Hofstater+Avi Shapira

Do eartquakes cluster?

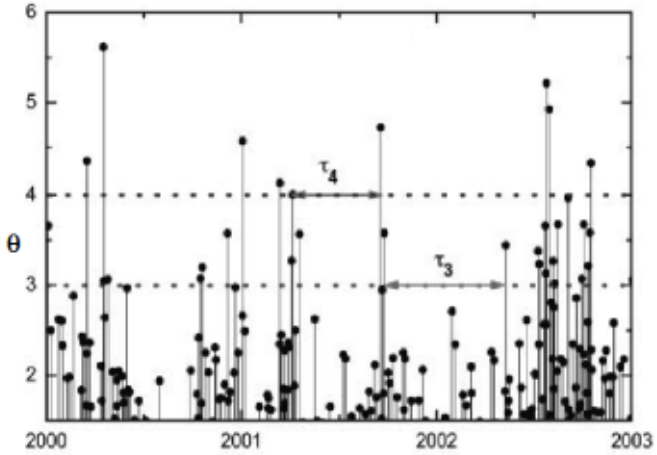
Das Erdbeben von Lissabon, kolorierter Holzschnitt aus der Sammlung Granger

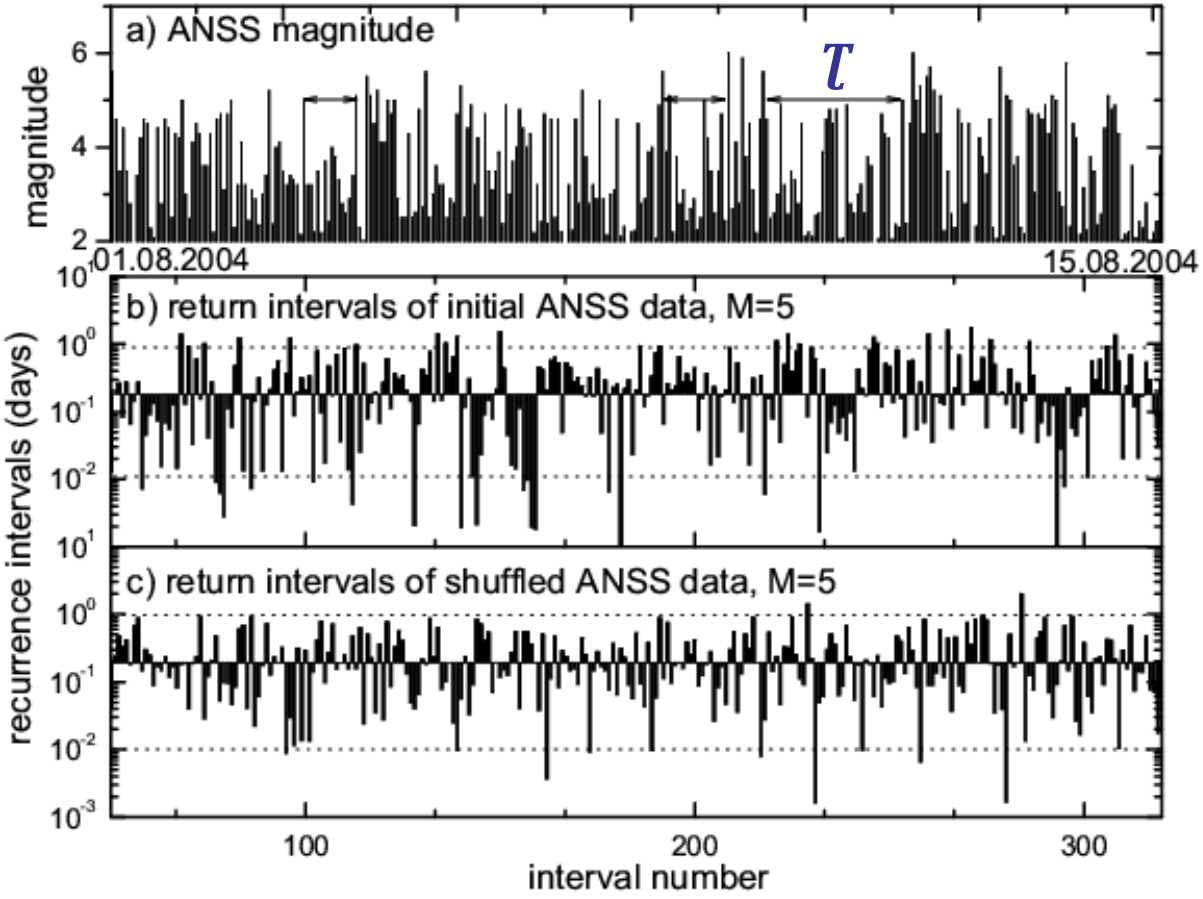
Foto Ullstein

Lisbon 1755

EARTHQUAKES CLUTERING

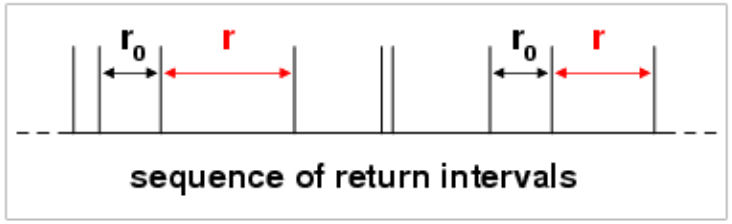
Clustering is found in the occurrence of earthquakes (similar to other extreme events in climate-fluds and extreme temperature)





Livina et al, PRL 2005

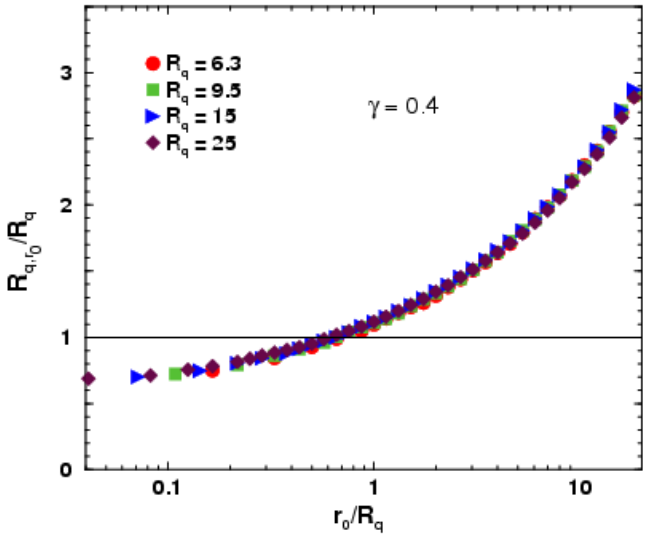
Earthquakes: Mean conditional return interval

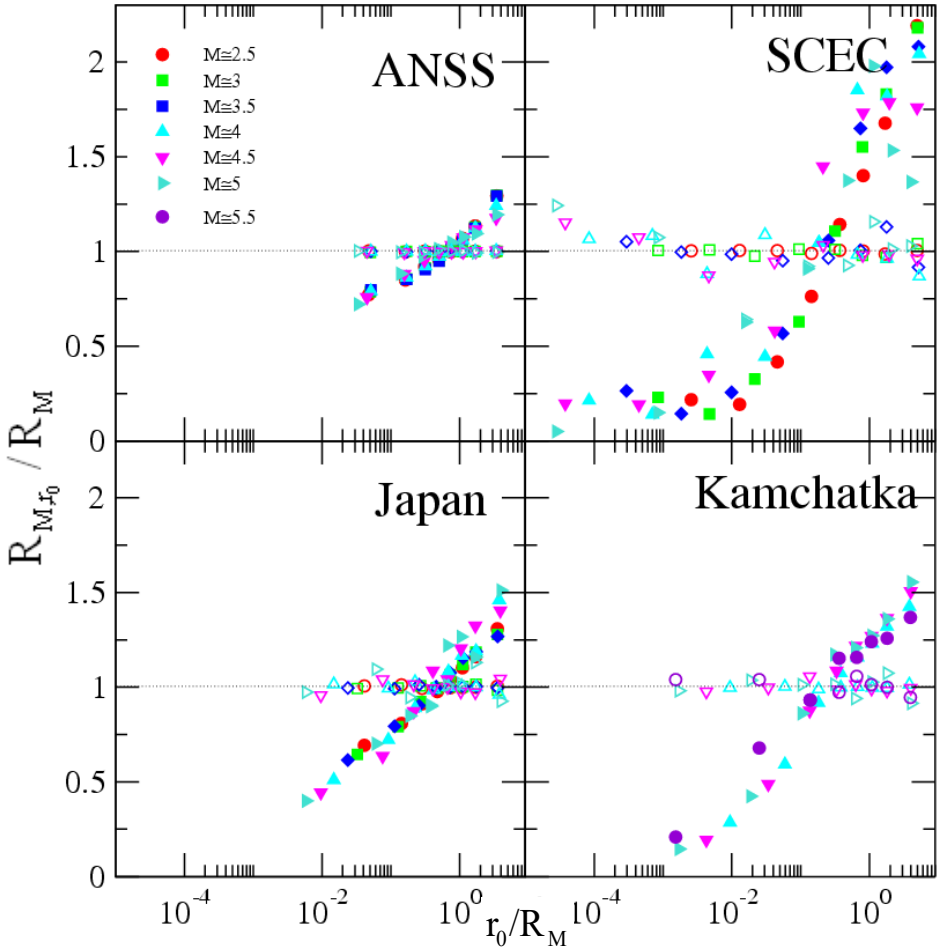


R_M – mean return intervals between earthquakes above magnitude M

R_{M,r_0} – mean conditional return intervals following r_0

Artificial LTC records



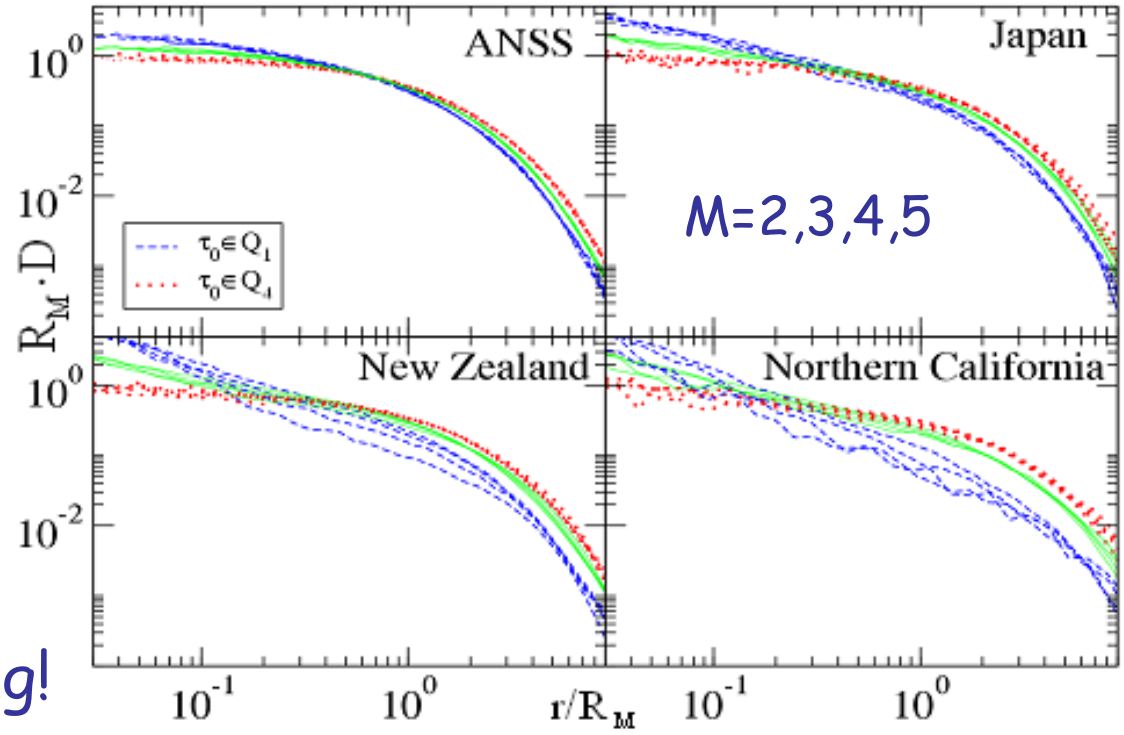


Possible origin:
Long-term correlations

Scaling in the distribution of return intervals

$D(r \mid r_0)$ Probability to have a return interval r following r_0

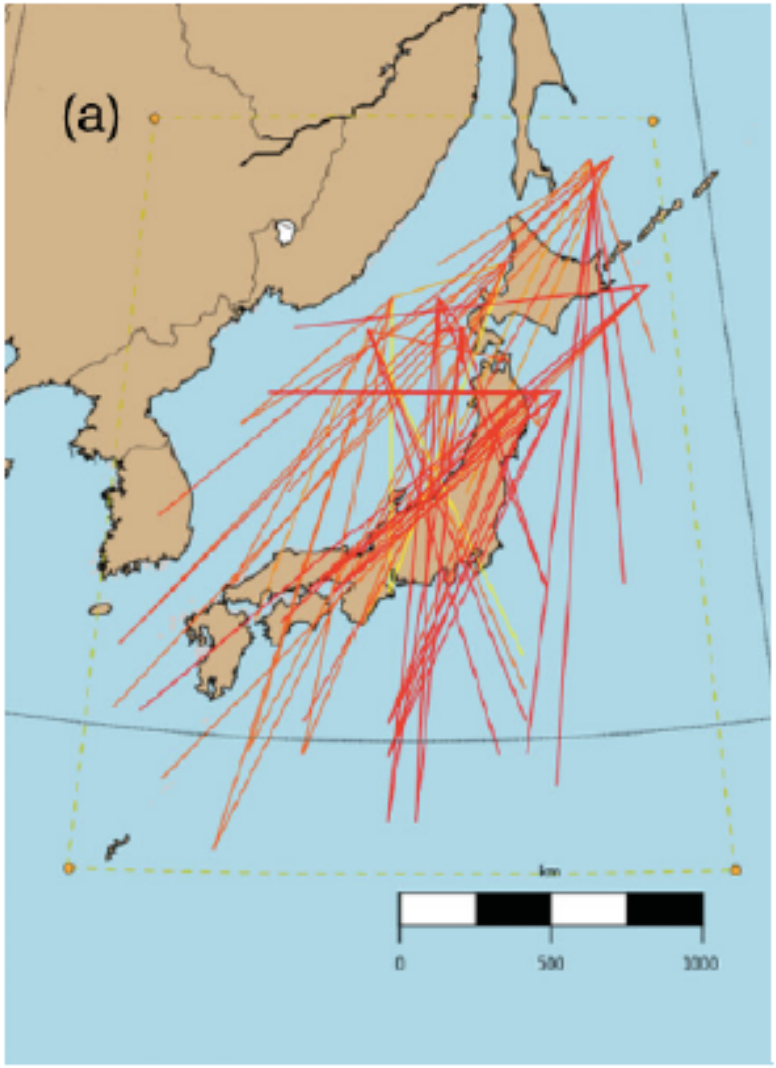
Q_1 lowest $\frac{1}{4}$ of r_0-blue
Q_4 highest $\frac{1}{4}$ of r_0-red
All r_0-green

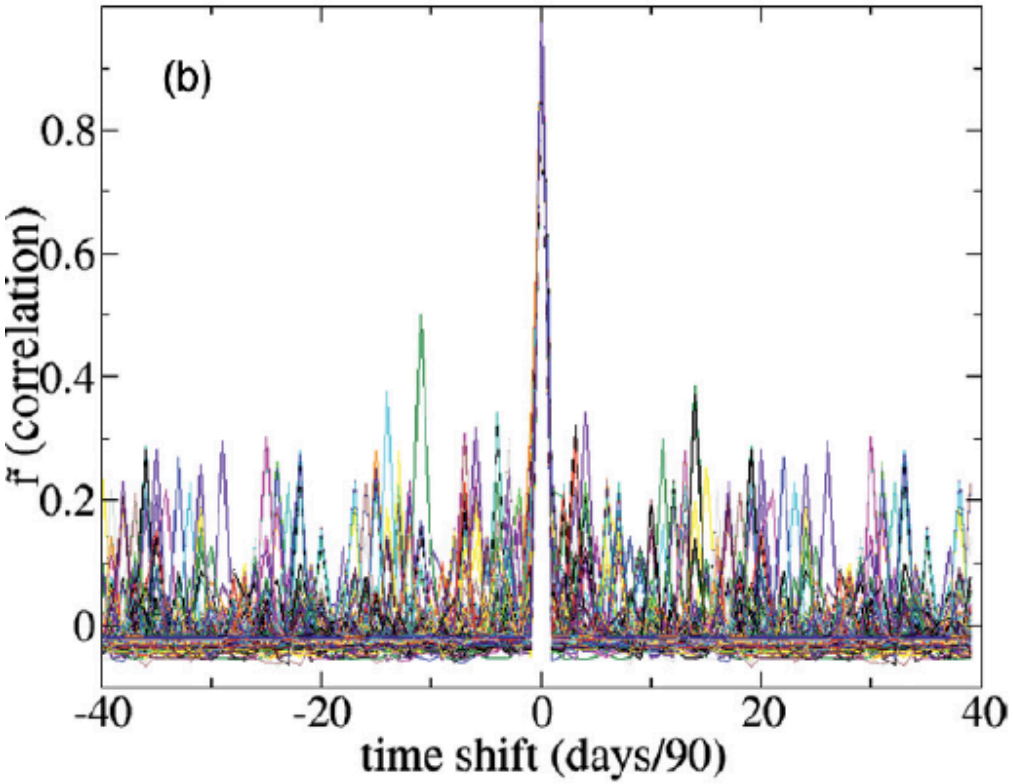


Short return intervals follow short ones
Long intervals follow long!

Memory+Scaling: Livina et al, PRL (2005)

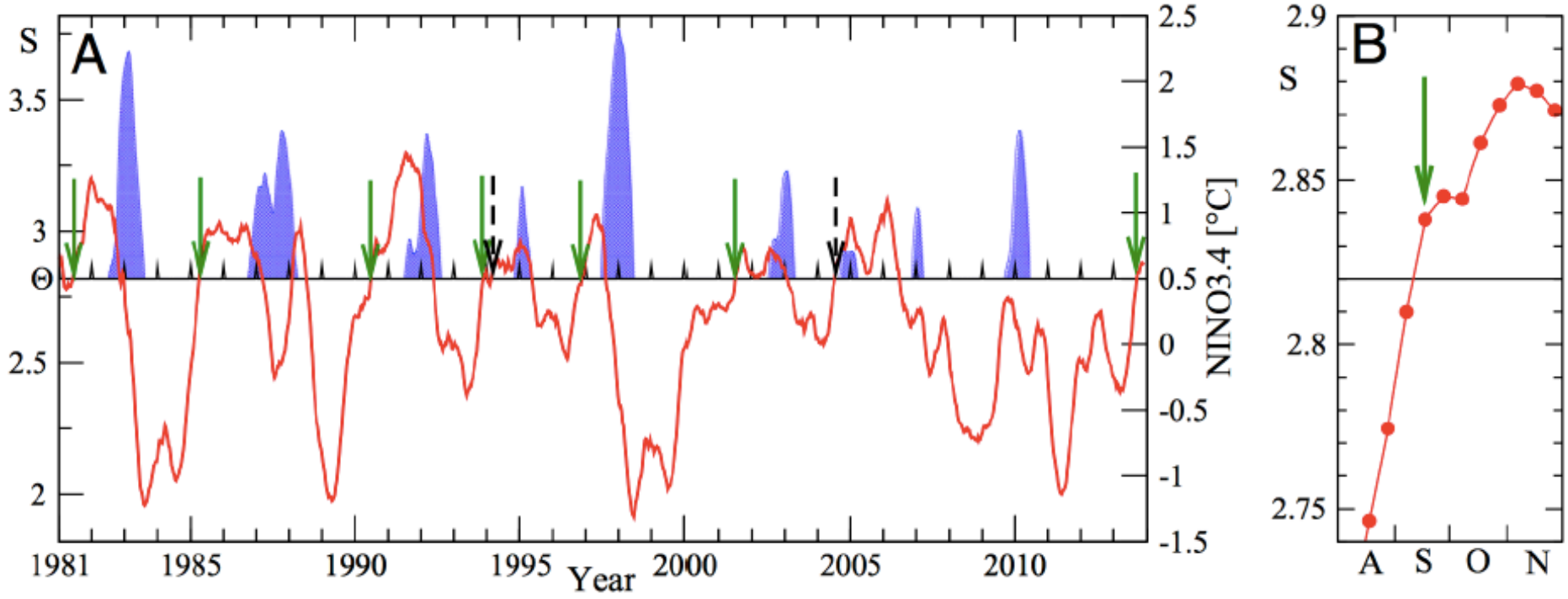
Earthquake Networks





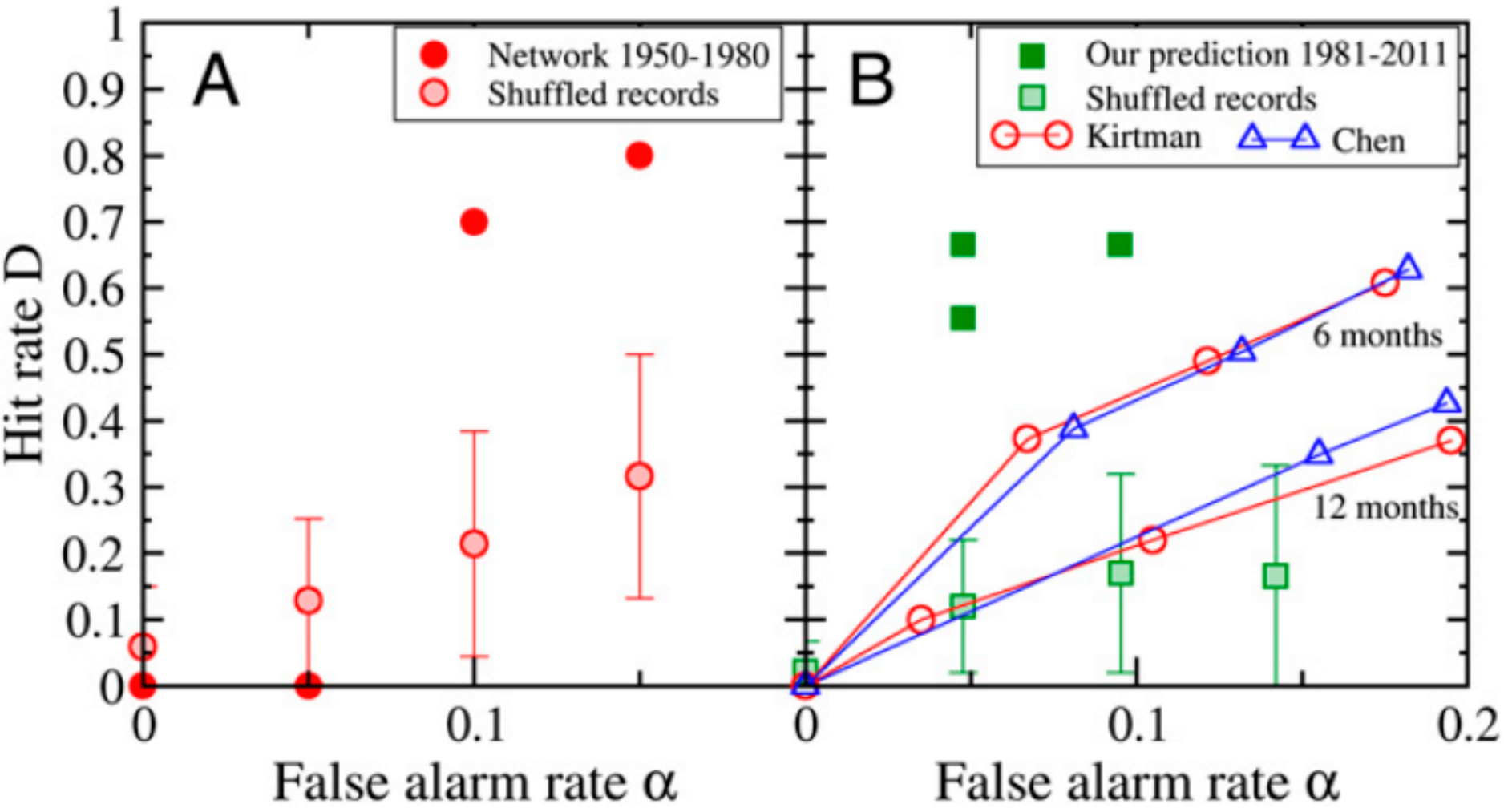
Tenenbaum et al PRE (2014)

Prediction using evolving network
Hypothesis: before extreme events —interactions in the network increase



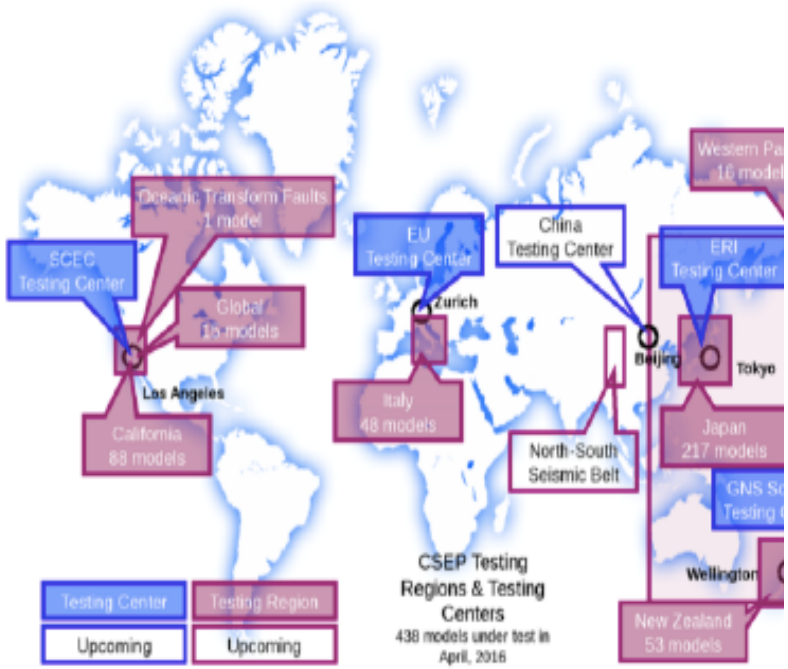
Example: El-Nino: Ludescher et al, PNAS (2014)

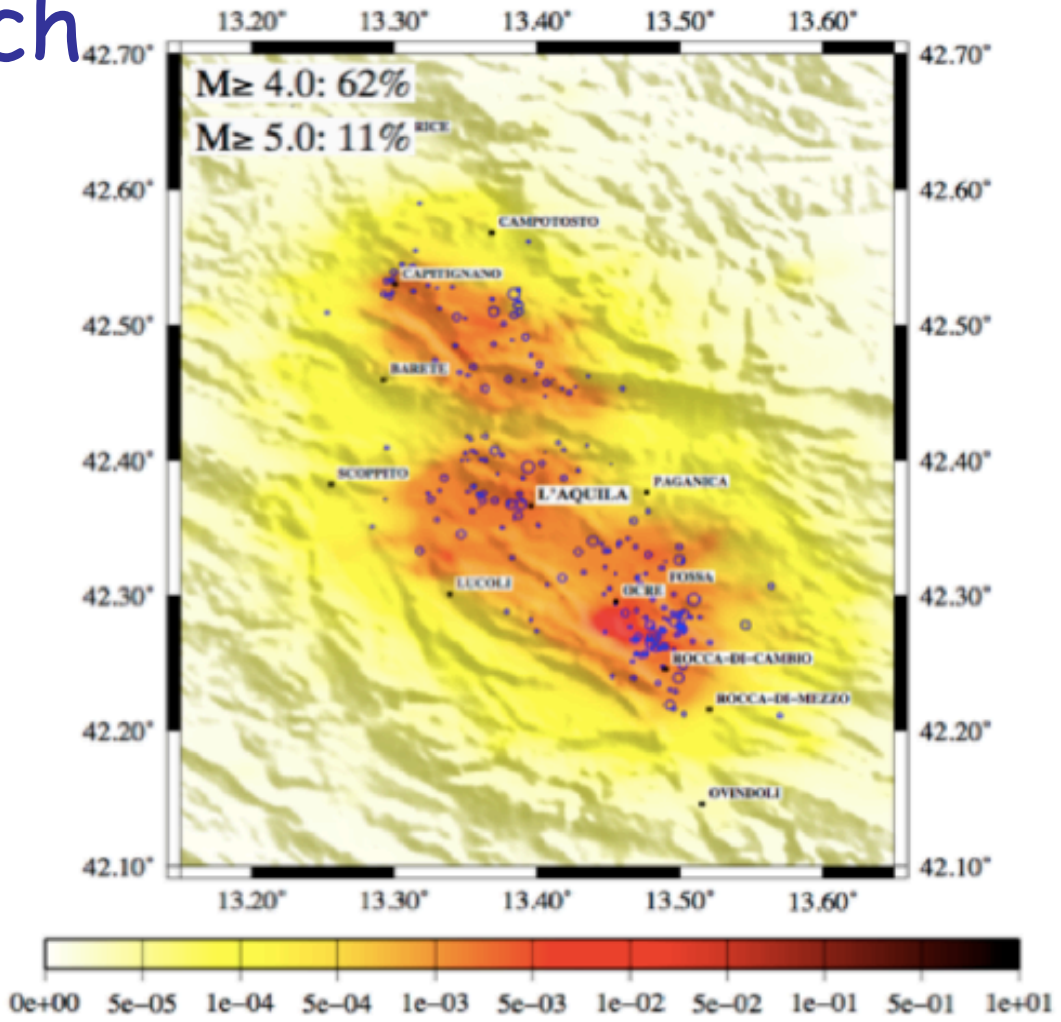
IMPROVED FORECASTING OF EL-NINO



Ludescher et al, PNAS (2014)

Marzocchi Approach



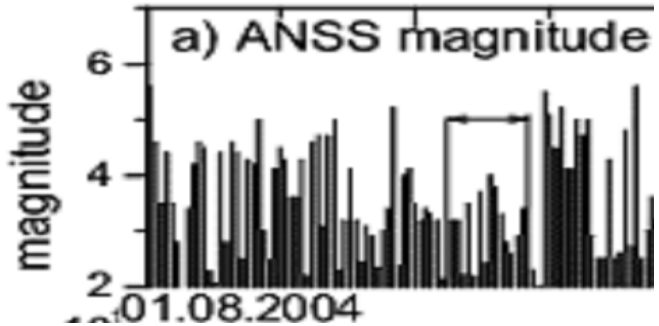


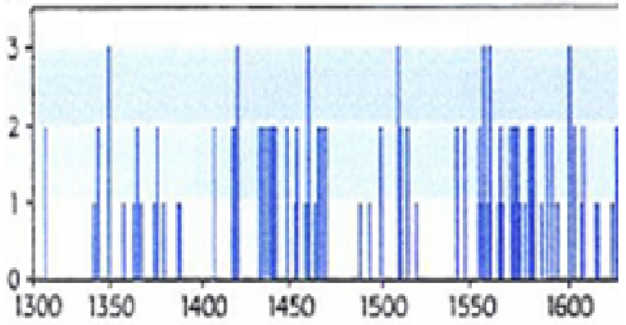
The testing regions and testing centers where (CSEP) experiments are ongoing.

The first real-time application of one-day earthquake forecast after the April 6, 2009, mainshock in L'Aquila Italy

SUMMARY

- Similar long range persistence of earthquakes, temperatures and rivers flow (floods).





- Scaling laws of distributions (stretched exponentials) and long term memory in return intervals between earthquakes above a threshold M
  - Short return intervals follow short ones
  - Long return intervals follow long ones

- Clustering of both short and long return intervals
  Clustering of extreme events! Like BUS at night and day!

- Challenges: (a) Improve forecasting of earthquakes (b) origin?