Impact of Incorporating Clustering into PSHA Models for Induced Seismicity

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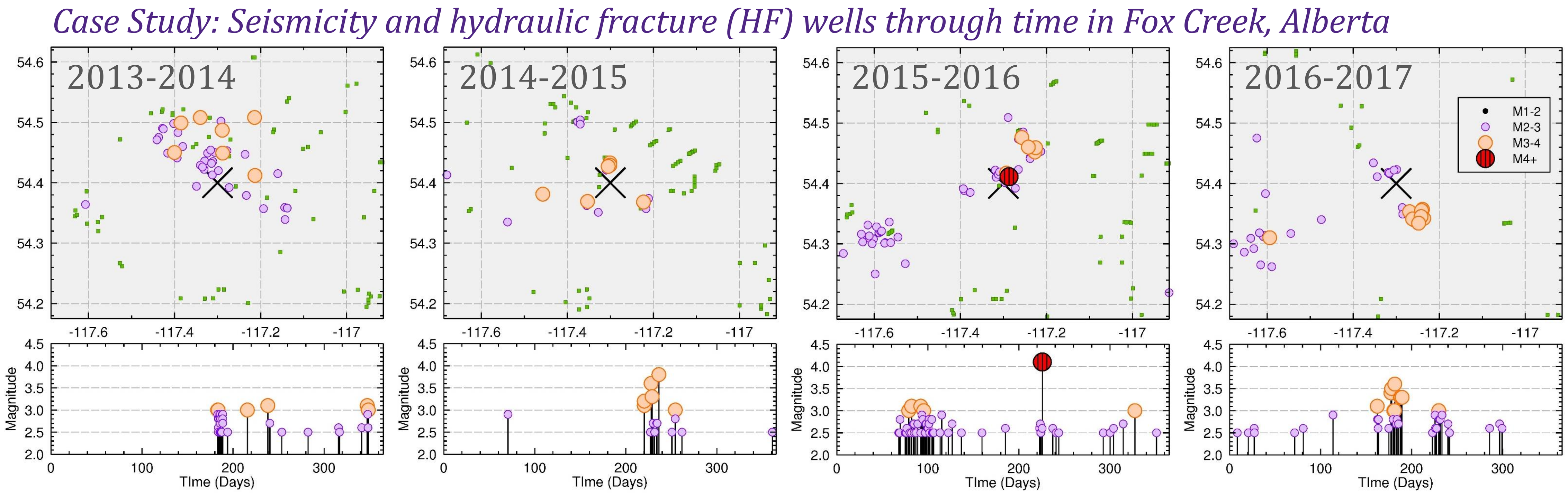
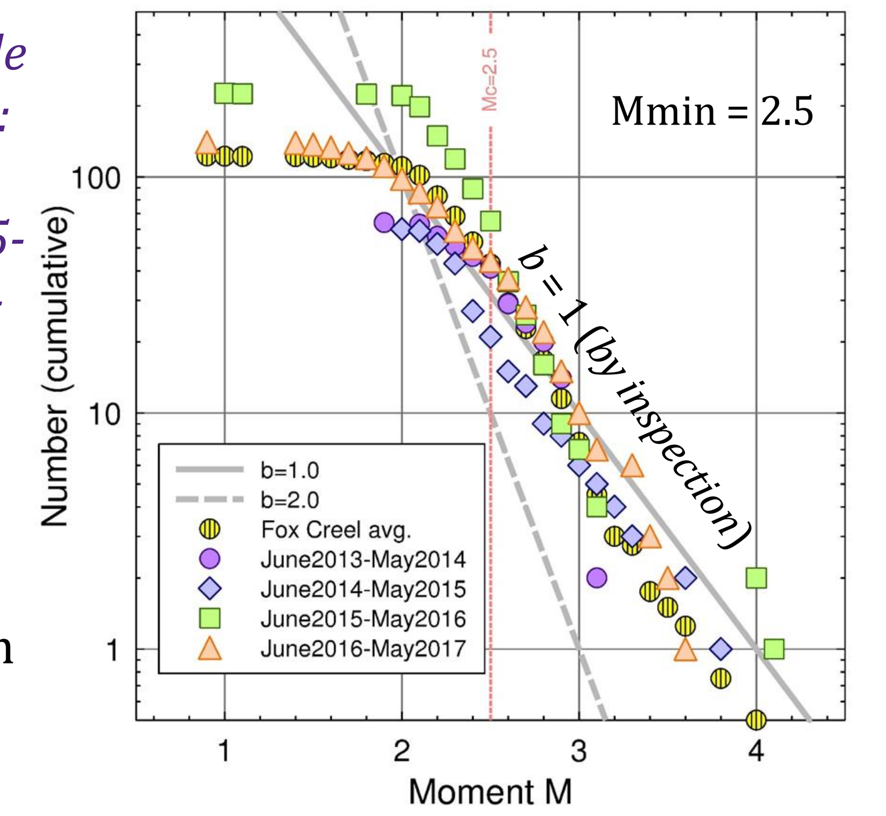
QUESTION: How is hazard impacted by clustering of seismicity (of a specified rate) in time and space?

Case Study: Seismicity and hydraulic fracture (HF) wells through time in Fox Creek, Alberta



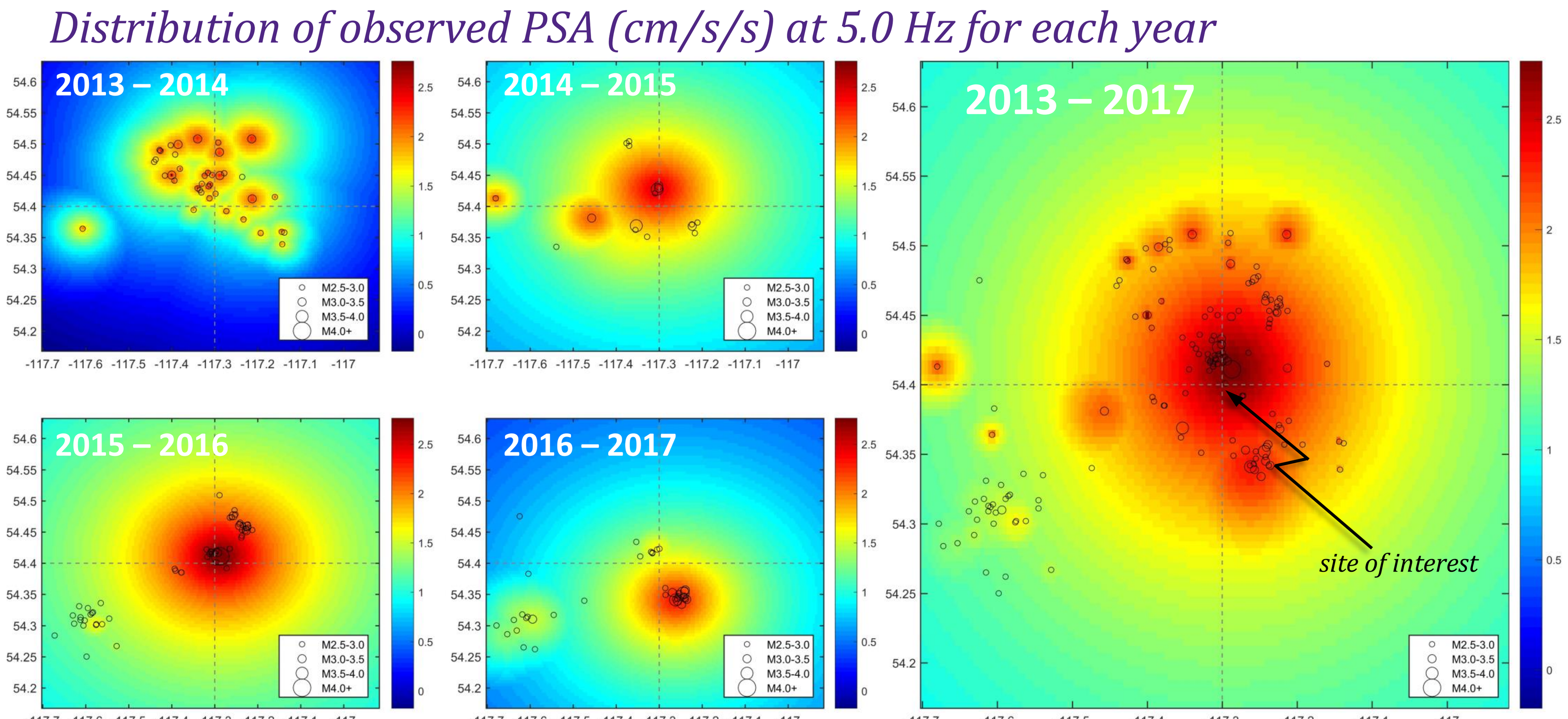
Subdivide observed seismicity for a 50 km × 50 km box into one-year time windows.

Per annum magnitude recurrence statistics: Fox Creek Area: 116-119W, 53.5-55.0N, years June 1 - May 31



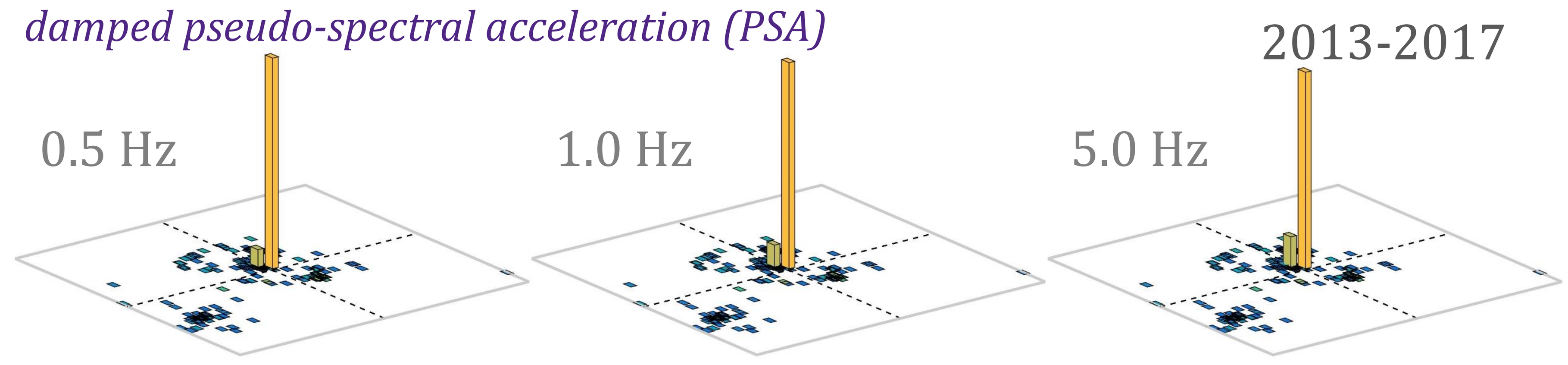
Gutenberg-Richter parameters by year. Slope $b \sim 1$. Minimum magnitude for completeness ~2.5

Distribution of observed PSA (cm/s/s) at 5.0 Hz for each year

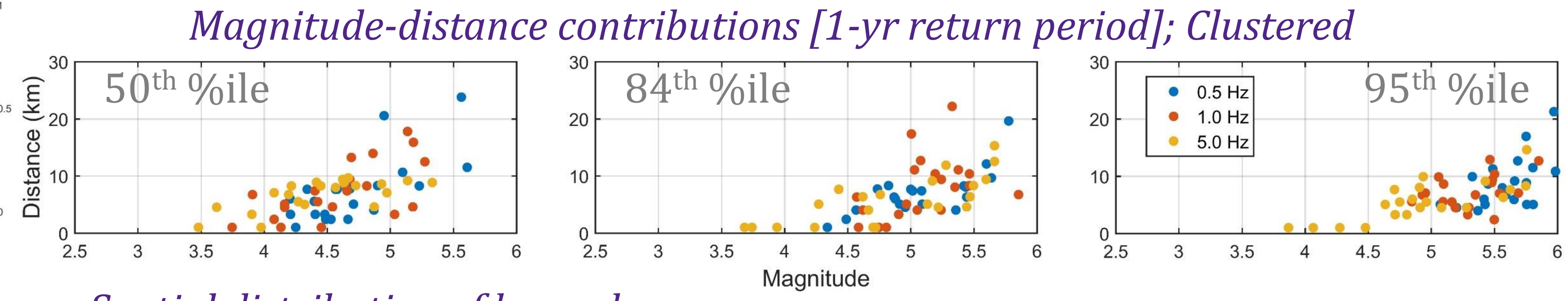


Maximum observed ground motion each year (from catalogue, with random draw of PSA from ground-motion distribution). Maximum moves each year, and area of maximum motion fills over time.

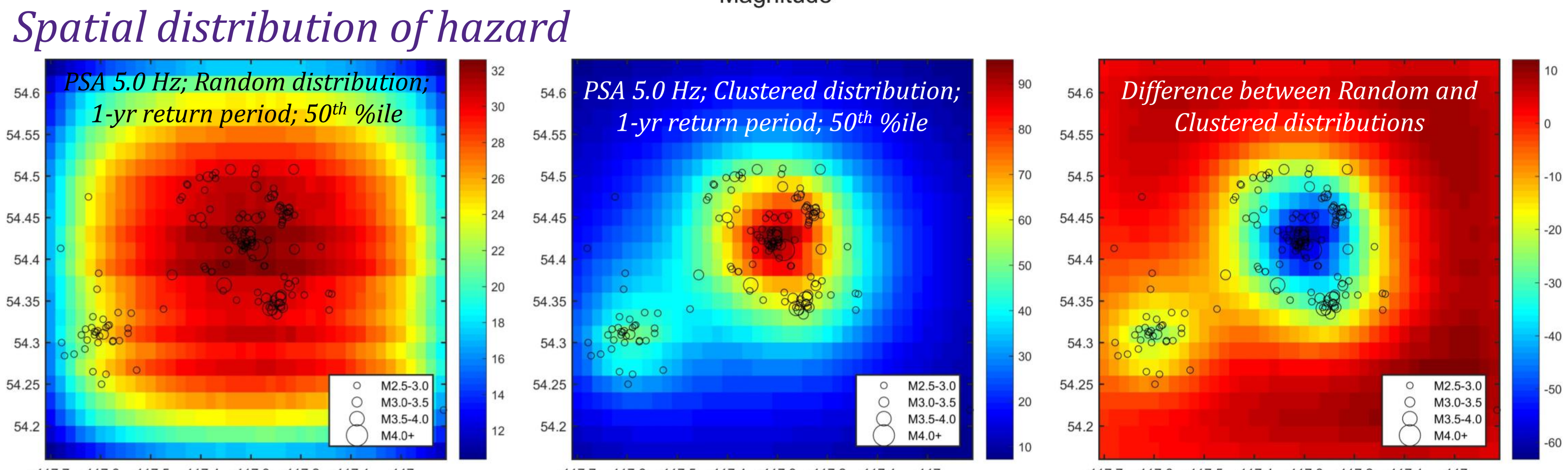
Magnitudes and distances contributing to 5%-damped pseudo-spectral acceleration (PSA)



Magnitude-distance contributions [1-yr return period]; Clustered

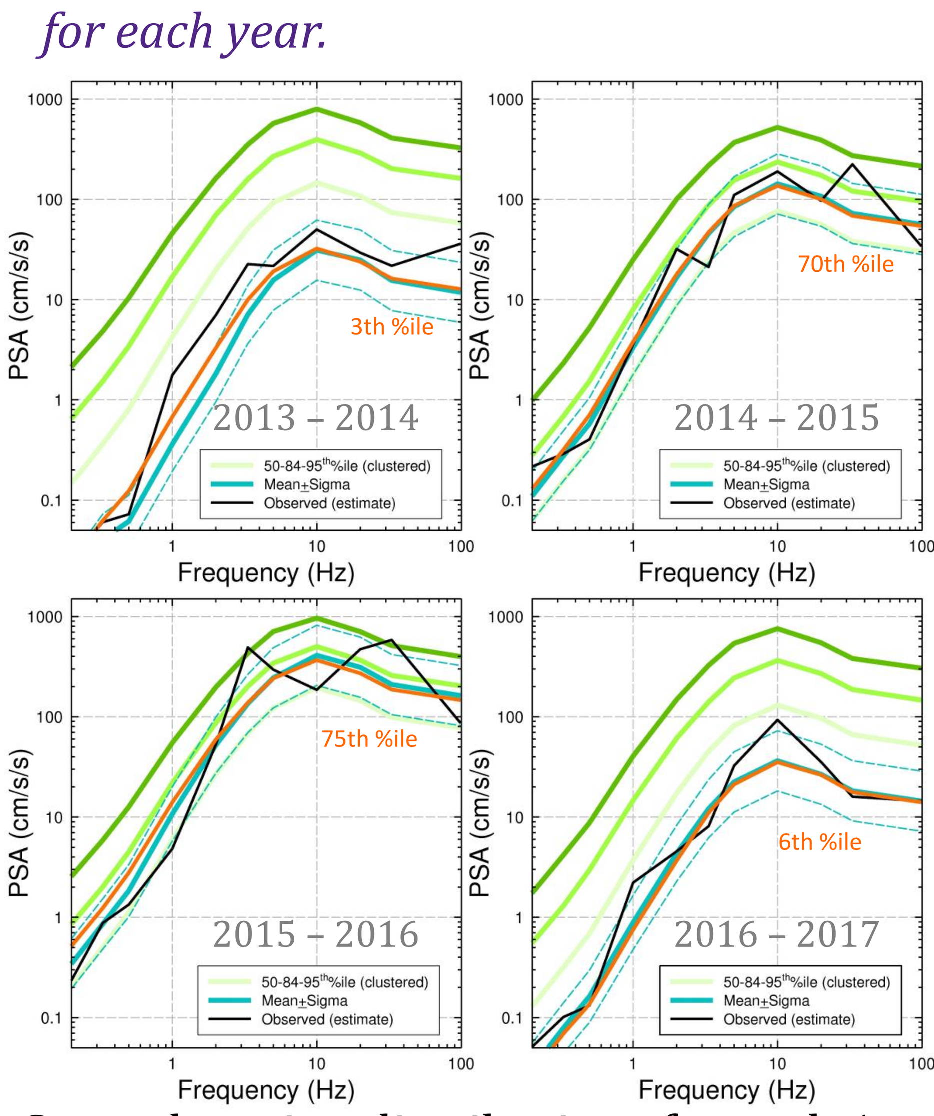


Spatial distribution of hazard



Clustered seismicity reflects hazard as observed to date, but may not reflect future trends.

Probabilistic Seismic Hazard Analysis (PSHA) by Monte Carlo: Calculate hazard for each year.



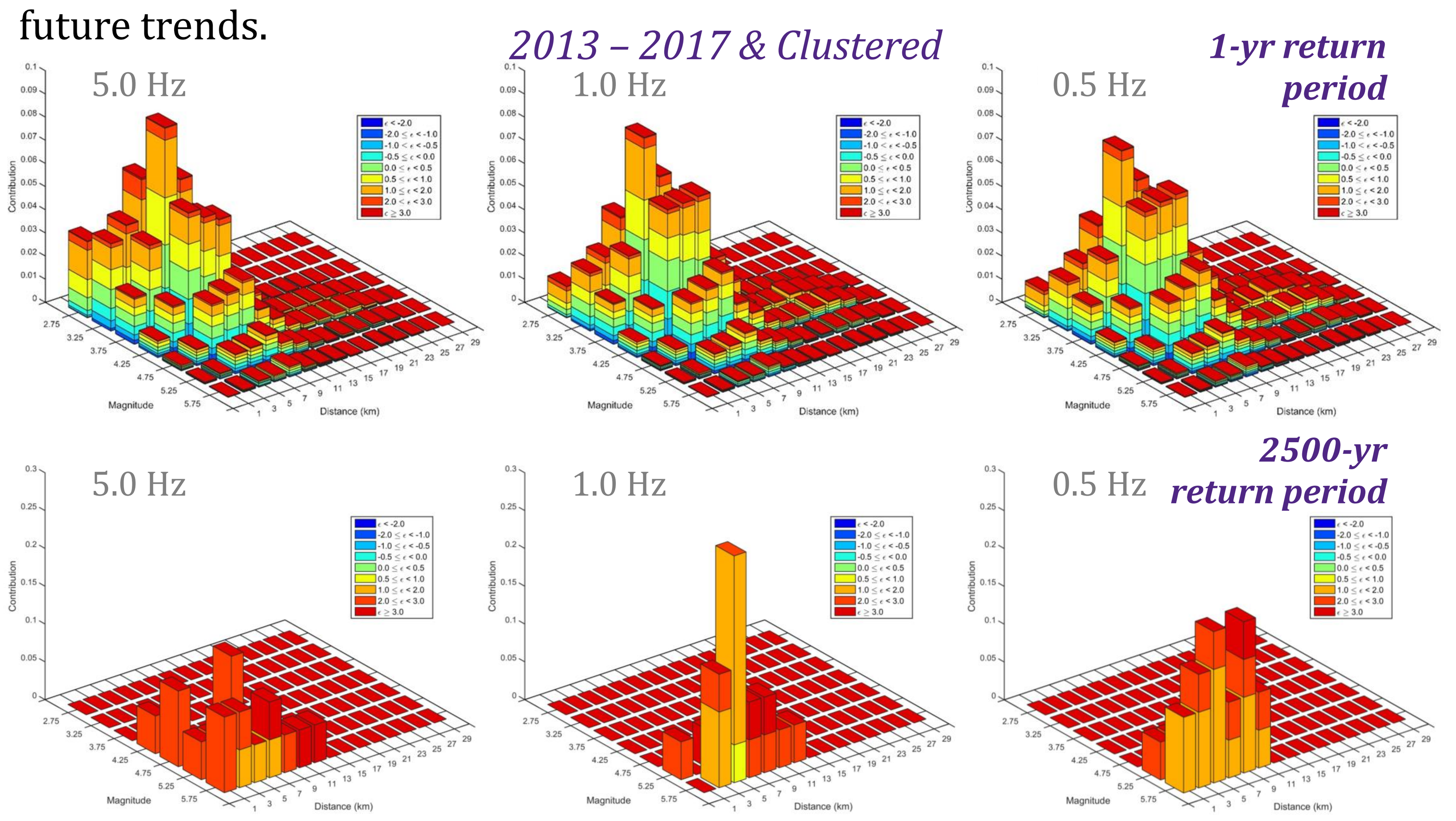
Ground motion distributions for each 1-yr simulated catalogue (above).

Explore whether the PSHA (clustered seismicity model) produces similar ground motions to those observed.

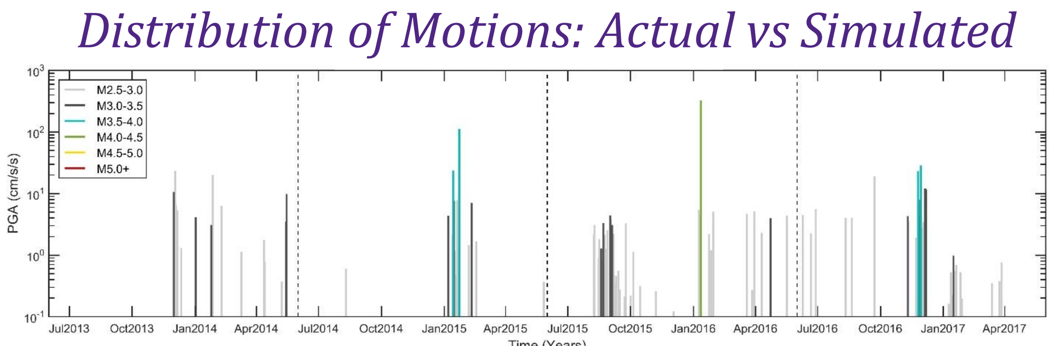
Details:

- PSHA using EQHAZ (*Assatourians and Atkinson, 2012 SRL*)
- Ground-motions from *Atkinson (2015 BSSA)* GMPE, with associated variability (sigma)
- Generate synthetic catalogues for 1 year windows for two cases: (*i*) uniform spatial distribution; and (*ii*) clustered seismicity distribution following the U.S. Geological Survey clustering model (*Frankel, 1995 SRL*)
- Use the rates in the observed catalogue for each year for simulated catalogues
- Simulated catalogues assume Poisson distribution of seismicity in time
- Actual catalogues reflect the observed clustering in both time and space (which varies from year to year)

2013 – 2017 & Clustered

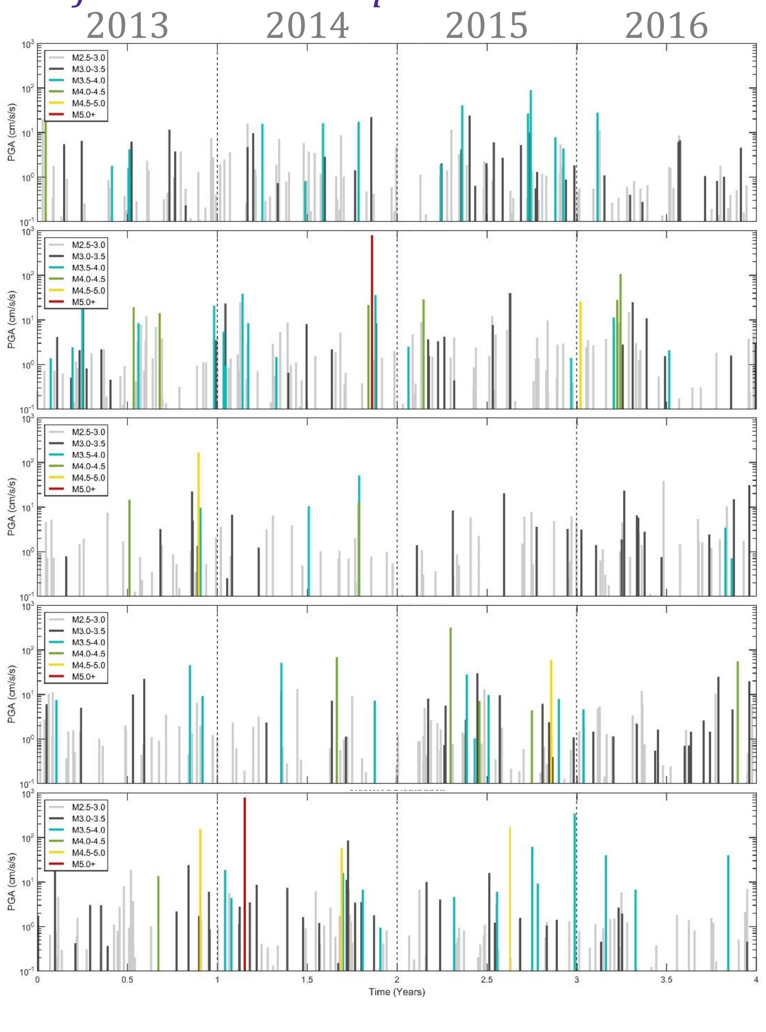


Distribution of Motions: Actual vs Simulated



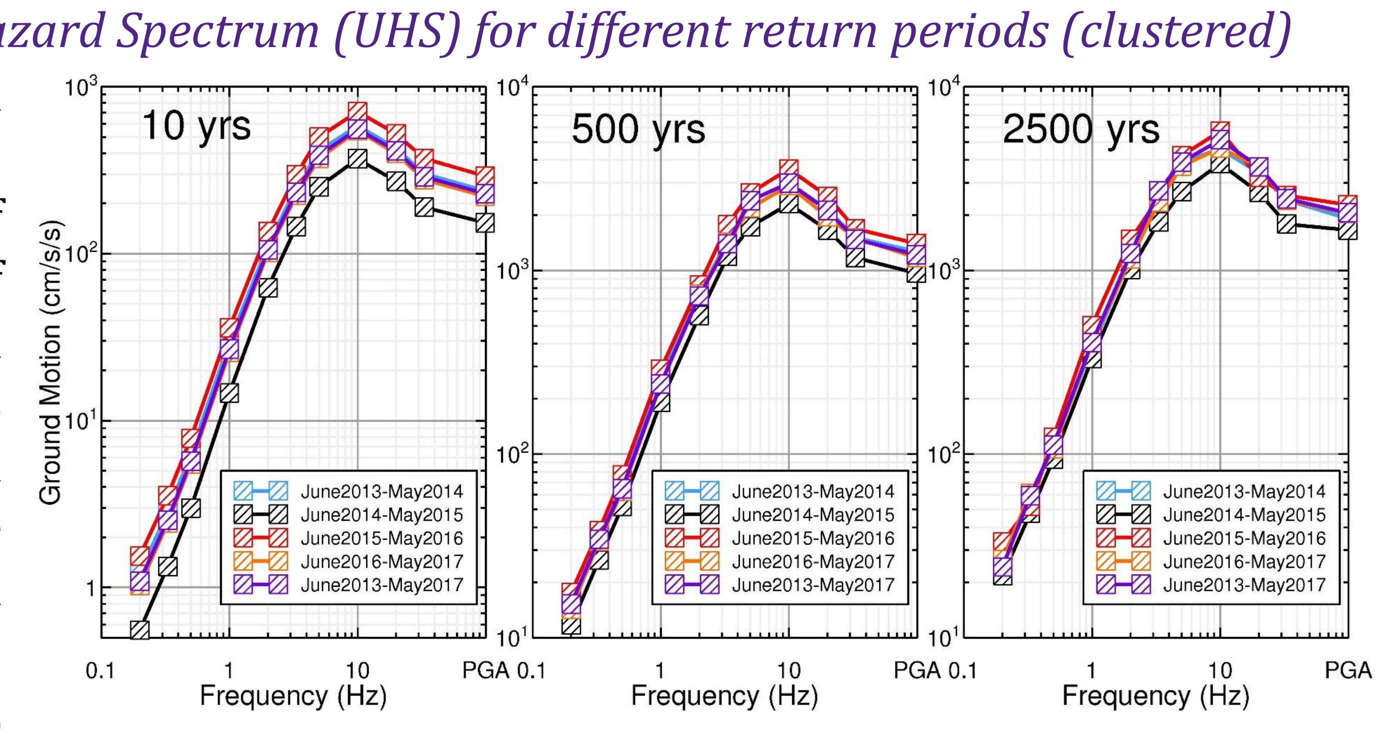
By comparing ground motion parameters at a site as obtained from the actual catalogues with corresponding random samples from the simulated catalogues, we demonstrate the effect of clustering of motions in time on hazard. Temporal distributions are different but overall hazard is reproduced.

a few random samples ...



Uniform Hazard Spectrum (UHS) for different return periods (clustered)

For longer return periods (e.g. 2500 yrs), the effect of changing rates of seismicity in each year on the UHS is less obvious in comparison to the shorter return periods (e.g. 10 yrs).



Summary

- Likelihood of strong shaking at any site strongly impacted by details of event clustering, which implies large uncertainties in hazard, and large variability in time/space.
- Clustering in time is less important than that in space, in terms of UHS motions.
- At building-code probabilities, hazard is less sensitive to clustering details (as these even out in space over time).

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