VALIDATION OF SIMULATED GROUND MOTIONS USING TIMEDOMAIN CUMULATIVE STATISTICAL MEASURES

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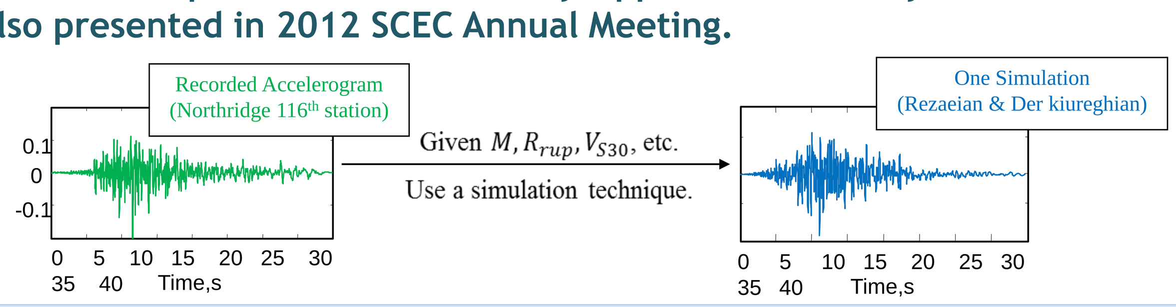
Introductions

Traditionally, ground motion recordings from historical earthquakes have been used as surrogates to represent the ground motions involved in the future earthquakes. Due to scarcity of recorded motions, these recordings are usually scaled and modified to match the spectral shape of a target earthquake event. An alternative is to use simulated motions for more realistic non-linear dynamic analyses, particularly for tall buildings and performance based earthquake engineering. The simulated ground motions have the advantage of better understanding the fault rupture processes, wave propagation and site response characterization; hence, these site-specific simulations can be more reliable and viable alternatives to the limited number of recorded strong motions and have the potential to be widely applied in industry and academic research. This poster was also presented in 2012 SCEC Annual Meeting.



Synthetic and Real Ground Motions Datasets

- Graves and Pitarka (2010) developed a hybrid broadband Ground motion simulation methodology which combines a deterministic approach at low frequency (f < 1 Hz) with a semistochastic approach at high frequency (f > 1 Hz).
- One set of simulations for a historic earthquake (1994 Northridge M 6.7) was generated using the above method.
- For this earthquake, the developed model covers a wide area surrounding the fault and including several strong motion recording sites.
- There is one simulated motion for each recorded motion at a given station.

Evolution of Intensity (Metric 1)

The evolutionary intensity, $\int a^2 dt$

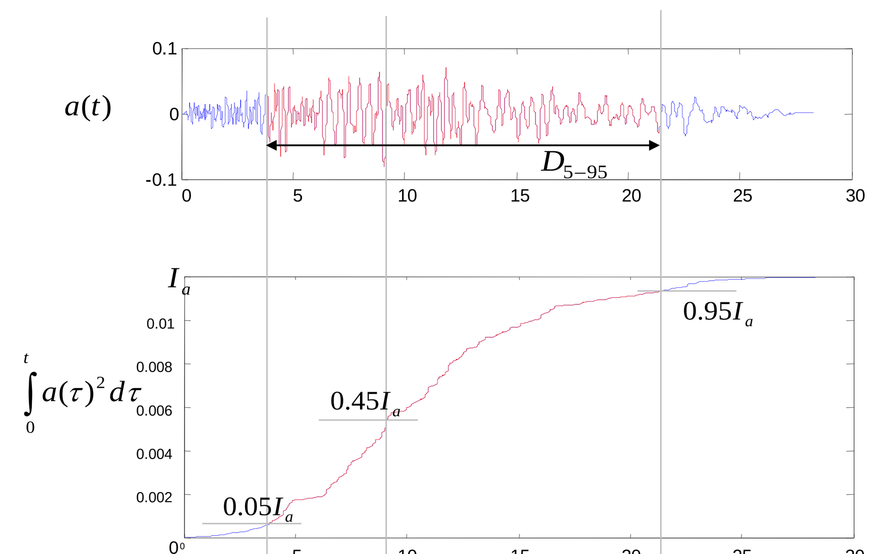
(a measure of the evolutionary intensity)

Define Three Parameters:

$I_a = \frac{\pi}{2g}\int_0^{t_n} a^2 dt$: Arias intensity

D_{5-95} : Effective duration (from 5% to 95% I_a)

t_{mid} : Middle of strong shaking (~ at 45% I_a)



Time-varying Frequency: Predominant frequency (Metric 2)

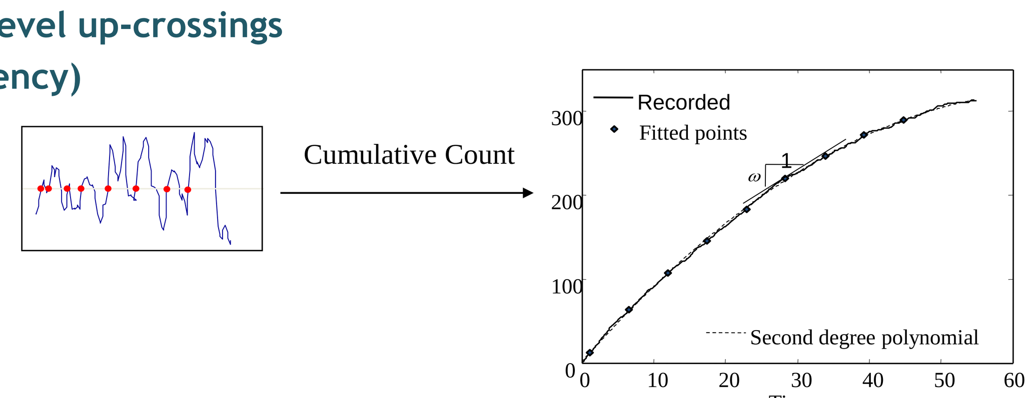
The cumulative number of zero- level up-crossings

(a measure of predominant frequency)

Define Two Parameters:

ω_{mid} : Filter frequency at t_{mid}

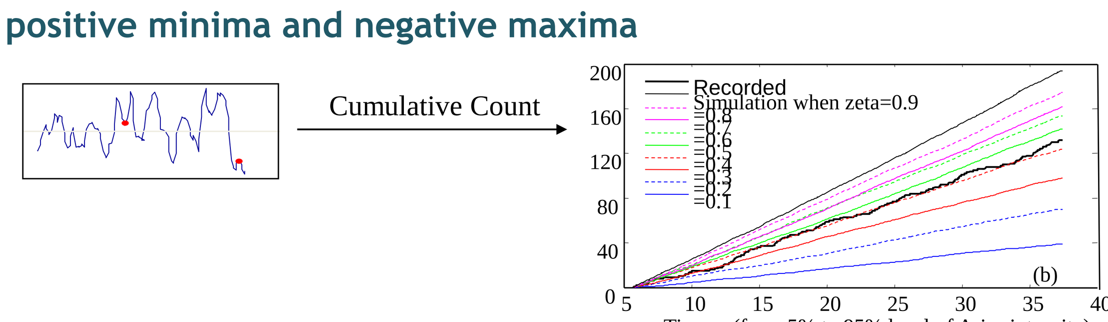
ω' : Rate of change of the filter frequency at t_{mid}



Time-varying Frequency: Bandwidth (Metric 3)

The cumulative number of positive minima and negative maxima

(a measure of bandwidth)



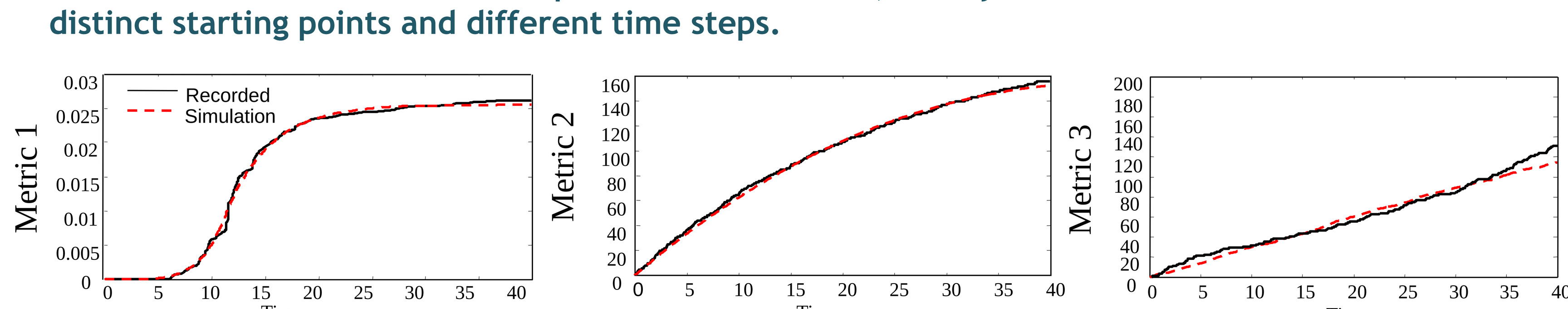
Proposed Validation Method

These three metrics are generated and compared for the recorded (target) and simulated ground motions. In order to quantify the difference, the following equation is used for each metric.

Δ Area is the accumulation of absolute different area between two vectors. Total Area represents the target vector area. (i.e., the vector corresponding the recorded motion).

$$Error = \frac{\Delta\ Area}{Total\ \ Area}$$

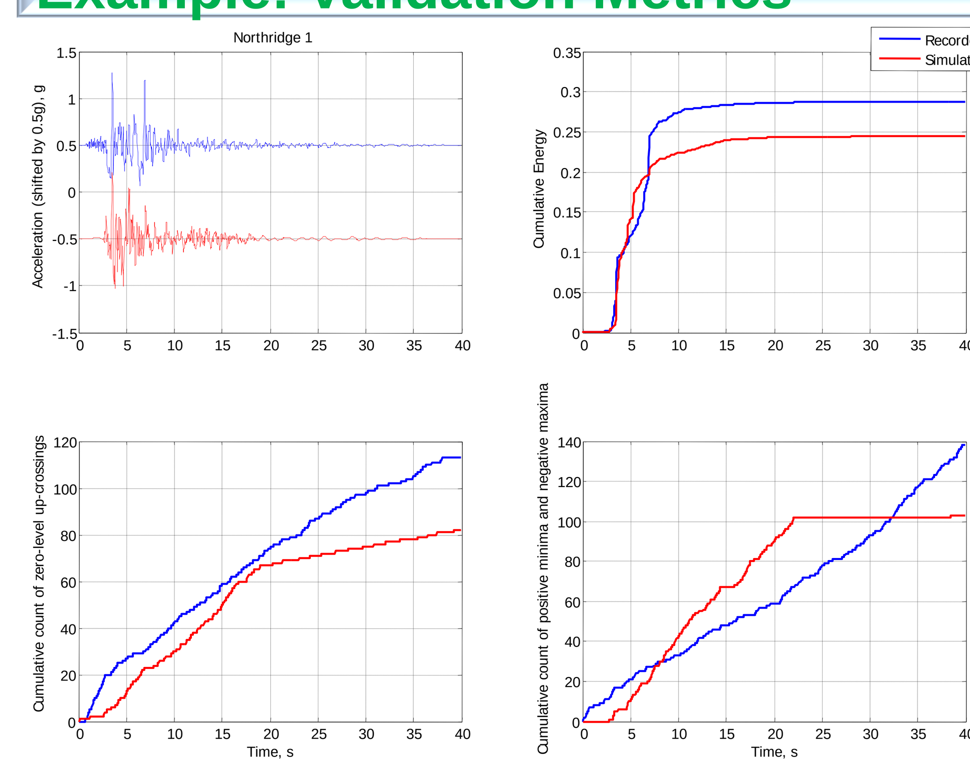
Attention: We have to down-sample and shift the GMs, if they have distinct starting points and different time steps.



Results

121 pair simulated and recorded ground motions of Northridge were validated by the aforementioned three metrics and five parameters.

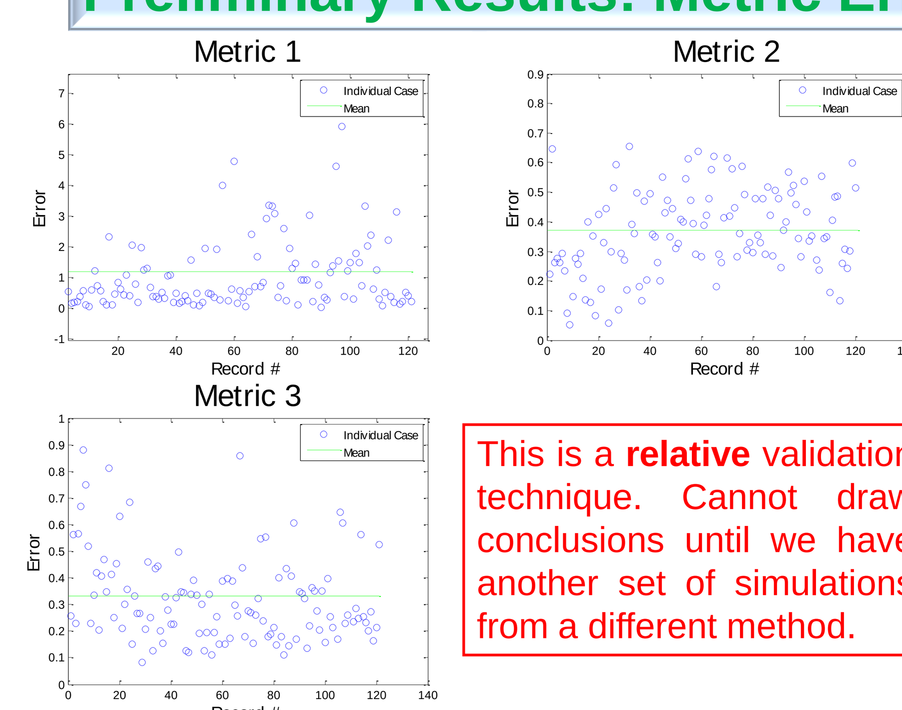
Example: Validation Metrics



From this example, we can get some discoveries, which can help to understand where the discrepancies between simulations and records come from, as follows:

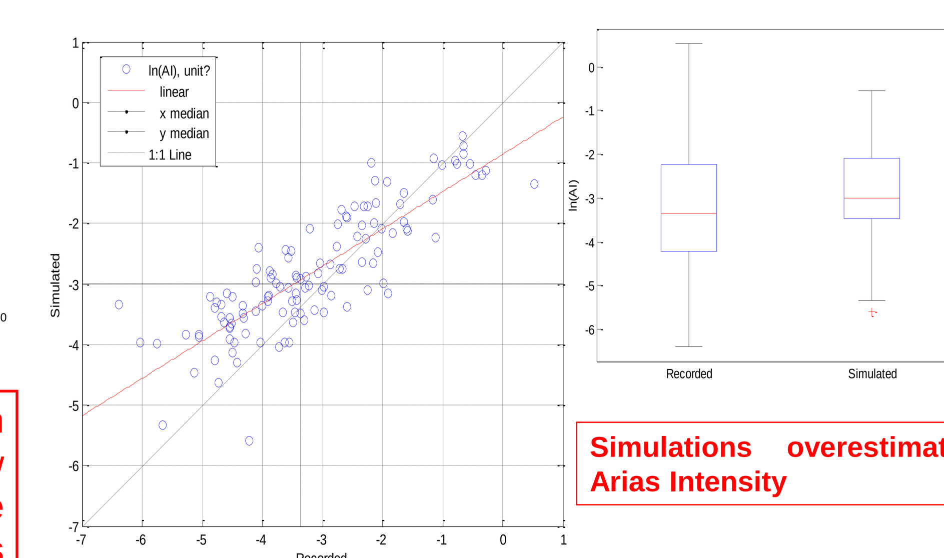
- The simulation make a similar evolution of intensity as recorded one, but the total energy is underestimated.
- The difference after 20s may not be important, since intensity is very low in that duration.
- Some discontinuities in the frequency content are observed.

Preliminary Results: Metric Errors



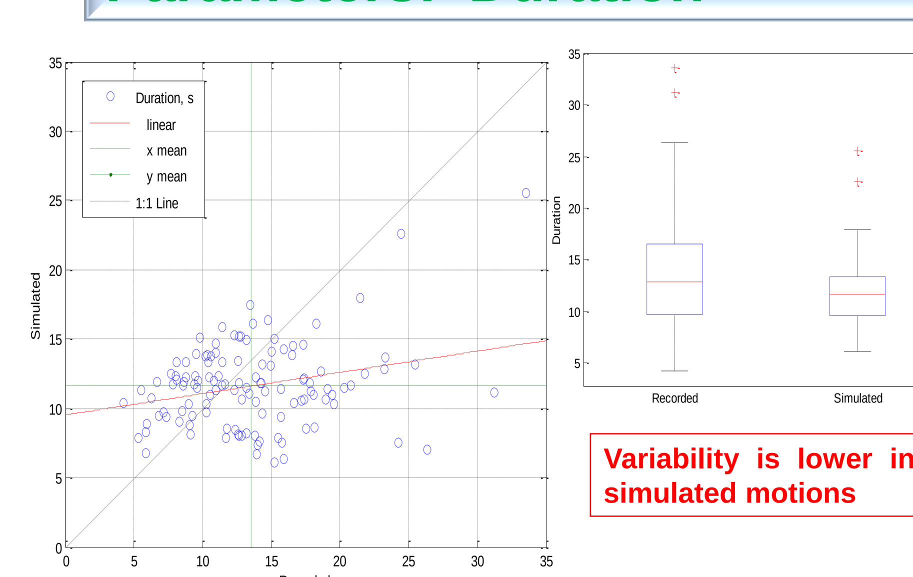
This is a **relative** validation technique. Cannot draw conclusions until we have another set of simulations from a different method.

Parameters: Arias Intensity



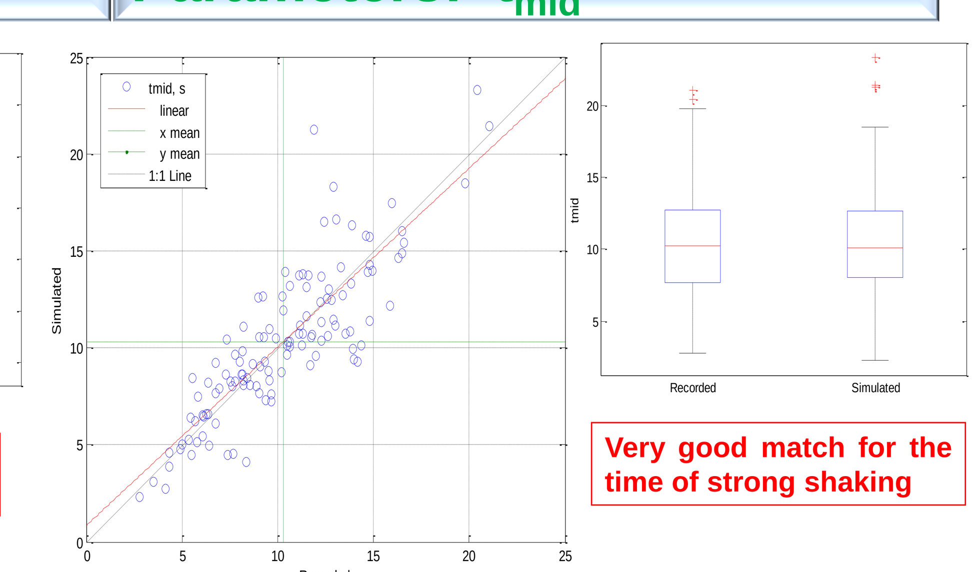
Simulations overestimate Arias Intensity

Parameters: Duration



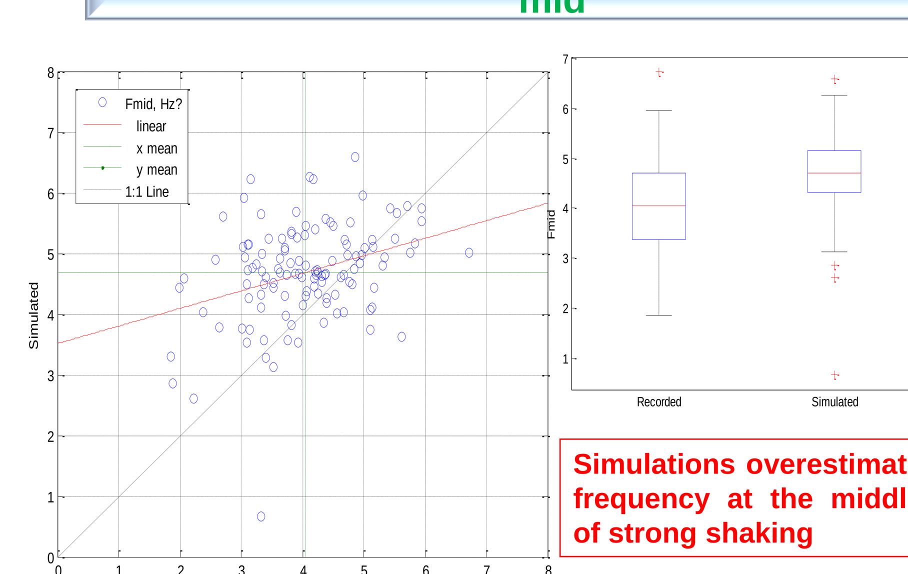
Variability is lower in simulated motions

Parameters: t_{mid}



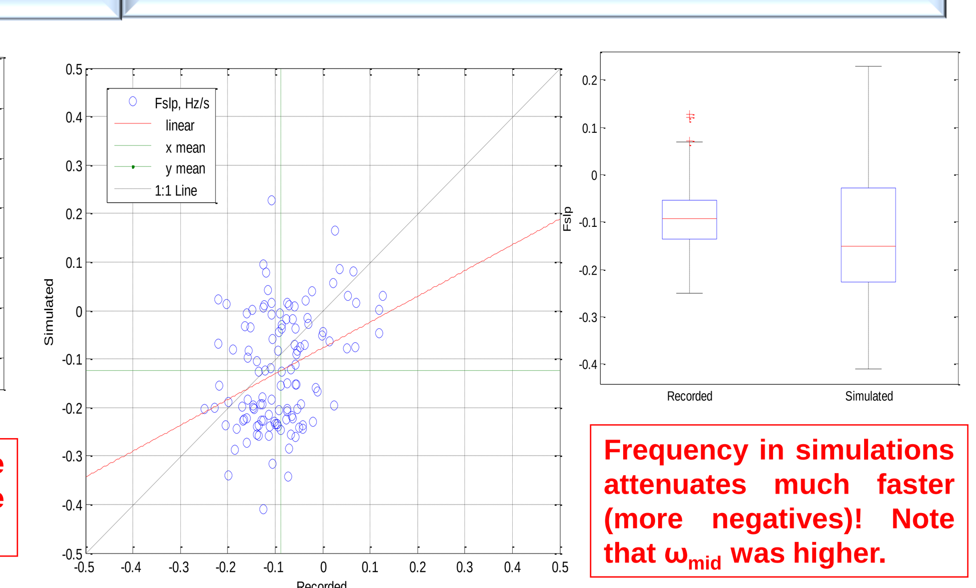
Very good match for the time of strong shaking

Parameters: ω_{mid}



Simulations overestimate frequency at the middle of strong shaking

Parameters: ω'



Frequency in simulations attenuates much faster (more negatives)! Note that ω_{mid} was higher.

Conclusion

- Results of this study show that simulations are generally in a good agreement with recorded motions in terms of the characteristics of the time-series, although, the underestimation and overestimation of total energy vary from case to case, and some discontinuities in the frequency content are observed.
- In general, parameters of simulated records tend to have less variation. Arias Intensity and t_{mid} of simulated and recorded motions are in good agreement, but the other parameters can be very different.
- This is a relative validation technique. Further analysis is underway to draw comparable and quantitative conclusions once we have other sets of simulations from different methods.

References:

Rezaeian, S. and Der Kiureghian, A. (2008), A stochastic ground motion model with separable temporal and spectral nonstationarities. Earthquake Engng. Struct. Dyn., 37: 1565–1584. doi: 10.1002/eqe.831

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Graves R. W. and Pitarka A. (2010). *Broadband Ground-Motion Simulation Using a Hybrid Approach. Bulletin of the Seismological Society of America, 100(5A), 2095-2123.*

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