Ground motion parameters based on evolution of intensity and frequency content with time

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Workshop on Implementation of GMSV Gauntlets on the Broadband Platform
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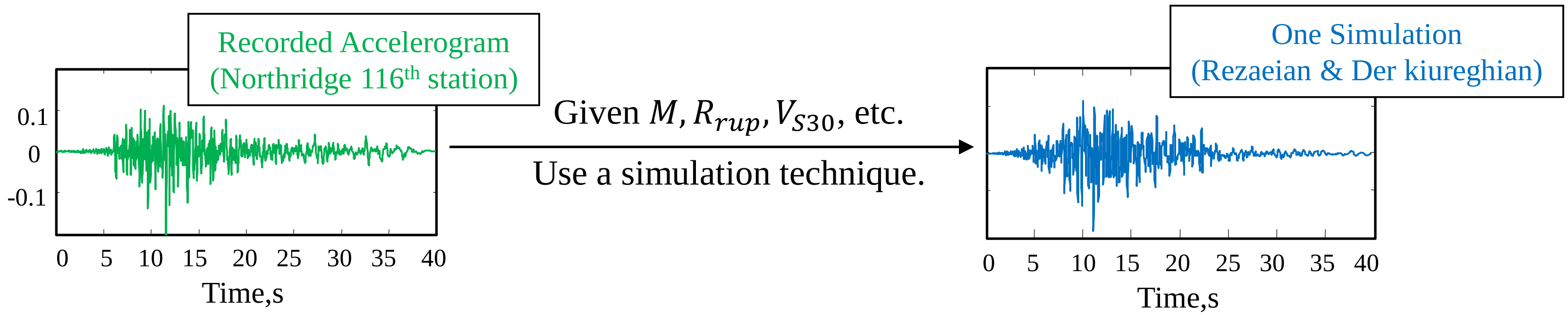
Rezaeian et al. Time-Domain Ground Motion Parameters:

Scope:

Statistical characteristics of ground motion time-series can be used to represent variations of the **intensity** and the **frequency content** over time. These features are compared for recorded and simulated motions.

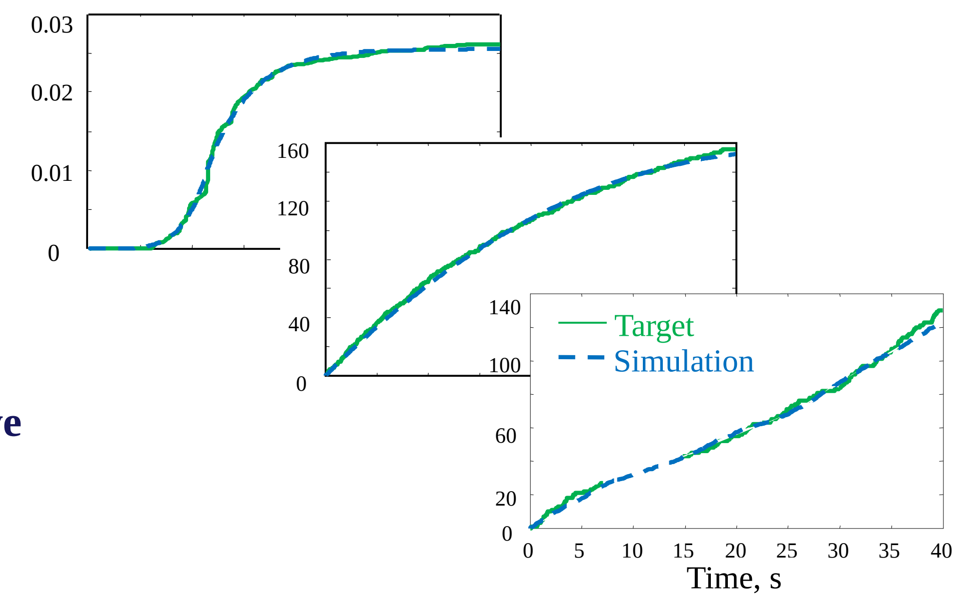


Three Time-Domain Parameters:

1) Compare the **cumulative intensity**, $\int a^2 dt$
(a measure of the evolutionary intensity)

2) Compare the **cumulative number of zero-level up-crossings**
(a measure of predominant frequency)

3) Compare the **cumulative number of positive minima and negative maxima**
(a measure of bandwidth)

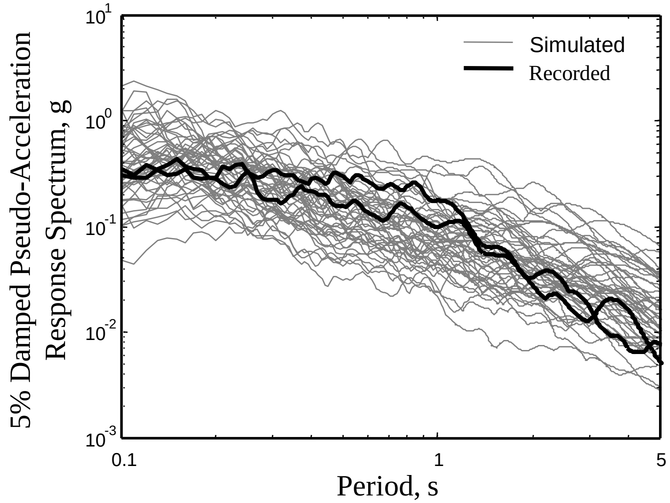


Scope:

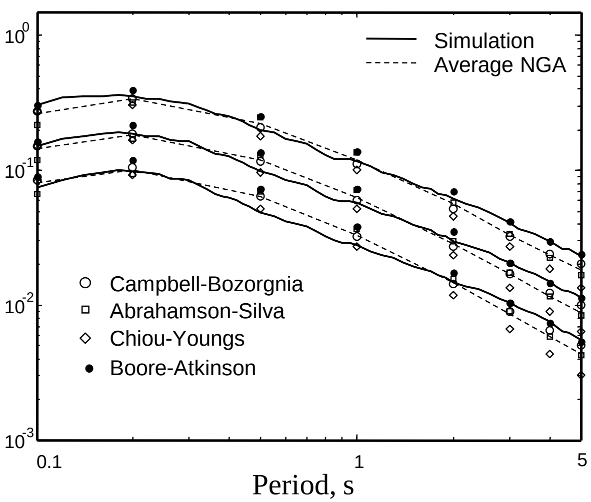
In a previous study, simulations that were based on matching these three metrics were validated against recorded motions and GMPEs in terms of response spectrum.

Elastic Response Spectrum:

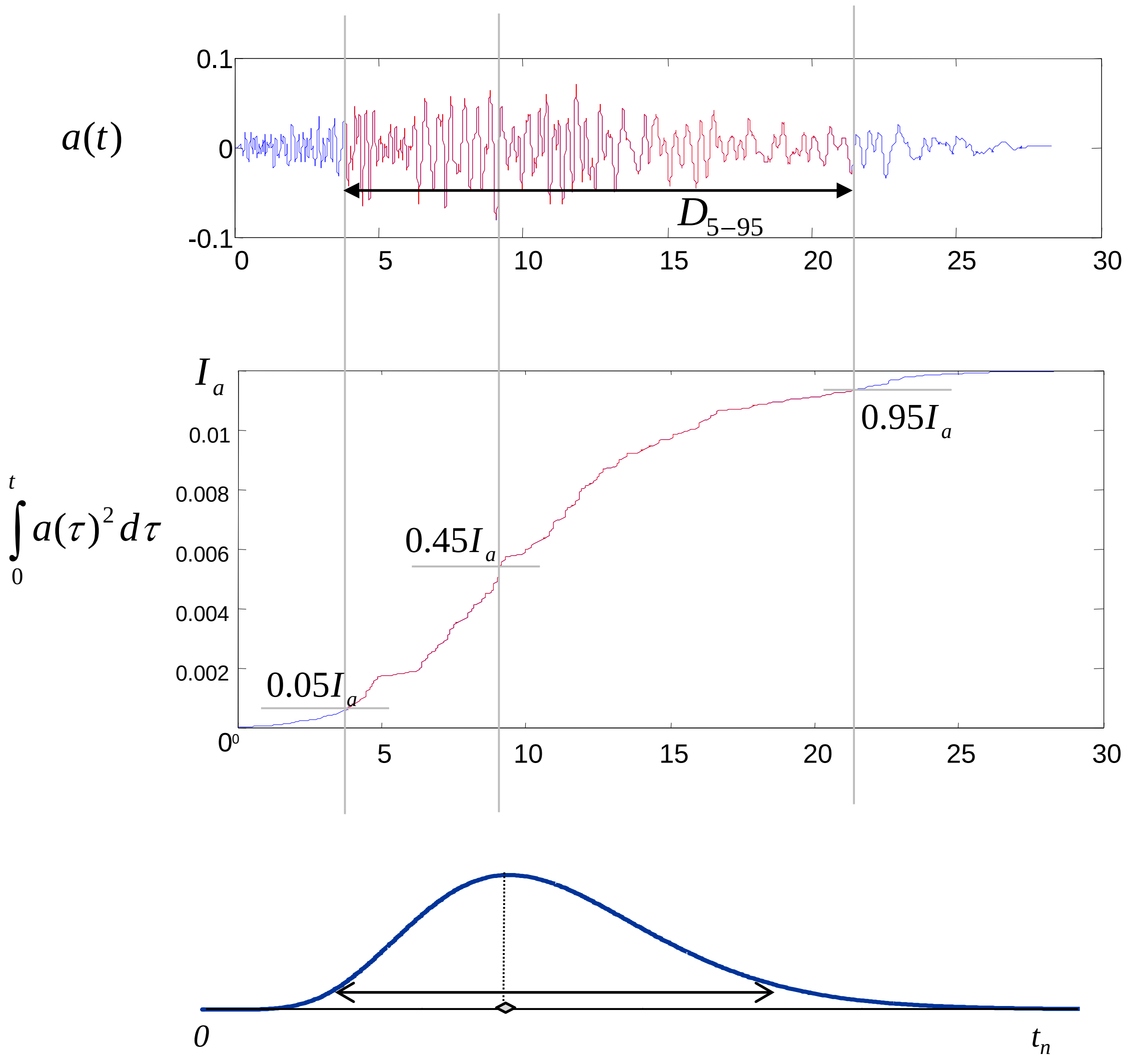
50 simulations for $\mathrm{F}_{rv}, M, R_{rup}, V_{S30}$
(1, 6.69, 20.3, 1223) of the recorded motion.



Median (±1std) of 500 simulations
$\left(\mathrm{F}_{rv}, M, R_{rup}, V_{S30}\right) = (0, 7.0, 40, 760)$



Evolution of Intensity (parameter 1):



Scalar 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)

$\dfrac{I_a}{D_{5-95}}$: Rate of input energy

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

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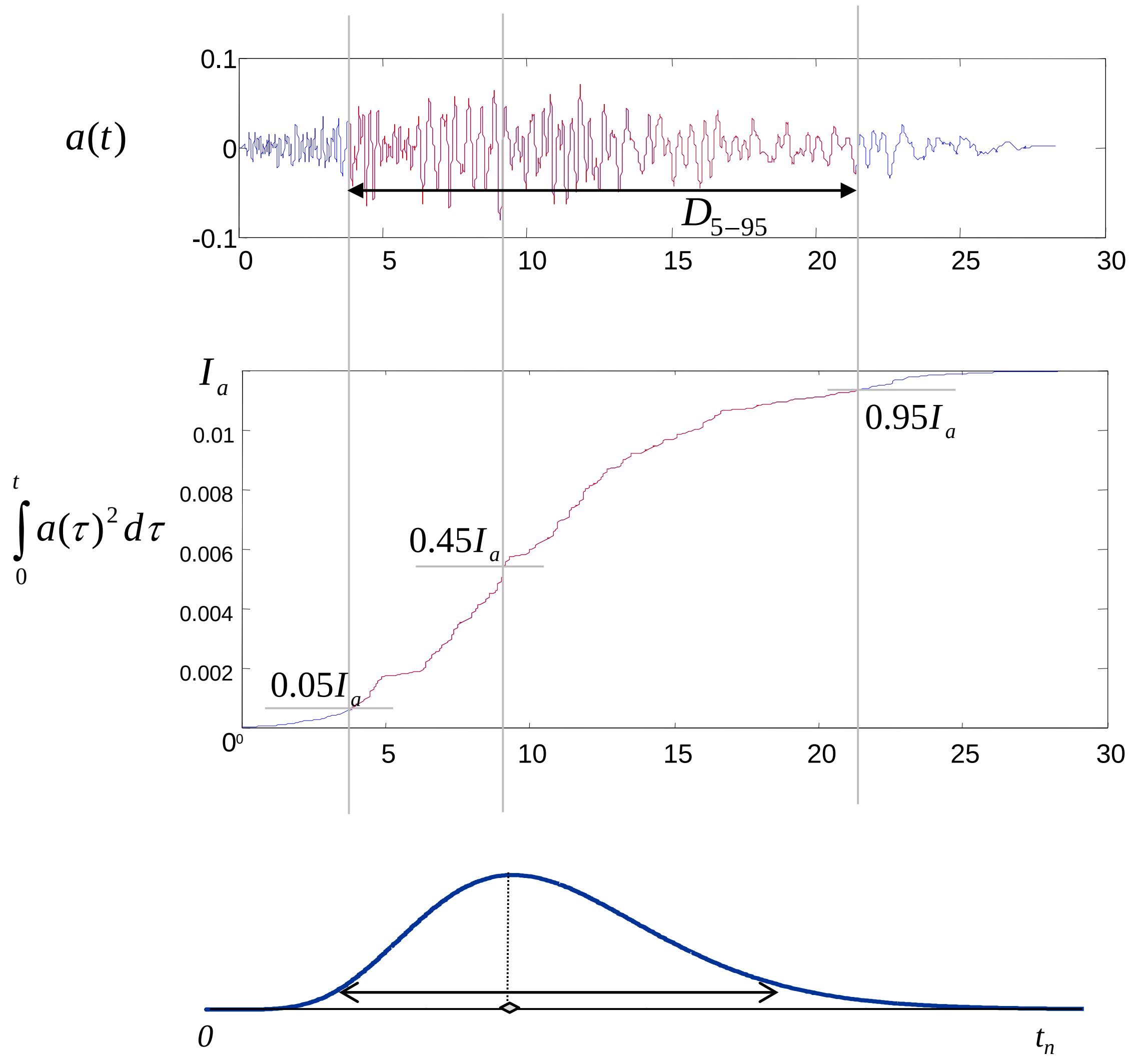

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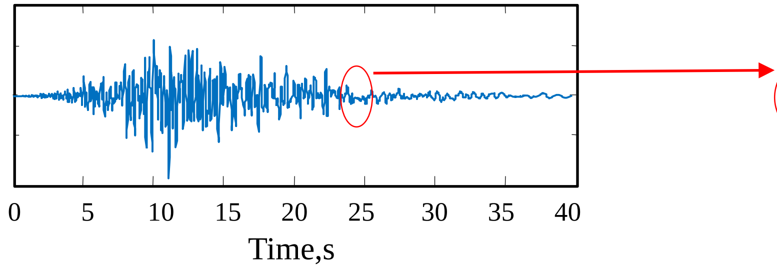
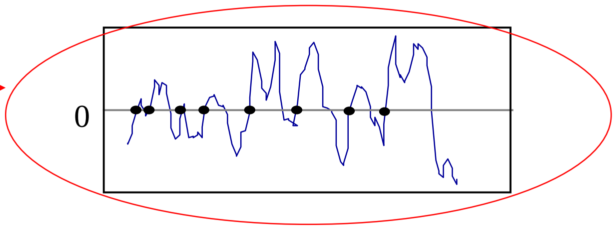
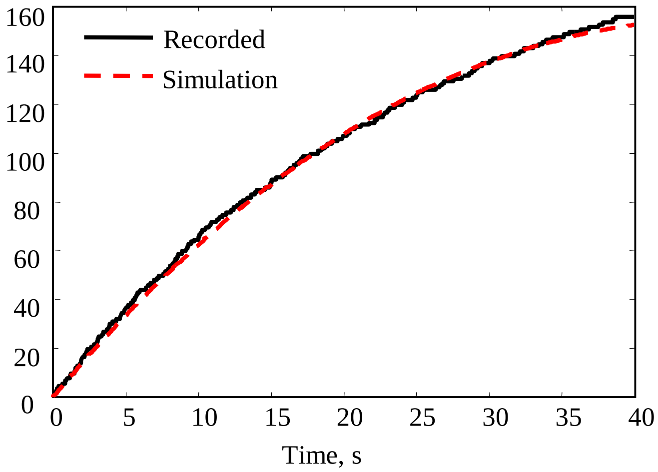
Evolution of Frequency (parameter 2):

A measure of predominant frequency:

Cumulative number of zero-level up crossings







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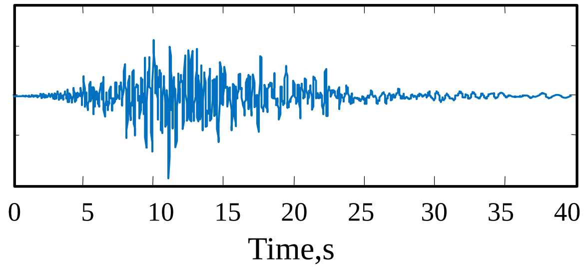
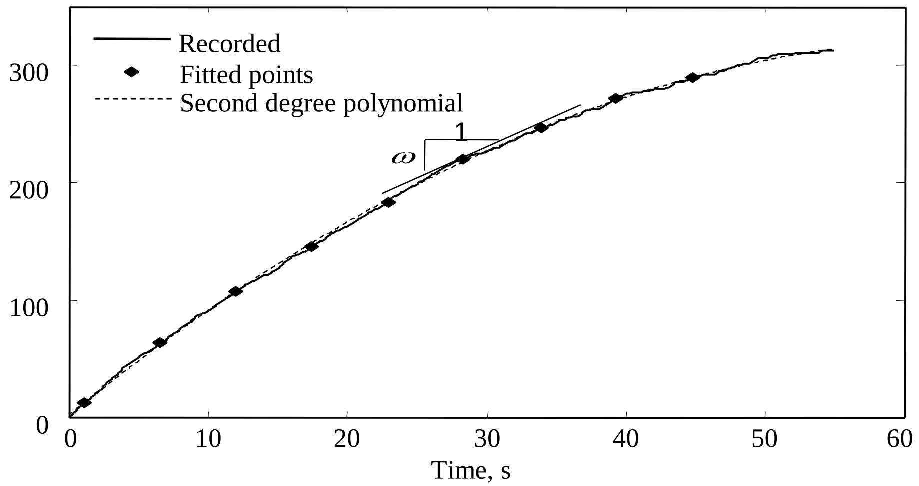




Scalar Parameters:

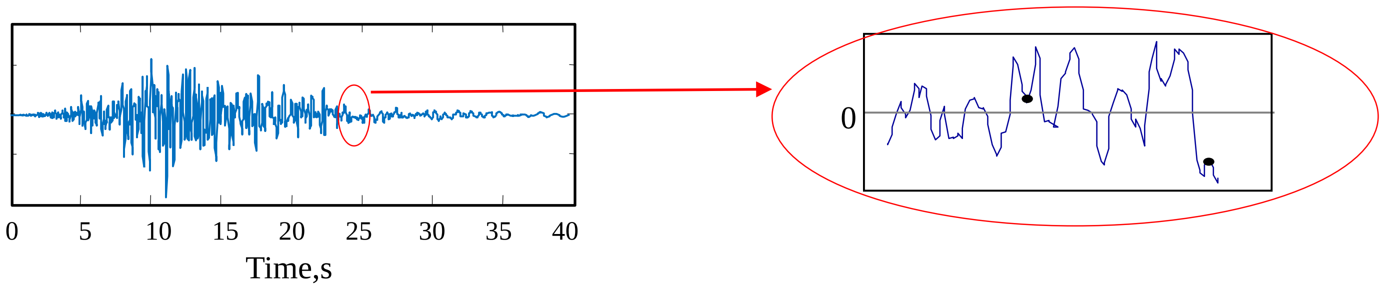
ω_{mid} : Frequency of strong shaking phase

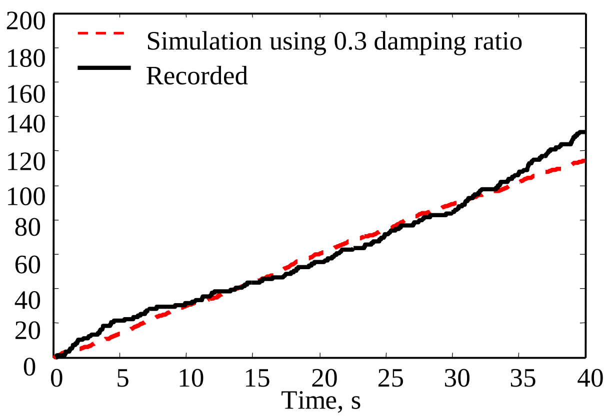
ω' : Rate of change of frequency

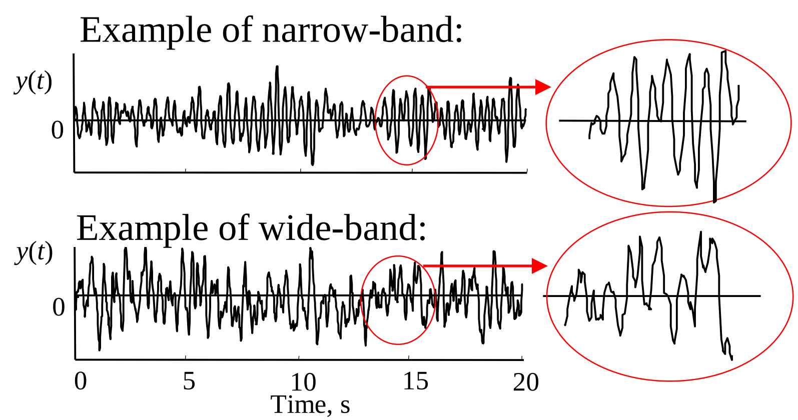
Evolution of Bandwidth (parameter 3):

A measure of bandwidth:

Cumulative number of positive minima and negative maxima



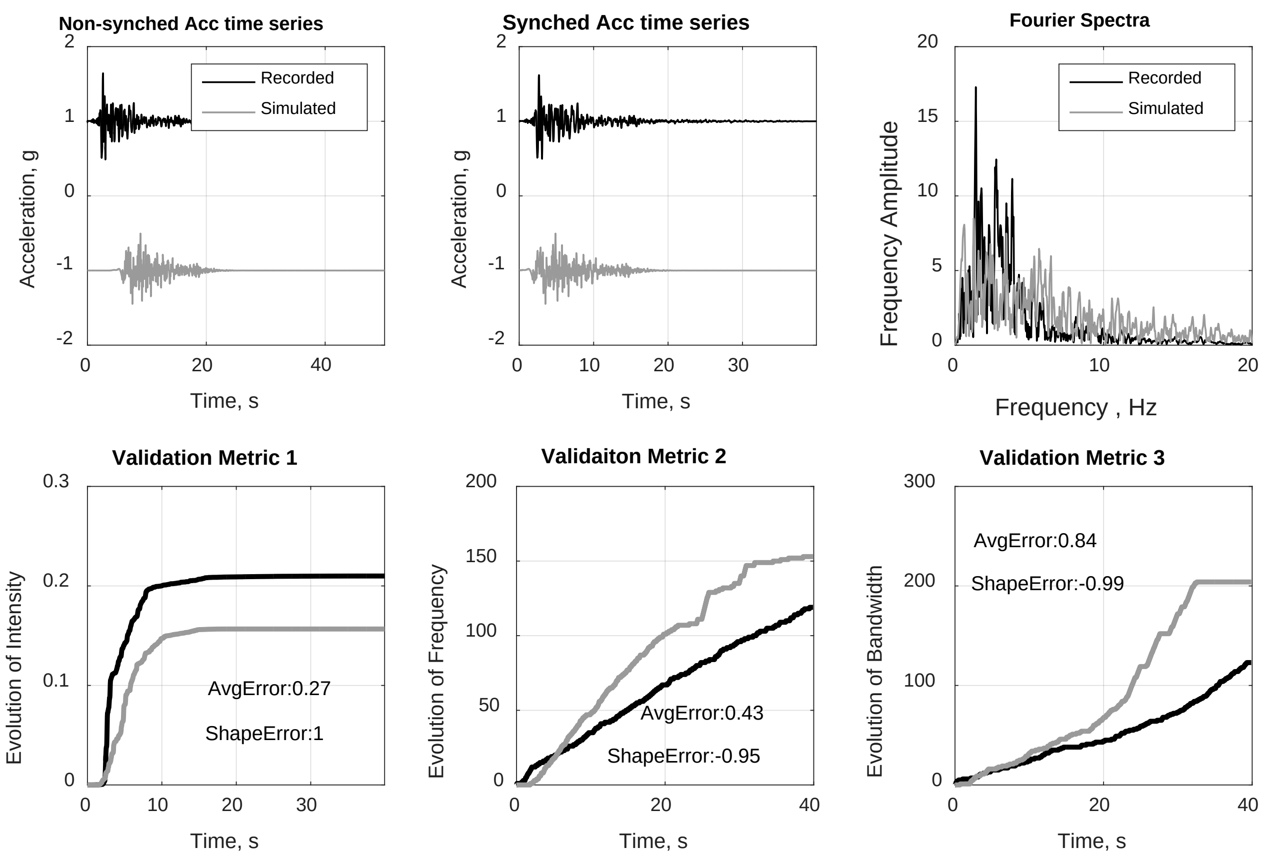




Summary:

A validation gauntlet using evolution of intensity and frequency content of ground motion waveform.
Explains discrepancies in response (including and) beyond elastic spectra and duration.

Example Output for Visual Inspection:



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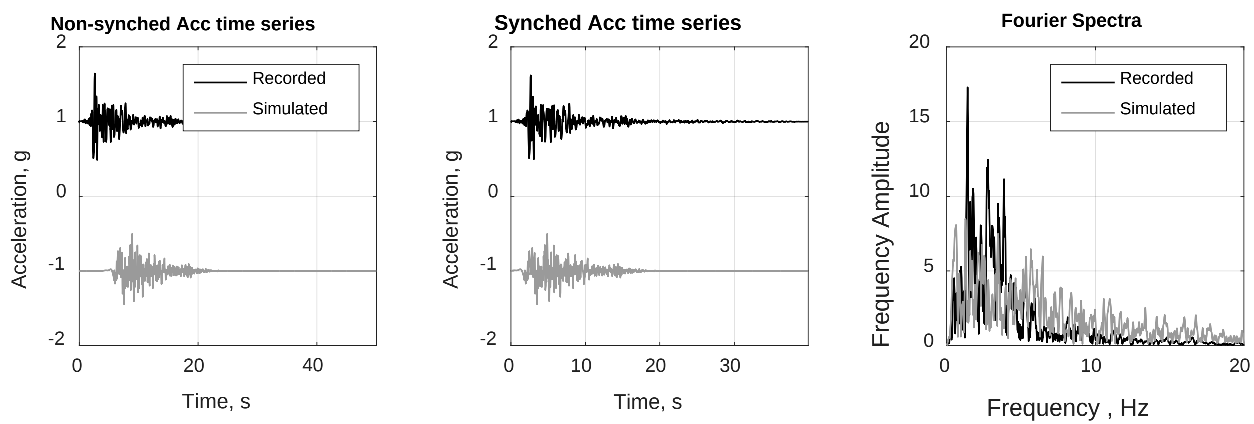

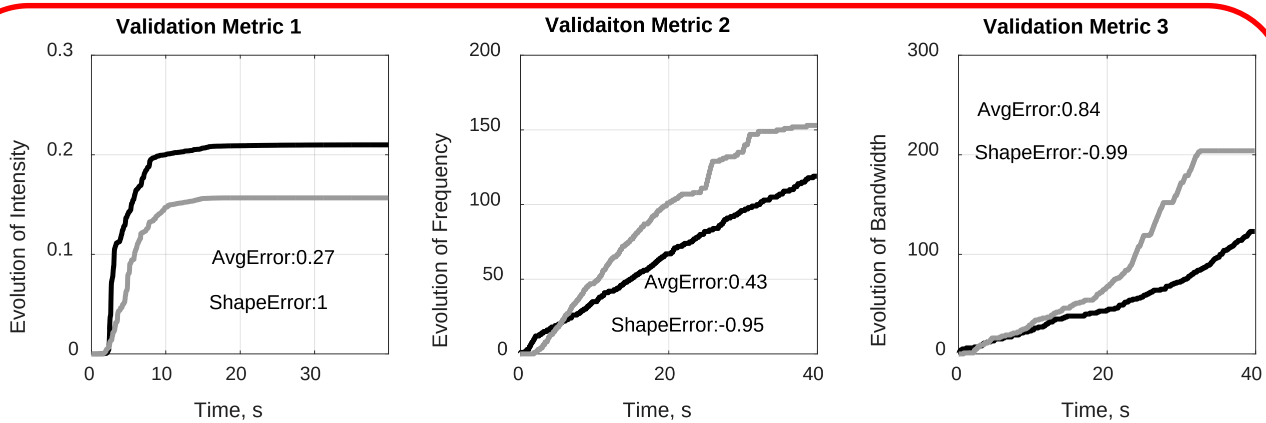

<u>For Visual Inspection:</u>

(model developers, individual records)

1) Evolution of intensity

2) Evolution of predominant frequency

3) Evolution of bandwidth

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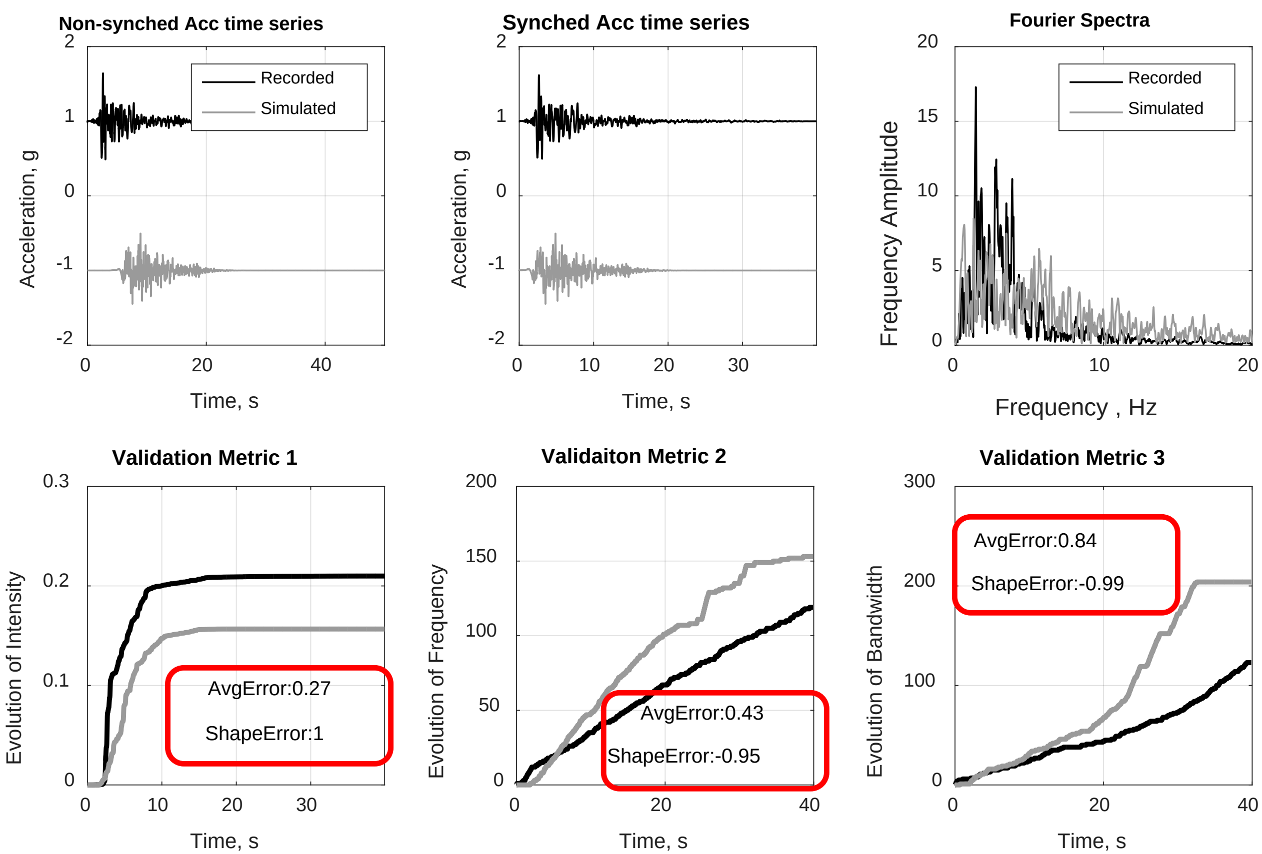
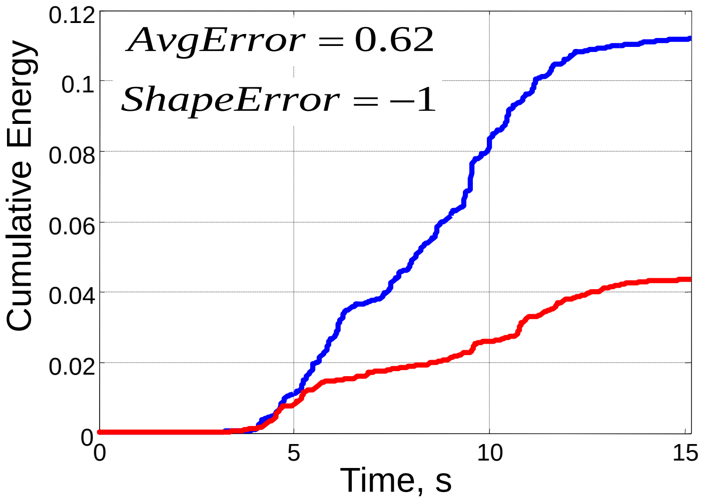


Quantified Errors -- Scalars:
(engineers, large number of records)
1) Average Error
2) Shape Error

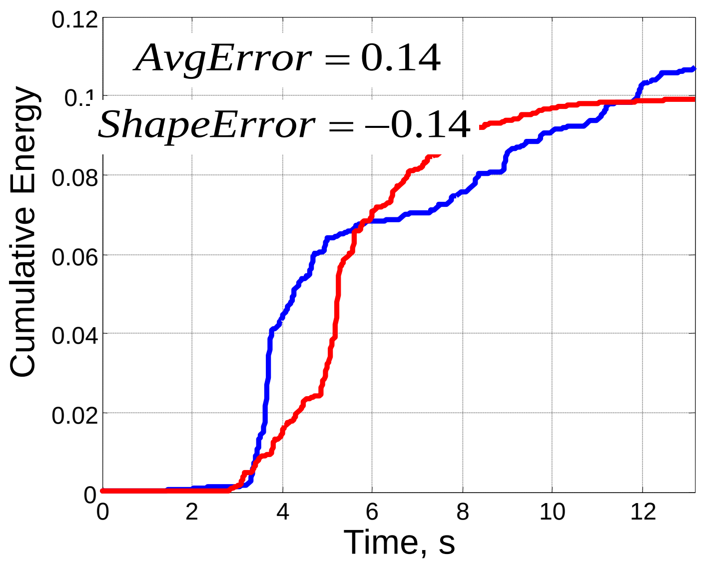
Scalar Error Terms :



Avg Error:

$$\epsilon_{ij} = \frac{\int_0^{t_n} |m_{ij,\text{rec}}(t) - m_{ij,\text{siml}}(t)| dt}{\int_0^{t_n} m_{ij,\text{rec}}(t) dt},$$

$$i = 1, 2, 3; \quad j = 1, \ldots, \text{number of simulations}$$



Shape Error:

$$v_{i,j} = \frac{\int_0^{t_n} (m_{ij,\text{rec}}(t) - m_{ij,\text{siml}}(t)) dt}{\int_0^{t_n} |m_{ij,\text{rec}}(t) - m_{ij,\text{siml}}(t)| dt},$$

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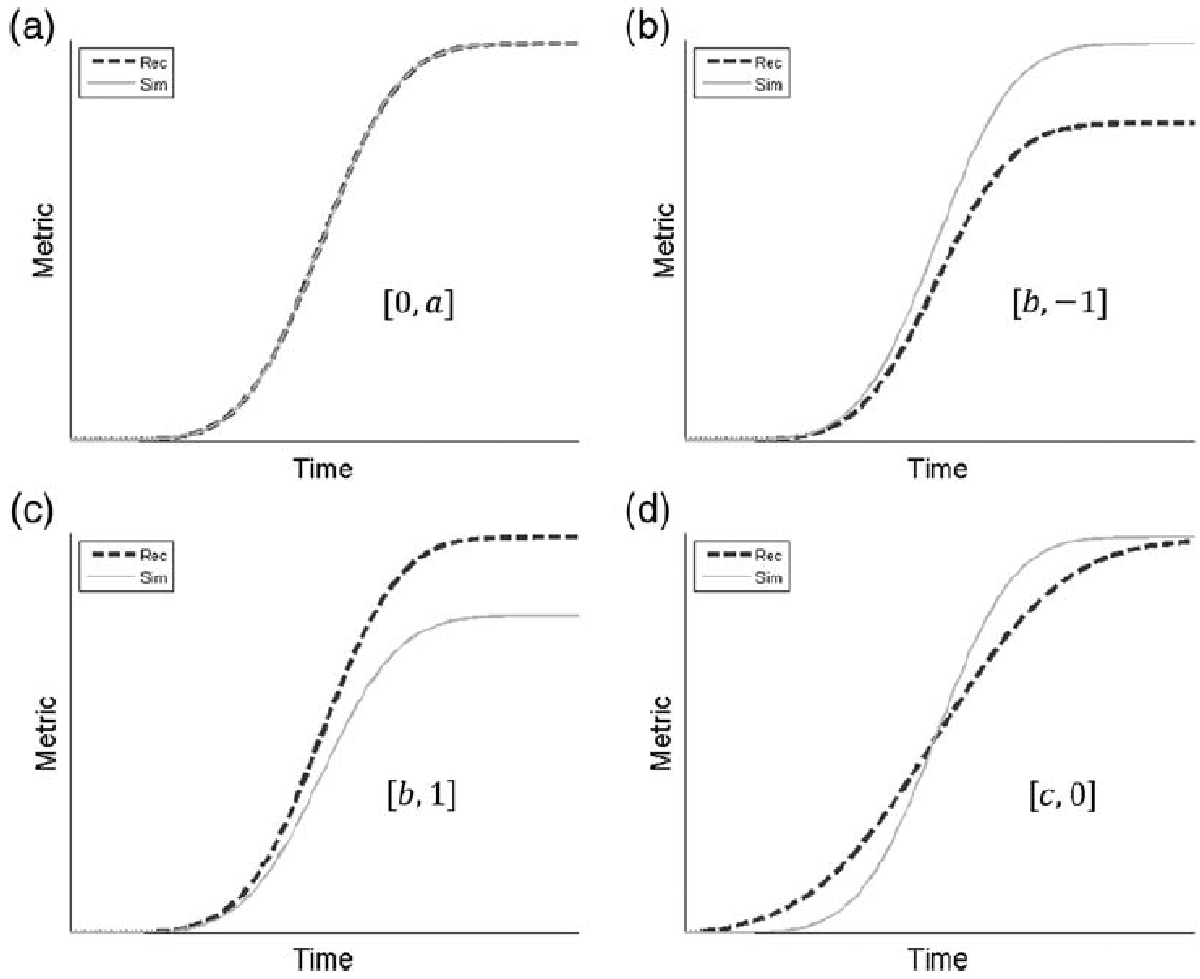
Scalar Error Terms :

[Avg Error , Shape Error]



For More Details :

Rezaeian et al. (2015) BSSA Journal:

Bulletin of the Seismological Society of America, Vol. 105, No. 6, pp. 3036–3049, December 2015, doi: 10.1785/0120140210

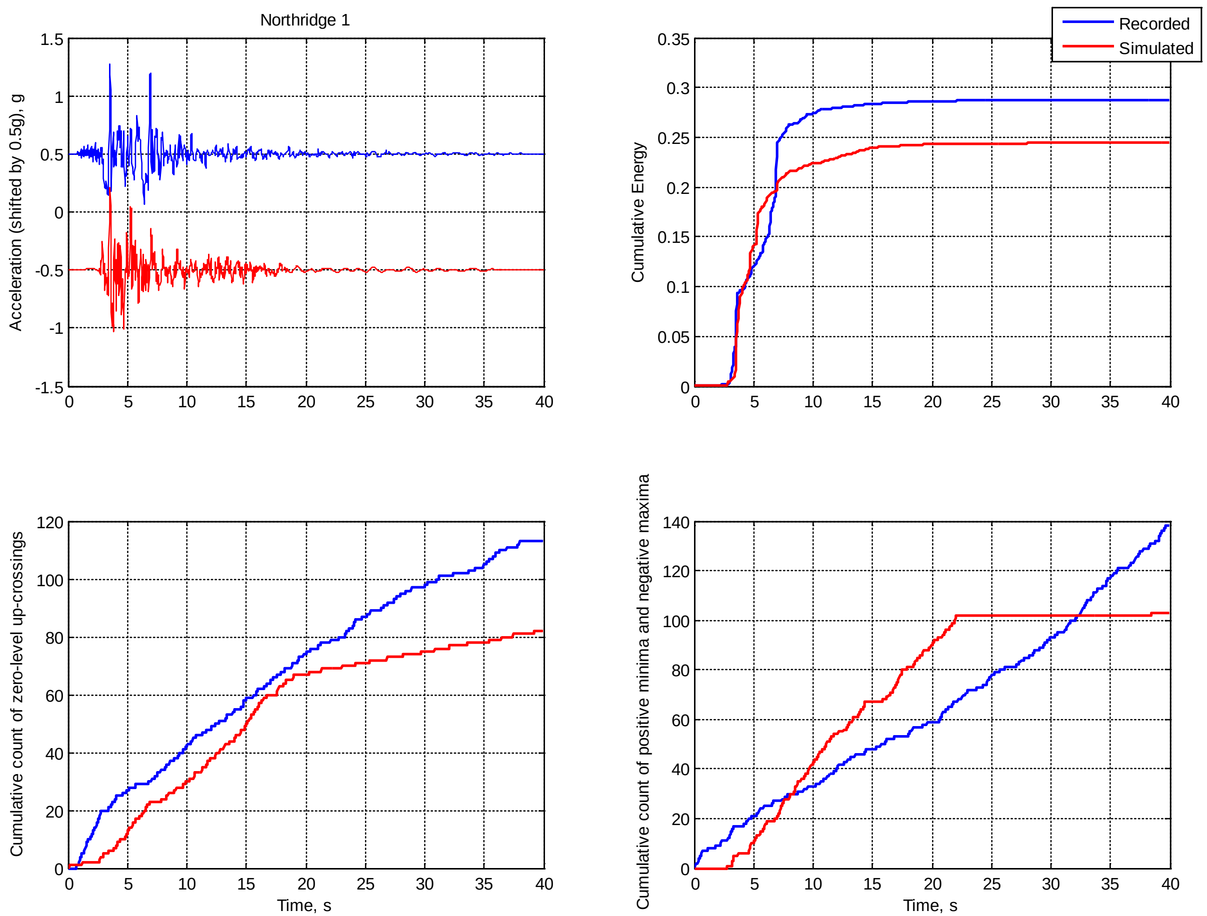
Validation of Simulated Earthquake Ground Motions Based on Evolution of Intensity and Frequency Content

by Sanaz Rezaeian, Peng Zhong, Stephen Hartzell, and Farzin Zareian

Abstract Simulated earthquake ground motions can be used in many recent engineering applications that require time series as input excitations. However, applicability and validation of simulations are subjects of debate in the seismological and engineering communities. We propose a validation methodology at the waveform level and directly based on characteristics that are expected to influence most structural and geotechnical response parameters. In particular, three time-dependent validation metrics are used to evaluate the evolving intensity, frequency, and bandwidth of a waveform. These validation metrics capture nonstationarities in intensity and frequency content of waveforms, making them ideal to address nonlinear response of structural systems. A two-component error vector is proposed to quantify the average and shape differences between these validation metrics for a simulated and recorded ground-motion pair. Because these metrics are directly related to the waveform char-

Example :

Use for Visual Inspection by Model Developers:



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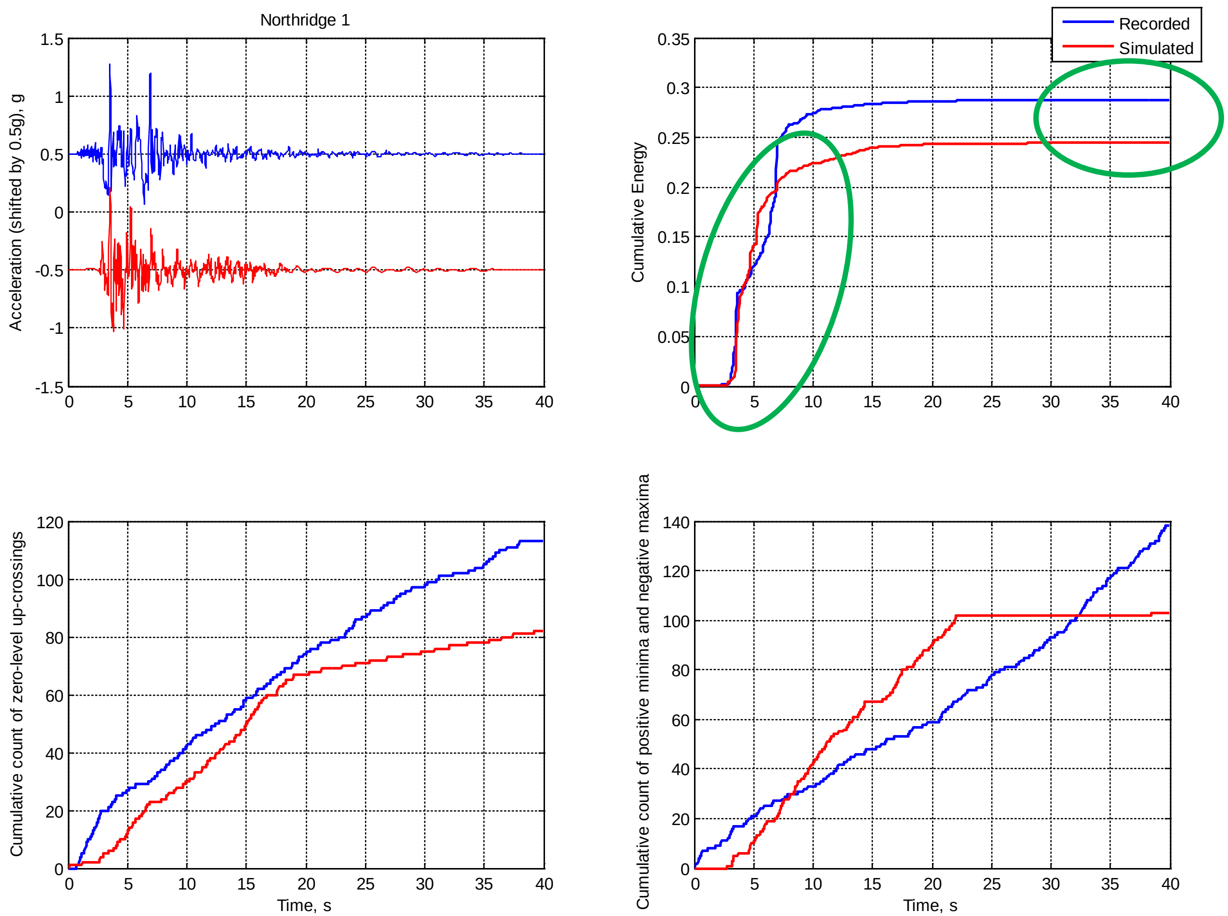

Evolution of Intensity

Example :

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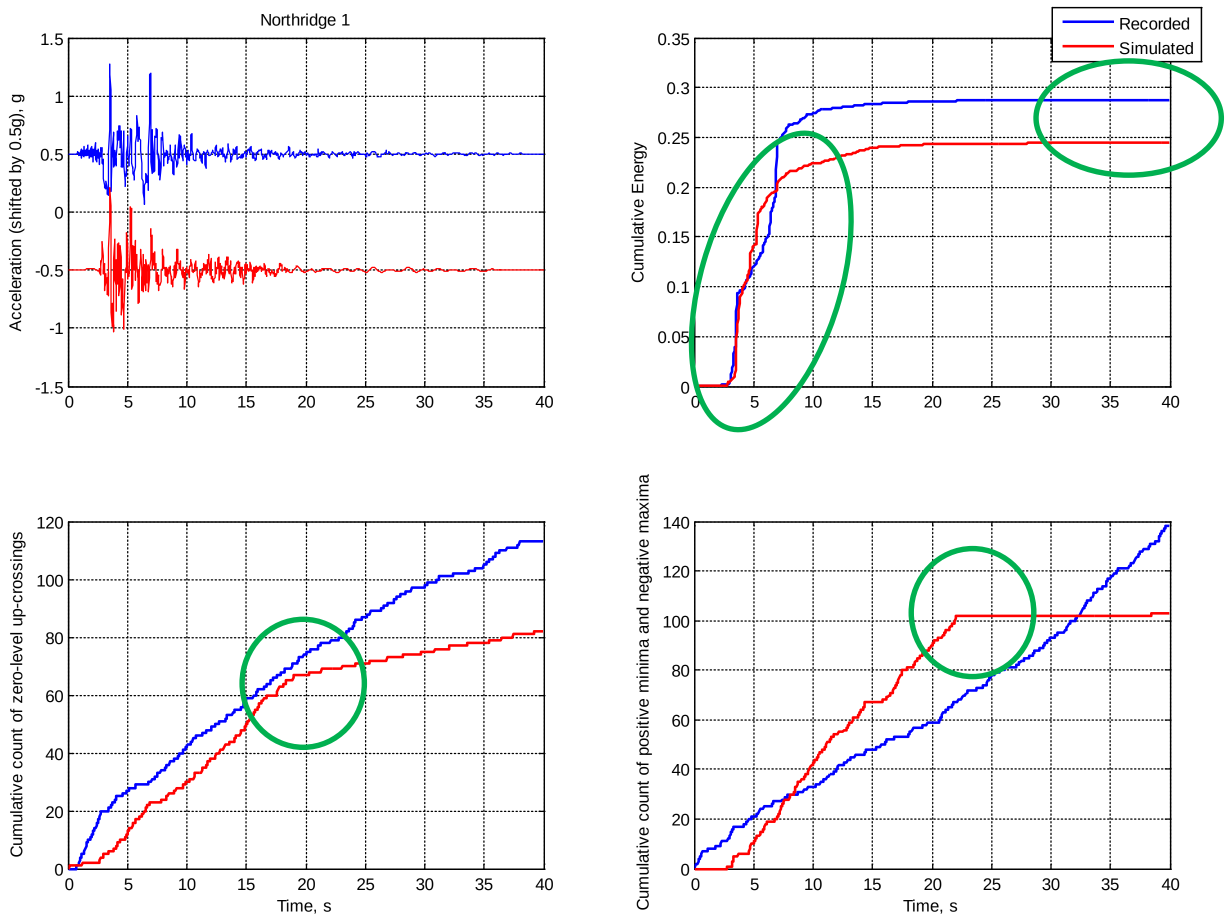

Evolution of Intensity

Discontinuity in frequency

Example :

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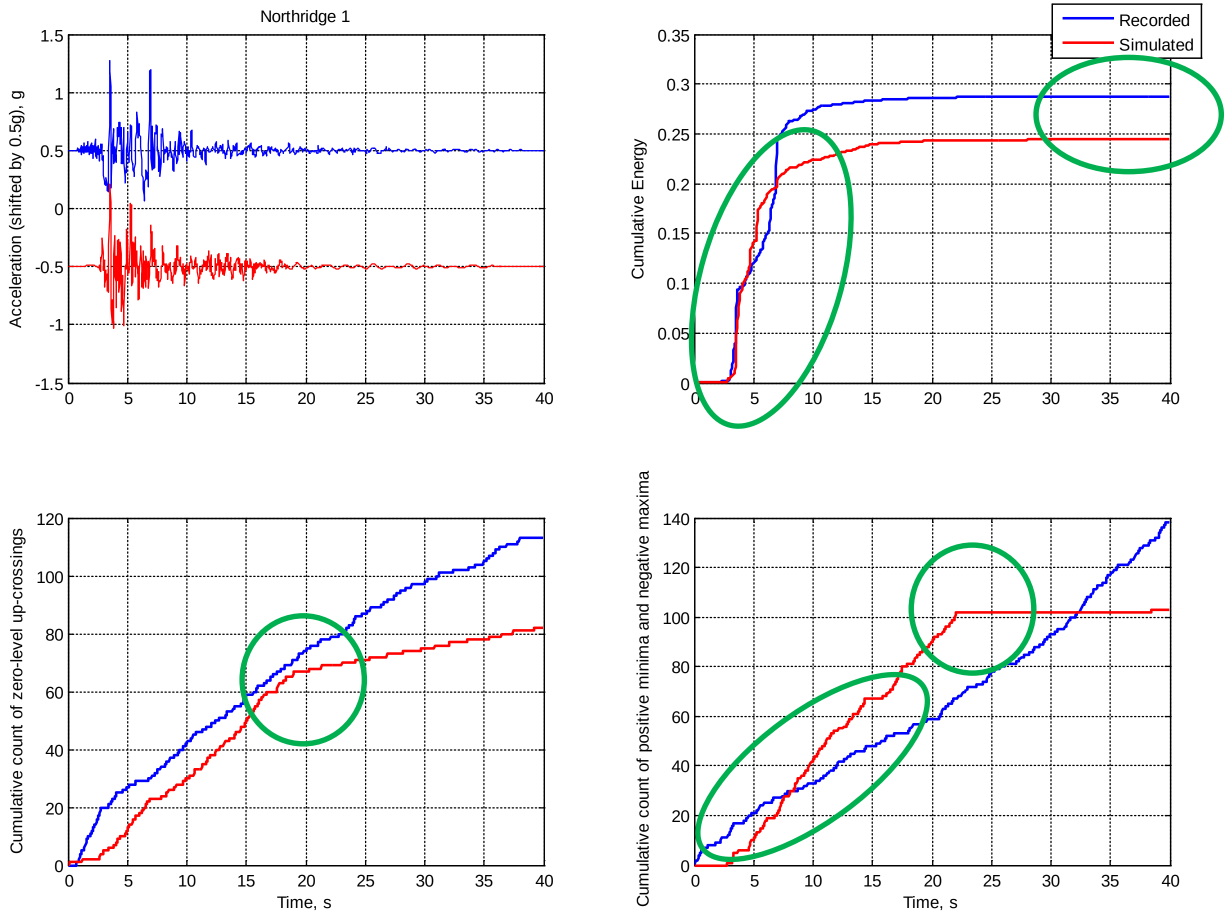


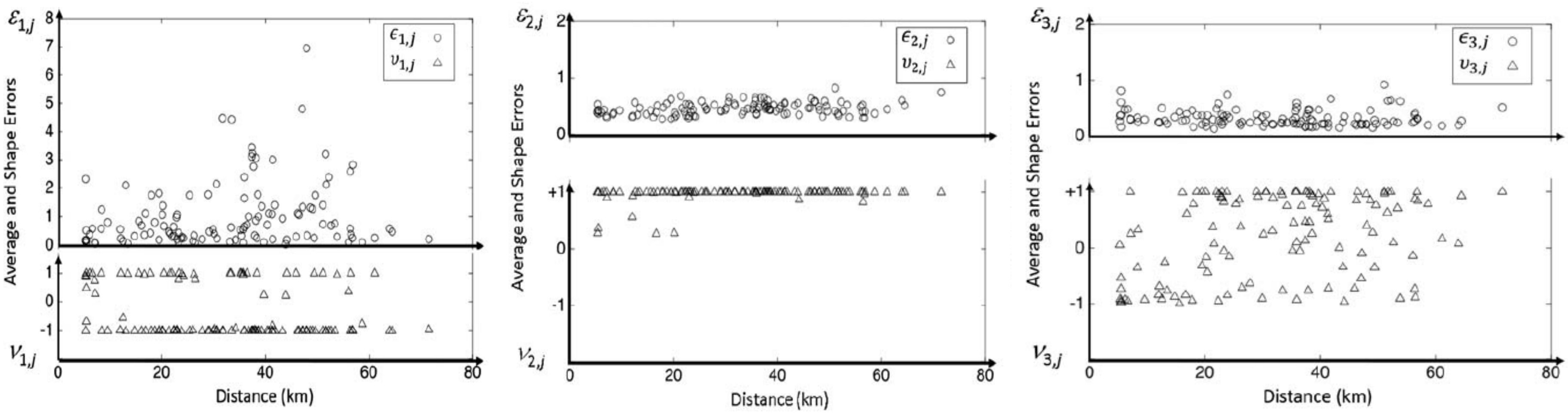
Evolution of Intensity

Discontinuity in frequency

Higher Bandwidth

Example :

Use of error terms for assessing a large number of simulations:



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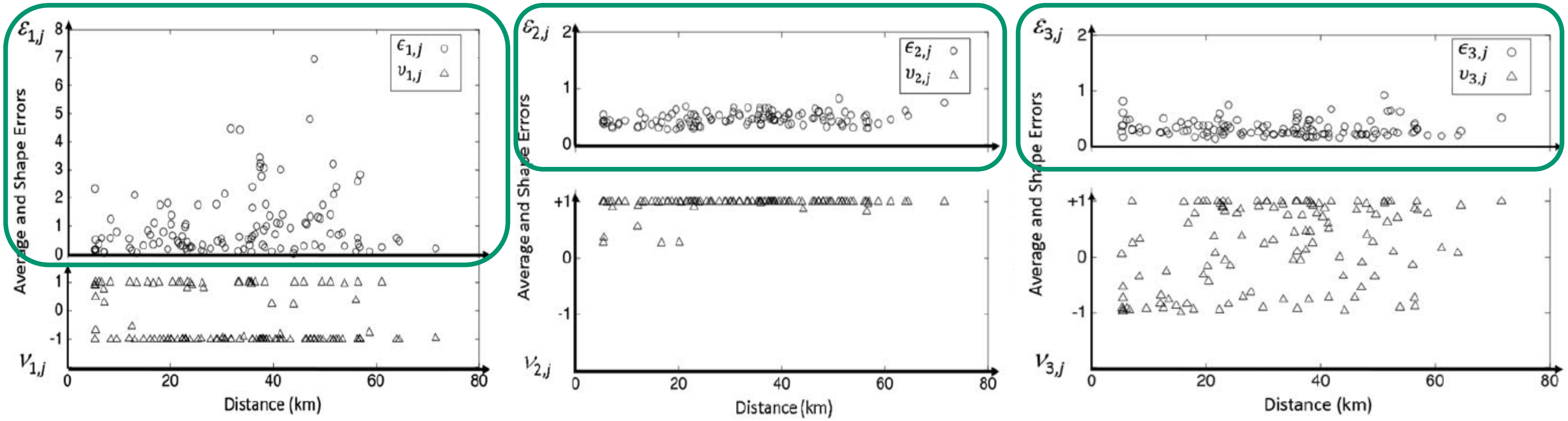

Note: A relative validation method

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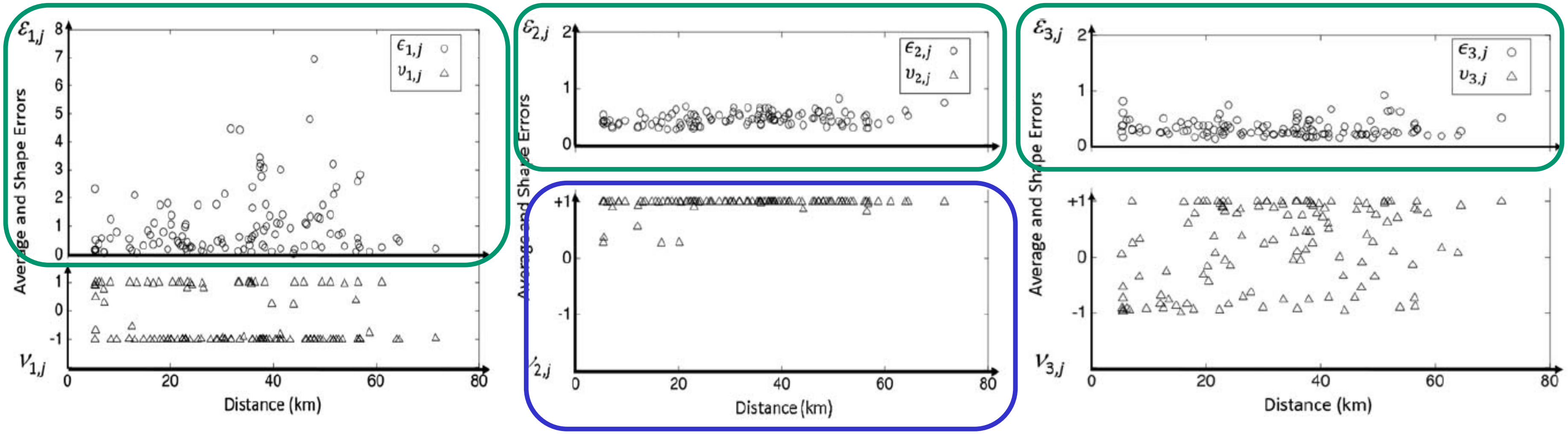

Note: A relative validation method

In general, underestimating metric 2 (frequency and how it changes with time)