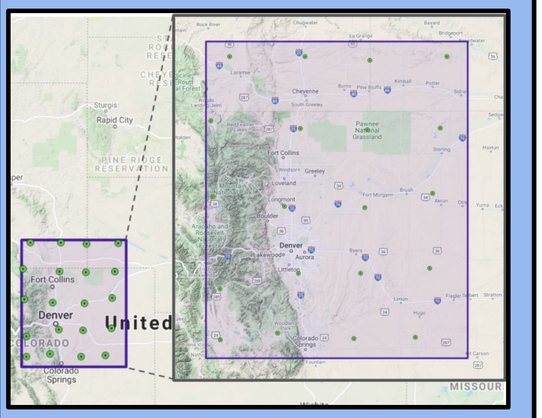
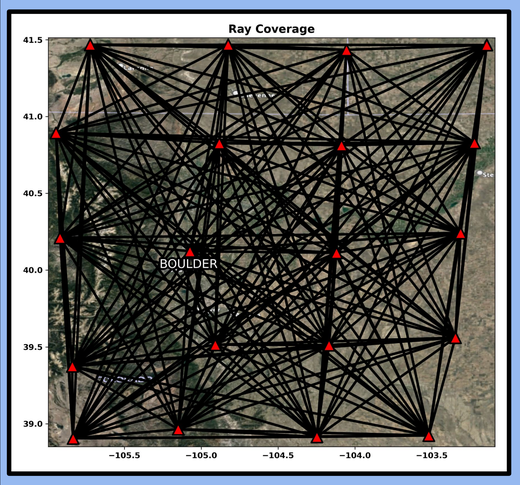
Convolutional Neural Network Waveform Inversion

By Charles Hoots and John Ortiz

Problem Space

Seismic surface waveform inversion is a uniquely valuable and challenging practice in Geophysics. Good models can produce a measurement of the Earth's response field to a seismic event known as a Green's function. These models are known to be computationally hard to create. Our goal is to utilize Convolutional Neural Networks to improve the efficiency of producing such a model.





Dataset

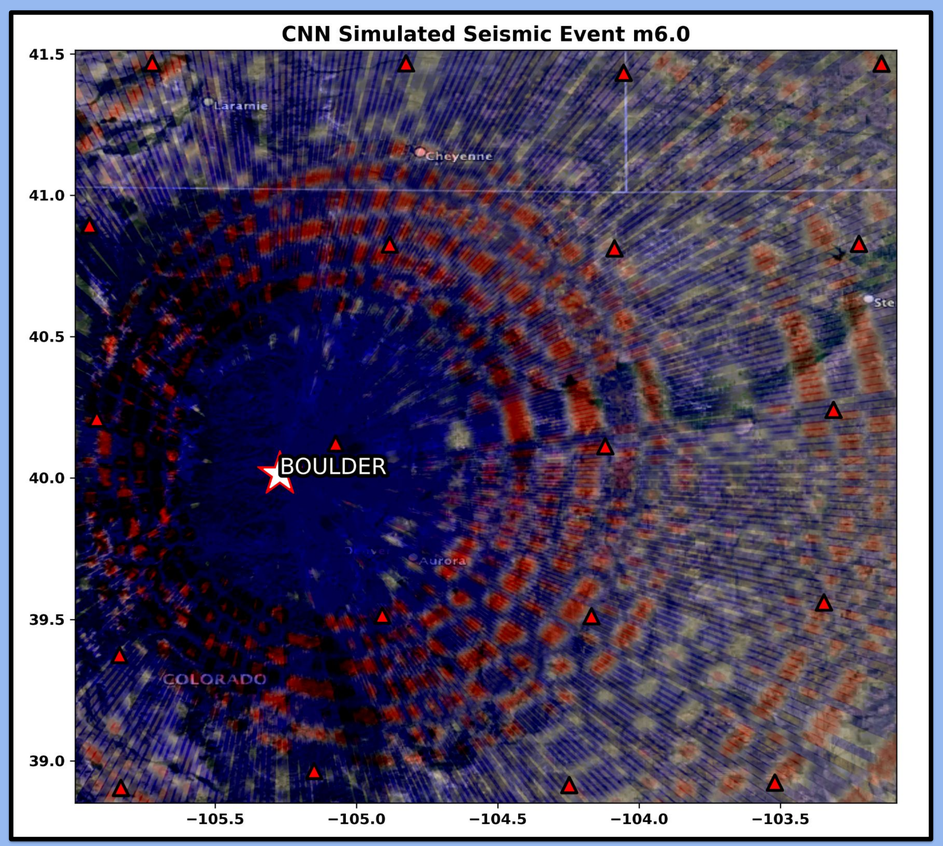
Features	1- Source Location	2- Receiver Location	3- Green's Function

| Rows (N*380) | Training Data

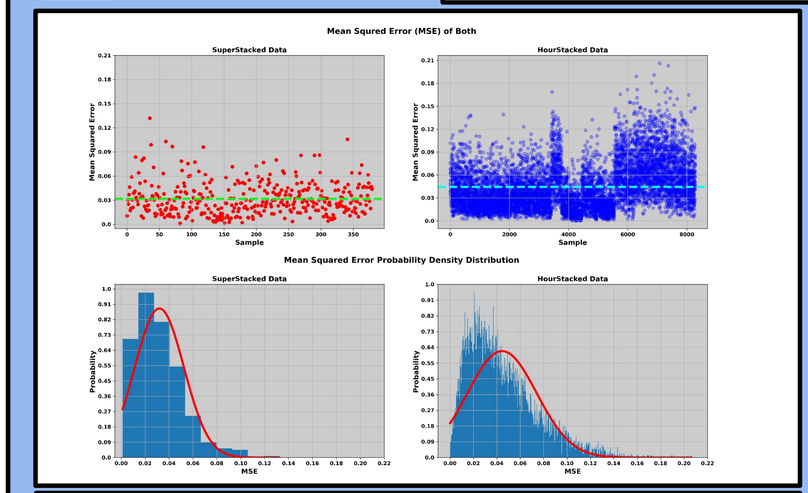
	Lat_src	Lon_src	Lat_rec	Lon_rec	Greens
0	41.467602	-104.824799	41.467999	-105.722099	[0.128344434441, 0.128796354764, 0.128748349422...
1	41.434700	-104.055099	41.467999	-105.722099	[0.154178659182, 0.15256275651, 0.151179637956...
2	41.466099	-103.142700	41.467999	-105.722099	[−0.272107318898, −0.267784034178, −0.26312246...
3	40.894699	-105.944000	41.467999	-105.722099	[0.0633291803589, 0.0658792427136, 0.068421755...
4	40.827099	-104.882401	41.467999	-105.722099	[0.0799129828139, 0.0668518871088, 0.053736139...
...	...	...	...	...	...
375	39.512501	-104.167999	38.923401	-103.519501	[−0.0520441417172, −0.0584936443926, −0.064587...
376	39.560200	-103.346497	38.923401	-103.519501	[0.0667402678326, 0.0661563441556, 0.065647422...
377	38.904499	-105.833702	38.923401	-103.519501	[−0.118052495448, −0.113282745096, −0.10842098...
378	38.964100	-105.149200	38.923401	-103.519501	[−0.235497197312, −0.233003846683, −0.23018301...
379	38.914501	-104.247200	38.923401	-103.519501	[0.150728336694, 0.154219911611, 0.15755717153...

380 rows × 8 columns

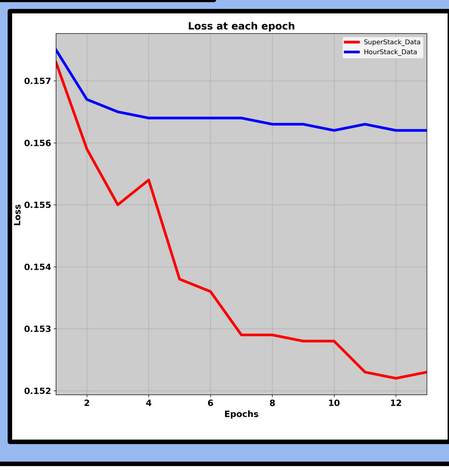
Trained on two datasets: An hour stacked set with 8284 traces and a station-pair stacked set of 380 traces. Both sets stacked from 547,200 samples, each with 5 parameters.



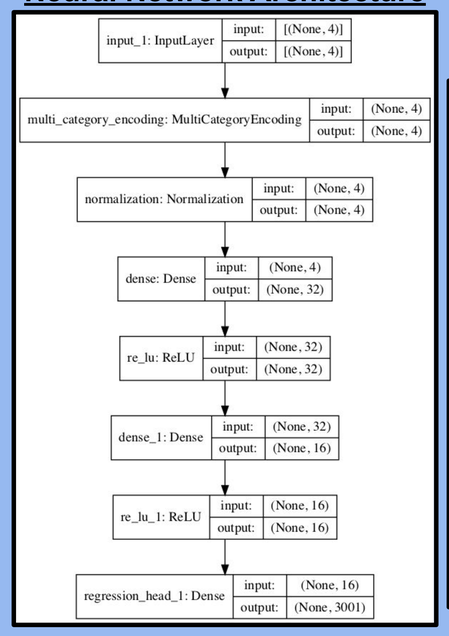
Error



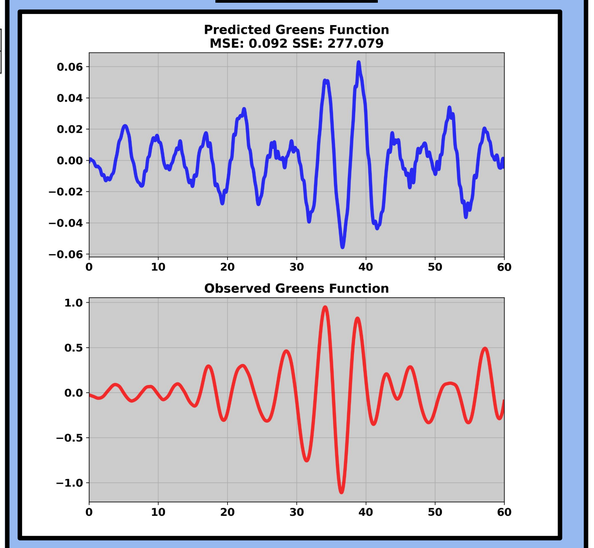
Prediction Errors: The top row is the MSE for every sample with dashed lines at the mean MSE. The bottom row is the probability density (PDF) of the MSE for each model with approximated distribution curves in red

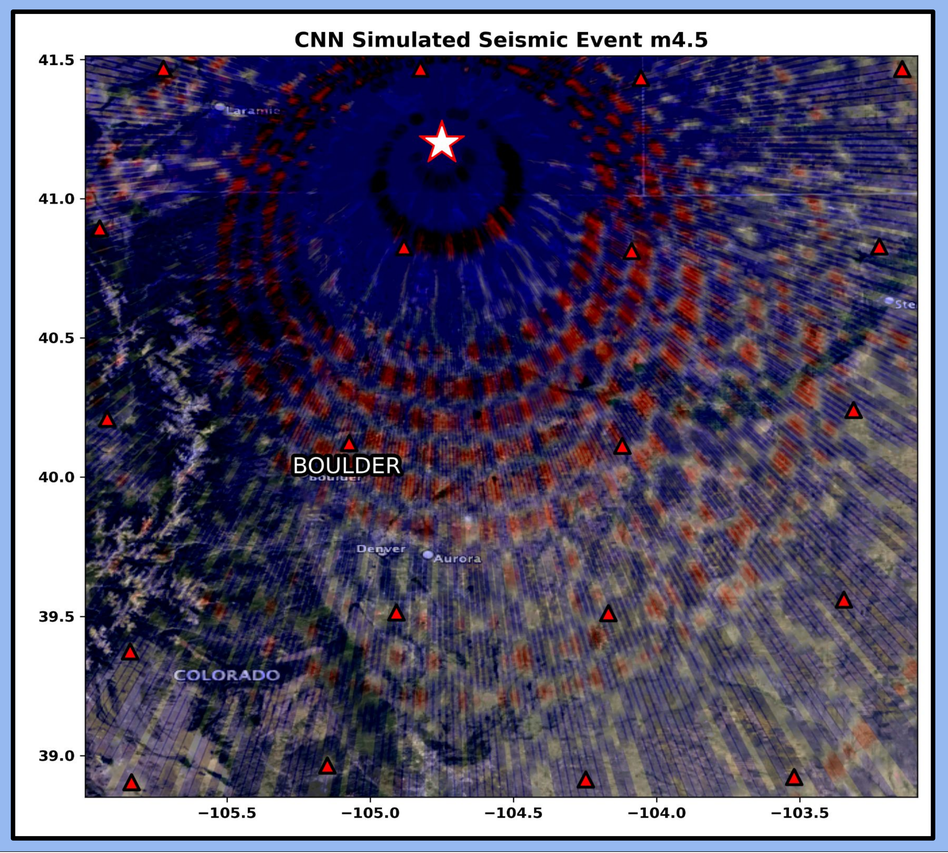


Neural Network Architecture



Model Predictions vs. Published Precendent





Discussion

- *Predictions consistently maintain higher band spectral density than what it was trained on suggesting training neural networks on time series data may bias weighting to higher frequency features in the training sets.*
- *Can be used for quick/efficient modeling for earthquake protection and mitigation.*

References

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