Supplementary Material for

DeepGEM-EGF: A Bayesian strategy for joint estimates of source time functions and empirical Green's functions

Théa Ragon[1,2,*], **Angela Gao**[3], **Zachary Ross**[1]

[1]Seismological Laboratory, California Institute of Technology, Pasadena, CA, USA, [2]*now at* CNRS, Univ. Grenoble Alpes, IRD, ISTerre, Grenoble, France, [3]Computing and Mathematical Sciences Department, California Institute of Technology, Pasadena, CA, USA, [*]Corresponding author: thea.ragon@univ-grenoble-alpes.fr

Contents

S1 Description of DeepGEM-egf arguments **2**

S2 Toy models with synthetic waveforms **4**
S2.1 Description of the forward model 4
S2.2 Prior assumptions for DeepGEM 4
S2.3 Prior assumptions for the Multitaper Spectrum Analysis 4
S2.4 Results 5

S3 Toy models with recorded waveforms: the 2016 Borrego Springs sequence, CA **27**
S3.1 Data 27
S3.2 Description of the forward model 27
Prior assumptions for DeepGEM 27
Prior assumptions for the Landweber approach 27
S3.3 Results 27

S4 Case study: the 2019 Cahuilla swarm, CA **31**
S4.1 Data 31
S4.2 Toy models with recorded waveforms 31
Description of the forward model 31
Prior assumptions for DeepGEM 31
Results 33
S4.3 Description of the forward model 48
Prior assumptions for the Landweber approach 48
S4.4 Results 48

S1 Description of DeepGEM-egf arguments

Table S1 List of arguments for DeepGEM (continued on Table S2).

Parameter	Description	type	Default value
User parameters			
dir	Output directory	string	'./results'
trc0	Path or name of trace file	string. File must be npy array or obspy stream	''
egf0	Path or name of EGF file	string. File must be npy array or obspy stream	''
stf0	Path or name of prior STF file	npy array	''
synthetics	True if we know the target	bool	**False**
gf_true	Path or name of target EGF file	string. File must be npy array or obspy stream	''
stf_true	Path or name of target STF file	string. File must be npy array or obspy stream	''
stf_size	Number of samples in STF (optional if stf_dur specified)	int	100
stf_dur	Duration of STF in seconds	float	**None**
samp_rate	Sampling rate (Hz)	float	**None**
num_egf	Number of EGFs	int	1
M0	Seismic moment of main event	float	**None**
M0_egf	Seismic moment of EGF event	float or list if several EGFs	**None**
Network parameters			
btsize	Batch size	int	1024
num_epochs	Number of epochs	int	150
num_subepochsE	Number of sub-epochs for E step	int	350
num_subepochsM	Number of sub-epochs for M step	int	50
EMFull	True: E to convergence, M to convergence False: alternate E, M every epoch	bool	**False**
x_rand	random x or from a certain sample	bool	**True**
seqfrac		6	
num_layers	number of layers for GF generator	int	7
Elr	Learning rate on E step	float	1e-3
Mlr	Learning rate on M step	float	1e-5

Table S2 List of arguments for DeepGEM (continued).

Parameter	Description	type	Default value
Weights			
data_sigma	Data sigma, weight for MSE loss	float	1e-6
stf0_sigma	E step - sigma on prior STF	float	2e-1
stf0_weight	E step - weight for distance to prior STF	float	**None** = function of data_sigma
stf_weight	E step - list of weights for priors on STF [boundaries, total variation, L1]	list	**None** = function of data_sigma
logdet_weight	E step - weight on q_θ, controls entropy	float	**None** = function of data_sigma
egf_norm_weight	M step - weight for L1 norm on EGF	float	**None** = function of data_sigma
prior_phi_weight	M step - list of weights for the priors on the EGFs [L1, L2, total variation]	list	**None** = function of data_sigma
egf_multi_weight	M step - if multiple EGFs, weight to closeness of EGFs to best EGF (the one that minimizes the fit to the data)	float	**None** = function of data_sigma
egf_qual_weight	Mstep - if multiple EGFs, weights the Mstep MSE loss of each EGFs	float	**None** = 1 for each
Misc.			
save_every	Save output every sub-epoch	int	50
print_every	Print output every sub-epoch	int	500
dv	which GPU to use, or cpu by default	string	'cpu'
multidv	use multiple gpus, use -1 for all	string	**None**
output	Plot figures, store output	bool	**True**
seed	random seed	int	1
reverse	permute parameter, if False, random, if True, reverse	bool	**False**

S2 Toy models with synthetic waveforms

S2.1 Description of the forward model

Waveforms for seismic events of reference are calculated from multiple variable and randomized parameters. The absolute source location is fixed. The source is defined by variable parameters (see Tables S3, S4, S5) that include moment magnitude (Mw), source depth, strike, dip and rake, and a source time function (STF). The STF is a stack of N_{STF} (ranging from 3 to 10) Gaussian STFs, each of the Gaussian STFs being characterized by a random risetime, a random amplitude, and a random padding, while the total duration D_{STF} of the stack of Gaussian STFs cannot be larger than a pre-defined duration (STF duration).

Green's functions are calculated with Fomosto with the QSEIS backend (Heimann et al., 2017), using one of three synthetic 1D crustal velocity models (see Tables S6, S7 and S8) for a randomly located receiver at distance D from the absolute source location of the event of reference. Sample rate is of 10 Hz.

EGFs are calculated for a double-couple source whose parameters are defined relatively to the ones of the event of reference. The EGF source is randomly located at a pre-defined δ distance (0 to 100 m) and δ depth (0 to 5 km) from the absolute location of the event of reference. The Mw varies from 1 to 3.5. Each parameter of the focal mechanism (strike, dip, rake) is equal to the one of the event of reference, to which is added a random variation whose value is between δ/2 and δ, δ ranging from 0 to 30°. A random variation is applied to all parameters (therefore if $\delta = 10°$, all 3 of strike, dip and rake will vary of more than 5°). Equivalent Kagan angles between moment tensors of the main event and assumed EGFs are similar to the assumed δ, but can reach up to 40° for $\delta = 30°$.

Some white noise can be added, with a peak signal to noise (PSNR) ratio ranging from 0 to 10% of the peak EGF amplitude.

As varying the δ depth or δ distance between the location of the source of reference and the location of the EGF have a similar effect on the EGF waveforms, we mostly investigate the effect of varying the δ depth.

S2.2 Prior assumptions for DeepGEM

We used the following non-default parameters for DeepGEM for tests a to s:

```
num_epochs = 150
EMFull = False
seqfrac = 6
stf_dur = 9
samp_rate = 10
Elr = 1e-3
Mlr = 5e-5
data_sigma = 1e-6
```

And the following for the other tests:

```
num_epochs = 10
num_subepochsE = 100
num_subepochsM = 100
EMFull = True
seqfrac = 6
samp_rate = 10
Elr = 1e-3
Mlr = 5e-5
data_sigma = 1e-6
```

S2.3 Prior assumptions for the Multitaper Spectrum Analysis

For some tests, we compare DeepGEM inference with frequency-domain deconvolution with the Multitaper Spectrum Analysis. We use a time-bandwidth product of 4 and 6 tapers. We first calculate individual spectral estimates for each channel of every time serie, calculate the cross-spectrum and finally the deconvolution, in the time domain, of the EGF to the waveform of reference. The deconvolved signal is filtered with a Butterworth bandpass between 0.2 and 3.0 Hz. When only one EGF is used, the inferred (and shown for comparison in following figures) STF is the mean of the deconvolved signals for each channel. When multiple EGFs are used, one STF is shown for each EGF.

S2.4 Results

List of figures:
First serie, tests a to s (in Fig. 1):
- Fig. S1
- Fig. S2
- Fig. S3
- Fig. S4

Second serie, tests a0 to g4:
- Fig. S5
- Fig. S6
- Fig. S7
- Fig. S8
- Fig. S9
- Fig. S10

The average run time for these toy models is of 1 s per iteration in a `EMFull = False` setting on one CPU, and 30 s per iteration in a `EMFull = True` setting. On average, run time is therefore of less than 1.5 minute for tests a to i, but can be of up to 5 minutes for the other tests. The additional runtime is not needed and those tests could have been run with the `EMFull = False` setting.

Table S3 Parameters used for the calculation of waveforms for synthetic tests **a** to **s**. D_{STF}= 5 to 9 s.

test	Mw	D (km)	Depth (km)	Strike (°)	Dip (°)	Rake (°)	Vel. model	STF (N_{STF})	STF duration (s, D_{STF})	EGF dist. to source (km)	EGF δ depth (km)	EGF Mw	EGF δ FM (°)	EGF vel. model	noise PSNR (%)
a	4.0	25	10.	25	83.	30	c1	8	5	1	1.5	2.5	5	c1	3
b	4.0	25	10.	35	65	160	c1	8	5	1	1.5	2.5	5	c1	3
c	4.0	25	10.	40	78	90	c1	10	10	1	1.5	2.5	5	c1	3
d	4.0	30	10.	55.	83.	30	c1	8	5	1	1.5	2.5	5	c1	3
e	4.0	30	10.	25	105	120	c1	10	5	1	1.5	2.5	5	c1	3
f	4.0	40	10.	35	78	78	c1	15	10	1	1.5	2.5	5	c1	3
g	4.0	40	10.	40	83.	30	c1	8	5	1	1.5	2.5	5	c1	3
h	4.0	50	10.	55.	78	90	c1	15	10	1	1.5	2.5	5	c1	3
i	4.0	50	10.	25	65	160	c1	8	5	1	1.5	2.5	5	c1	3
j	4.0	25	10.	25	83.	30	c1	8	5	1	1.5	2.5	15	c1	3
k	4.0	25	10.	35	65	160	c1	8	5	1	1.5	2.5	15	c1	3
l	4.0	25	10.	40	78	90	c1	10	10	1	1.5	2.5	15	c1	3
m	4.0	30	10.	55.	83.	30	c1	8	5	1	1.5	2.5	15	c1	3
n	4.0	30	10.	25	105	120	c1	10	5	1	1.5	2.5	15	c1	3
o	4.0	25	10.	25	83.	30	c1	8	5	1	1.5	2.5	30	c1	3
p	4.0	25	10.	35	65	160	c1	8	5	1	1.5	2.5	30	c1	3
q	4.0	25	10.	40	78	90	c1	10	10	1	1.5	2.5	30	c1	3
r	4.0	30	10.	55.	83.	30	c1	8	5	1	1.5	2.5	30	c1	3
s	4.0	30	10.	25	105	120	c1	10	5	1	1.5	2.5	30	c1	3

Table S4 Parameters used for the calculation of waveforms for synthetic tests **a0** to **g4**. D_{STF}= 3 s.

test	Mw	D (km)	Depth (km)	Strike (°)	Dip (°)	Rake (°)	Vel. model	STF (N_{STF})	EGF dist. to source (km)	EGF δ depth (km)	EGF Mw	EGF δ FM (°)	EGF vel. model	noise PSNR (%)
a0	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	0	c1	0
a1	4.0	5.	10.	5.	83.	180.	c1	3	0	0.1	2.5	0	c1	0
a2	4.0	5.	10.	5.	83.	180.	c1	3	0	0.2	2.5	0	c1	0
a3	4.0	5.	10.	5.	83.	180.	c1	3	0	0.5	2.5	0	c1	0
a4	4.0	5.	10.	5.	83.	180.	c1	3	0	1	2.5	0	c1	0
a5	4.0	5.	10.	5.	83.	180.	c1	3	0	2	2.5	0	c1	0
a6	4.0	5.	10.	5.	83.	180.	c1	3	0	5	2.5	0	c1	0
b1	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	2	c1	0
b2	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	4	c1	0
b3	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	6	c1	0
b4	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	8	c1	0
b5	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	10	c1	0
c2	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	0	c2	0
c3	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	0	c3	0
d1	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	0	c1	2
d2	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	0	c1	5
d3	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.5	0	c1	10
e1	4.0	5.	10.	5.	83.	180.	c1	2	0	0	2.5	0	c1	0
e2	4.0	5.	10.	5.	83.	180.	c1	4	0	0	2.5	0	c1	0
e3	4.0	5.	10.	5.	83.	180.	c1	5	0	0	2.5	0	c1	0
e4	4.0	5.	10.	5.	83.	180.	c1	6	0	0	2.5	0	c1	0
f1	4.0	5.	10.	5.	83.	180.	c1	3	0	0	3.5	0	c1	0
f2	4.0	5.	10.	5.	83.	180.	c1	3	0	0	3.25	0	c1	0
f3	4.0	5.	10.	5.	83.	180.	c1	3	0	0	3	0	c1	0
f4	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.75	0	c1	0
f5	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2.25	0	c1	0
f6	4.0	5.	10.	5.	83.	180.	c1	3	0	0	2	0	c1	0
f7	4.0	5.	10.	5.	83.	180.	c1	3	0	0	1.75	0	c1	0
f10	4.0	5.	10.	5.	83.	180.	c1	3	0	0	1	0	c1	0
g1	4.0	5.	10.	5.	83.	180.	c1	3	0.1	1	2.25	3	c2	2.
g2	4.0	5.	10.	5.	83.	180.	c1	3	0.1	1	2	5	c3	2.
g3	4.0	5.	10.	55.	63.	80.	c1	3	0.1	1	2.25	3	c2	2.
g4	4.0	5.	10.	55.	63.	80.	c1	3	0.1	1	2	5	c3	2.

Table S5 Parameters used for the calculation of waveforms for synthetic tests **2a1** to **2b11**. D_{STF}= 10 s.

test	Mw	D (km)	Depth (km)	Strike (°)	Dip (°)	Rake (°)	Vel. model	STF (N_{STF})	EGF dist. to source (km)	EGF δ depth (km)	EGF Mw	EGF δ FM (°)	EGF vel. model	noise PSNR (%)
2a0	4.0	20.	10.	5.	83.	180.	c1	3	0	0	2.5	0	c1	0
2a1	4.0	20.	10.	5.	83.	180.	c1	3	0	0.1	2.5	0	c1	0
2a2	4.0	20.	10.	5.	83.	180.	c1	3	0	0.2	2.5	0	c1	0
2a3	4.0	20.	10.	5.	83.	180.	c1	3	0	0.5	2.5	0	c1	0
2a4	4.0	20.	10.	5.	83.	180.	c1	3	0	1	2.5	0	c1	0
2a5	4.0	20.	10.	5.	83.	180.	c1	3	0	2	2.5	0	c1	0
2a6	4.0	20.	10.	5.	83.	180.	c1	3	0	5	2.5	0	c1	0
2b1	4.0	20.	10.	5.	83.	180.	c1	3	0	0	2.5	2	c1	0
2b2	4.0	20.	10.	5.	83.	180.	c1	3	0	0	2.5	4	c1	0
2b3	4.0	20.	10.	5.	83.	180.	c1	3	0	0	2.5	6	c1	0
2b4	4.0	20.	10.	5.	83.	180.	c1	3	0	0	2.5	8	c1	0
2b5	4.0	20.	10.	5.	83.	180.	c1	3	0	0	2.5	10	c1	0
2b6	4.0	20.	10.	55.	63.	80.	c1	3	0	0	2.5	10	c1	0
2c2	4.0	20.	10.	5.	83.	180.	c1	3	0	0	2.5	0	c2	0
2e1	4.0	20.	10.	5.	83.	180.	c1	2	0	0	2.5	0	c1	0
2e2	4.0	20.	10.	5.	83.	180.	c1	4	0	0	2.5	0	c1	0
2e3	4.0	20.	10.	5.	83.	180.	c1	5	0	0	2.5	0	c1	0
2e4	4.0	20.	10.	5.	83.	180.	c1	6	0	0	2.5	0	c1	0
2f1	4.0	20.	10.	5.	83.	180.	c1	3	0	0	3.5	0	c1	0
2f2	4.0	20.	10.	5.	83.	180.	c1	3	0	0	3.25	0	c1	0
2f3	4.0	20.	10.	5.	83.	180.	c1	3	0	0	3	0	c1	0
2f4	4.0	20.	10.	5.	83.	180.	c1	3	0	0	2.75	0	c1	0
2f5	4.0	20.	10.	5.	83.	180.	c1	3	0	0	2.25	0	c1	0
2f6	4.0	20.	10.	5.	83.	180.	c1	3	0	0	2	0	c1	0
2f7	4.0	20.	10.	5.	83.	180.	c1	3	0	0	1.75	0	c1	0
2f8	4.0	20.	10.	5.	83.	180.	c1	3	0	0	1.5	0	c1	0
2f9	4.0	20.	10.	5.	83.	180.	c1	3	0	0	1.25	0	c1	0
2f10	4.0	20.	10.	5.	83.	180.	c1	3	0	0	1	0	c1	0
2g1	4.0	20.	10.	5.	83.	180.	c1	3	0.1	1	2.25	3	c2	2.
2g2	4.0	20.	10.	5.	83.	180.	c1	3	0.1	1	2	5	c3	2.
2g3	4.0	20.	10.	55.	63.	80.	c1	3	0.1	1	2.25	3	c2	2.
2g4	4.0	20.	10.	55.	63.	80.	c1	3	0.1	1	2	5	c3	2.
2g5	4.0	20.	10.	5.	83.	180.	c1	3	0.1	1	2.25	3	c2	5
2g6	4.0	20.	10.	5.	83.	180.	c1	3	0.1	1	2	5	c3	5
2g7	4.0	20.	10.	55.	63.	80.	c1	3	0.1	1	2.25	3	c2	10
2g8	4.0	20.	10.	55.	63.	80.	c1	3	0.1	1	2	5	c3	10
2b10	4.0	20.	10.	56.	64.	81.	c1	3	0	0	2.5	20	c1	0
2b11	4.0	20.	10.	56.	64.	81.	c1	3	0	0	2.5	20	c1	0

Table S6 Crustal velocity model **c1** used for calculation of the synthetic Green's functions.

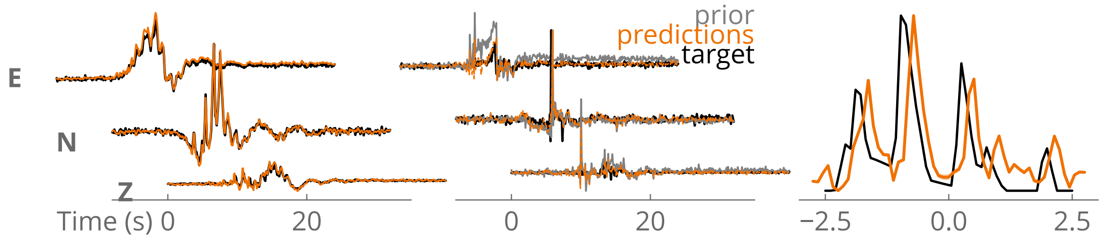
Depth (km)	Vp (km/s)	Vs (km/s)	density (kg/cm^3)	P-wave attenuation Qp	S-wave attenuation Qs
0.	2.5	1.2	2.1	50.	50.
1.	2.5	1.2	2.1	50.	50.
1.	4.	2.1	2.4	200.	200.
2.	4.	2.1	2.4	200.	200.
2.	6.2	3.6	2.8	600.	400.
14.	6.2	3.6	2.8	600.	400.
14.	6.6	3.7	2.9	1432.	600.
27.	6.6	3.7	2.9	1432.	600.
27.	7.3	4.	3.1	1499.	600.
36.	7.3	4.	3.1	1499.	600.

Table S7 Crustal velocity model **c2** used for calculation of the synthetic Green's functions.

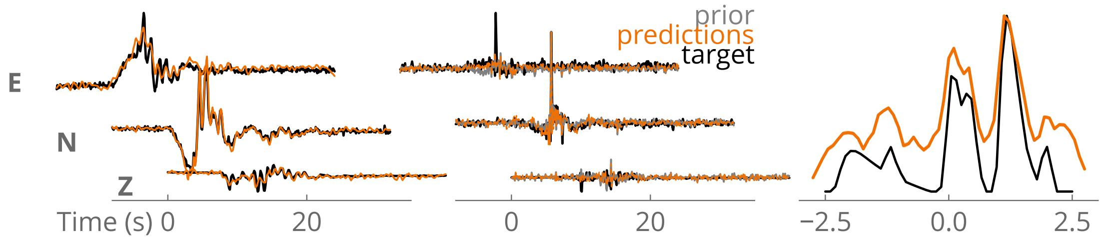
Depth (km)	Vp (km/s)	Vs (km/s)	density (kg/cm^3)	P-wave attenuation Qp	S-wave attenuation Qs
0.	2.5	1.2	2.1	50.	50.
3.	2.5	1.2	2.1	50.	50.
3.	4.	2.1	2.4	200.	200.
4.	4.	2.1	2.4	200.	200.
4.	6.2	3.6	2.8	600.	400.
10.	6.2	3.6	2.8	600.	400.
10.	6.6	3.7	2.9	1432.	600.
12.	6.6	3.7	2.9	1432.	600.
12.	4.	2.1	2.4	200.	200.
18.	4.	2.1	2.4	200.	200.
18.	6.6	3.7	2.9	1432.	600.
24.	6.6	3.7	2.9	1432.	600.
24.	7.3	4.	3.1	1499.	600.
36.	7.3	4.	3.1	1499.	600.

Table S8 Crustal velocity model **c3** used for calculation of the synthetic Green's functions.

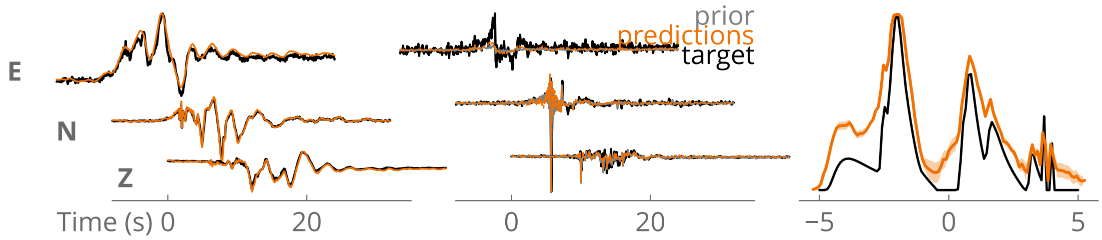
Depth (km)	Vp (km/s)	Vs (km/s)	density (kg/cm^3)	P-wave attenuation Qp	S-wave attenuation Qs
0.	2.5	1.2	2.1	50.	50.
2.	2.5	1.2	2.1	50.	50.
2.	4.	2.1	2.4	200.	200.
4.	4.	2.1	2.4	200.	200.
4.	2.5	1.2	2.1	50.	50.
8.	2.5	1.2	2.1	50.	50.
8.	6.2	3.6	2.8	600.	400.
10.	6.2	3.6	2.8	600.	400.
10.	6.6	3.7	2.9	1432.	600.
12.	6.6	3.7	2.9	1432.	600.
12.	4.	2.1	2.4	200.	200.
18.	4.	2.1	2.4	200.	200.
18.	8.037	4.485	3.598	966.6	401.3
19.	8.037	4.485	3.598	966.6	401.3
19.	6.6	3.7	2.9	1432.	600.
24.	6.6	3.7	2.9	1432.	600.
24.	7.3	4.	3.1	1499.	600.
36.	7.3	4.	3.1	1499.	600.



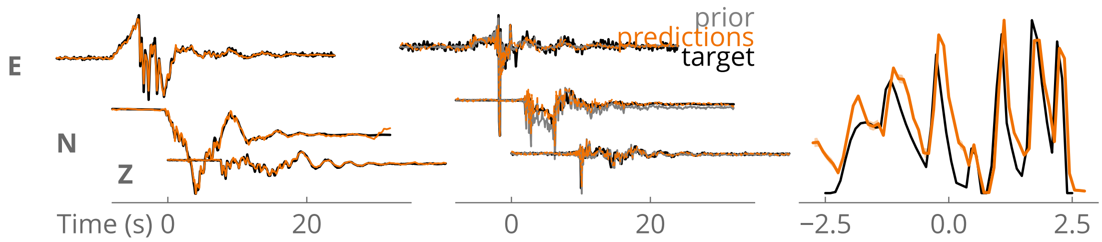
(a) Test a



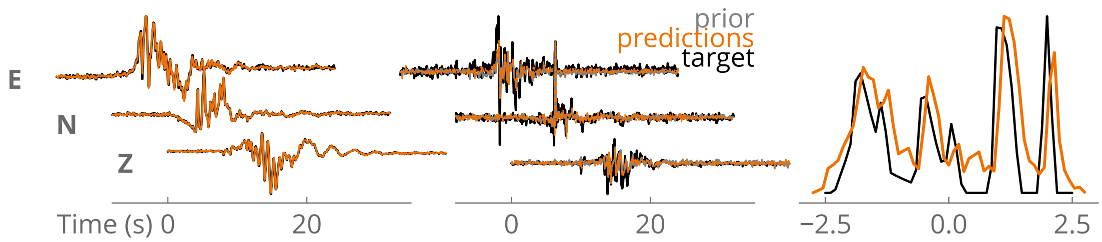
(b) Test b



(c) Test c

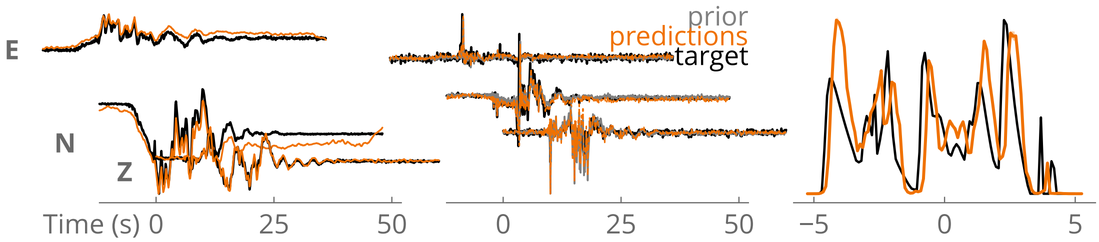


(d) Test d

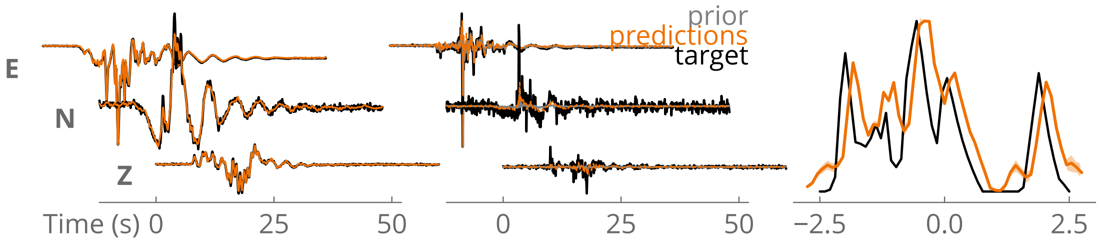


(e) Test e

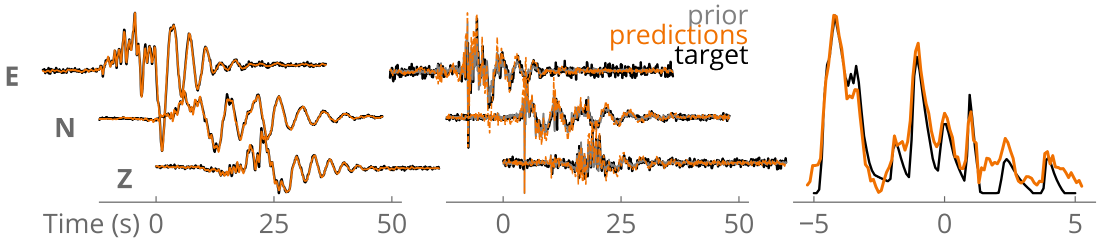
Figure S1 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **a** to **e**. Prior EGF is in gray.



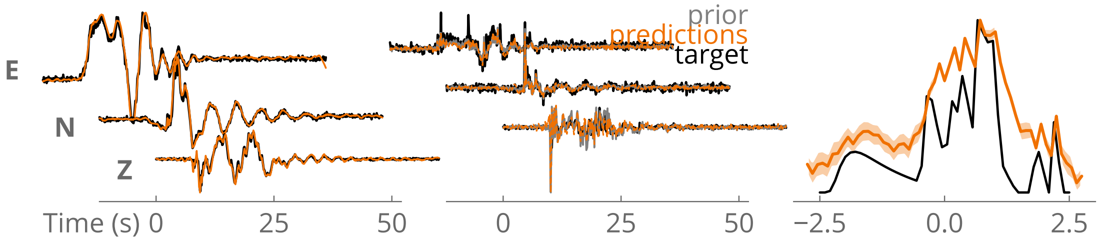
(a) Test f



(b) Test g

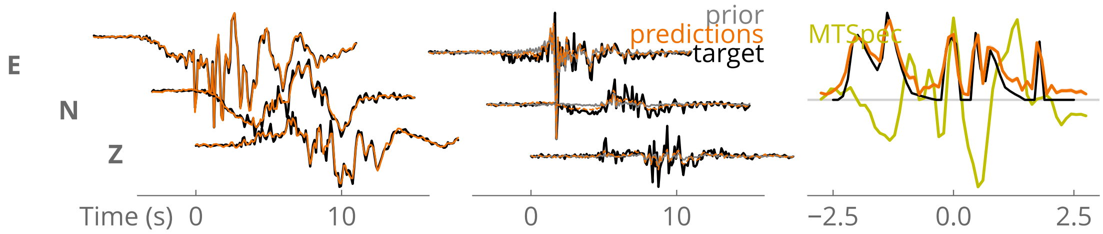


(c) Test h

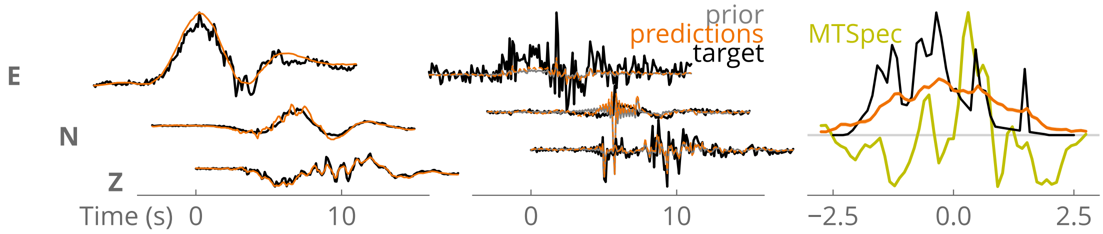


(d) Test i

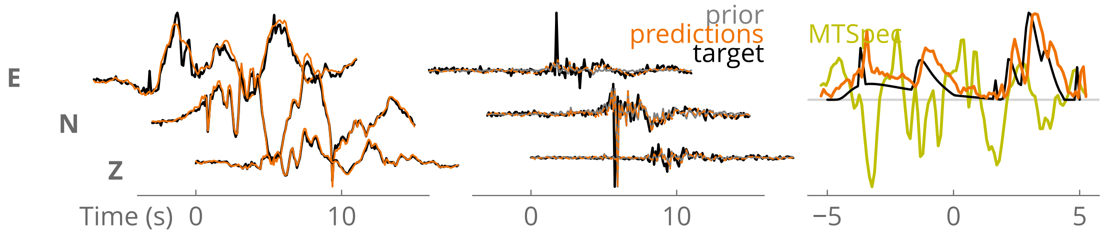
Figure S2 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **f** to **i**. Prior EGF is in gray.



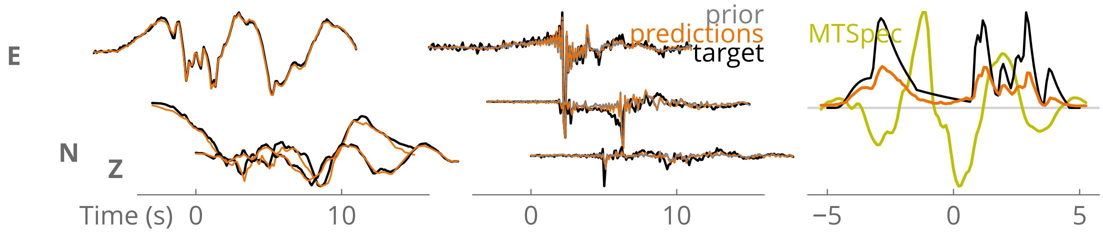
(a) Test j



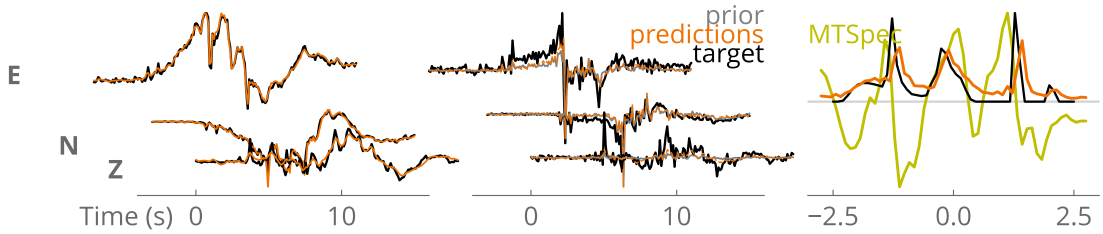
(b) Test k



(c) Test l

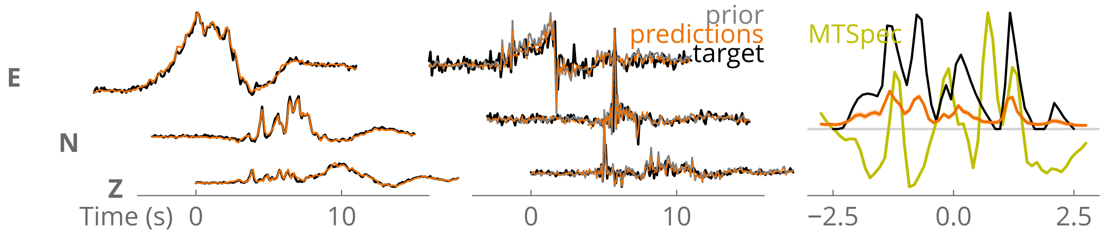


(d) Test m

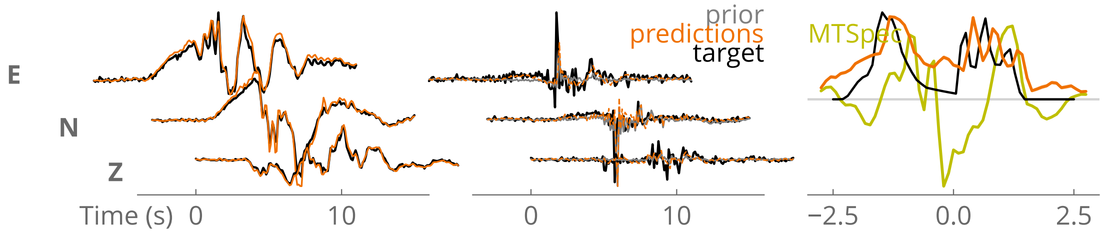


(e) Test n

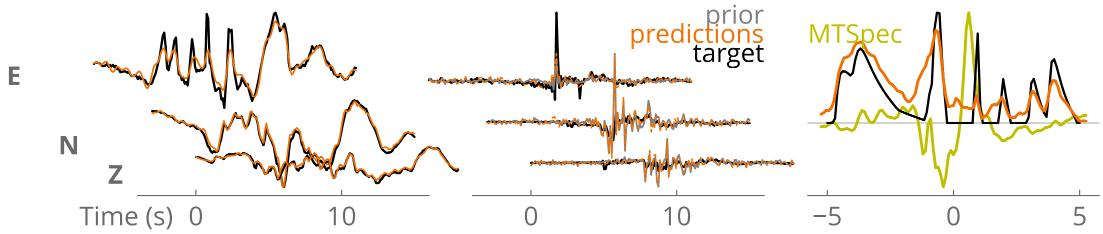
Figure S3 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **j** to **n**. Prior EGF is in gray.



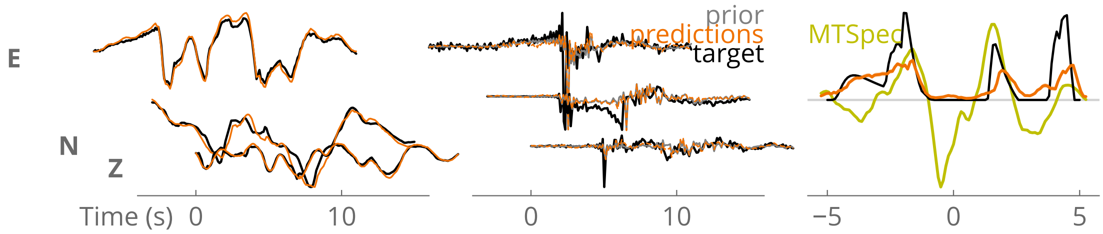
(a) Test o



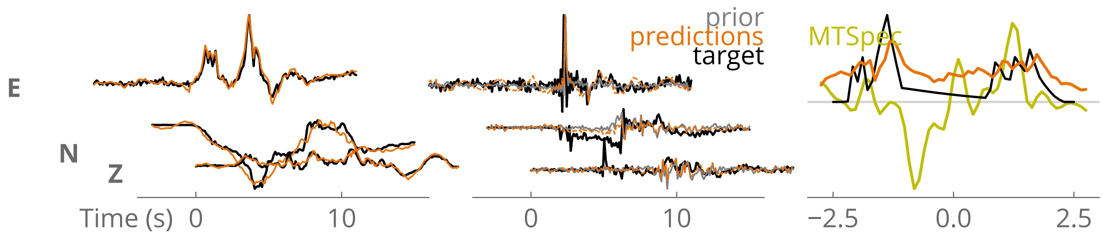
(b) Test p



(c) Test q

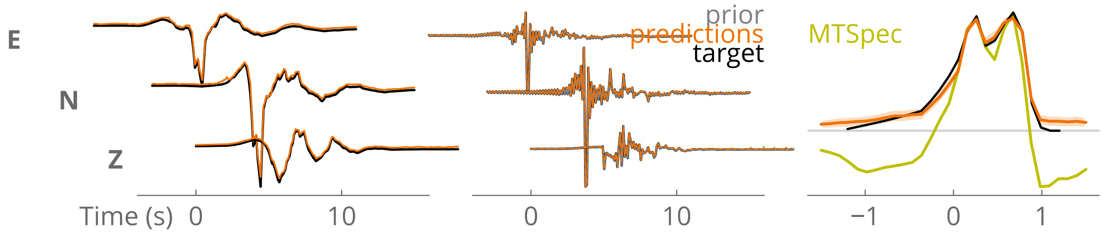


(d) Test r

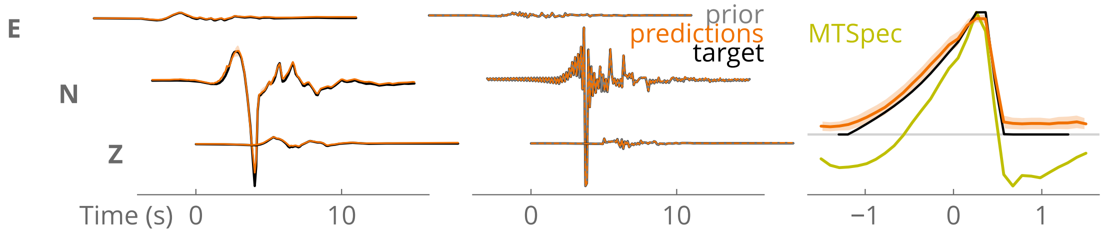


(e) Test s

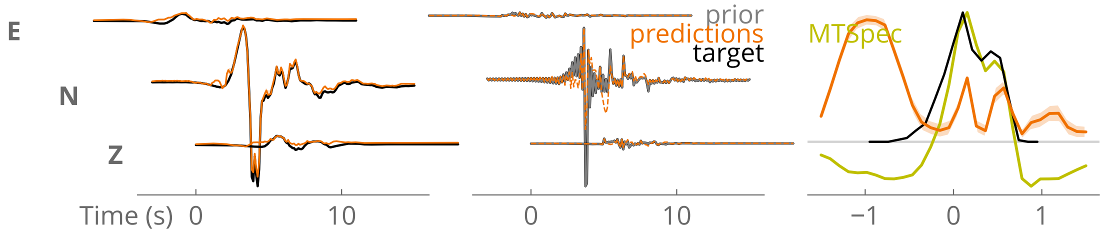
Figure S4 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **o** to **s**. Prior EGF is in gray.



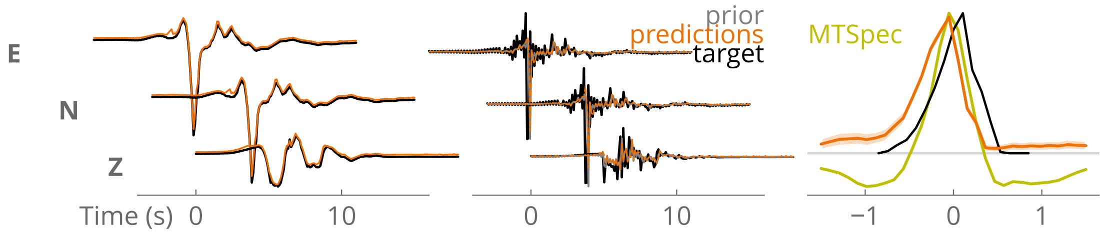
(a) Test a0



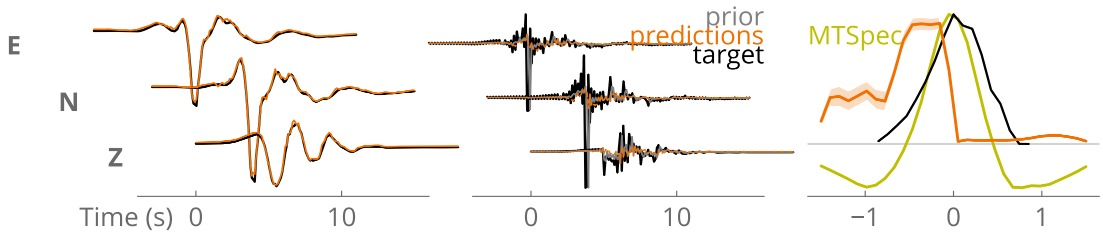
(b) Test a1



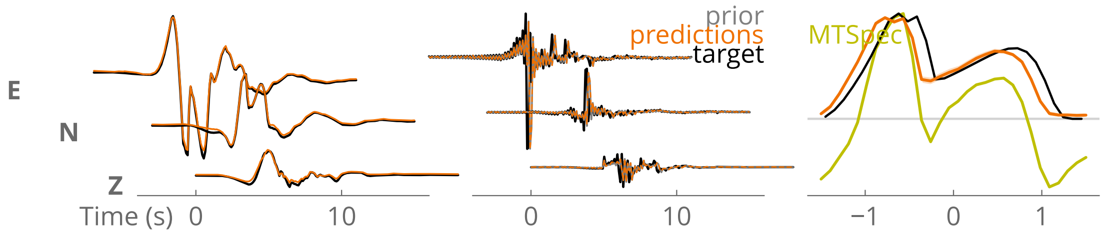
(c) Test a2



(d) Test a3

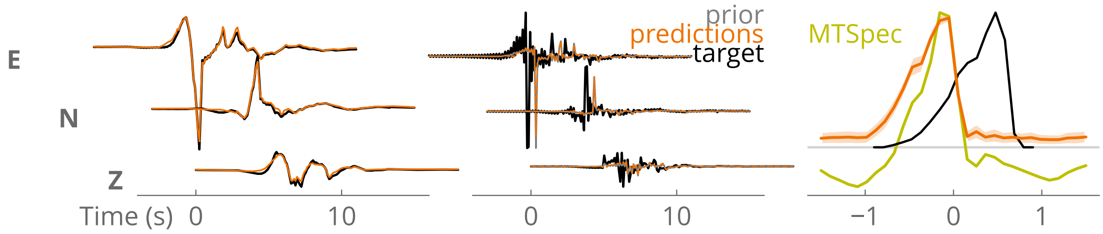


(e) Test a4

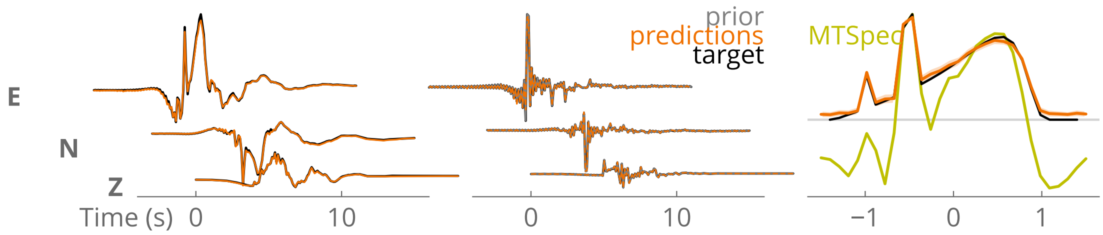


(f) Test a5

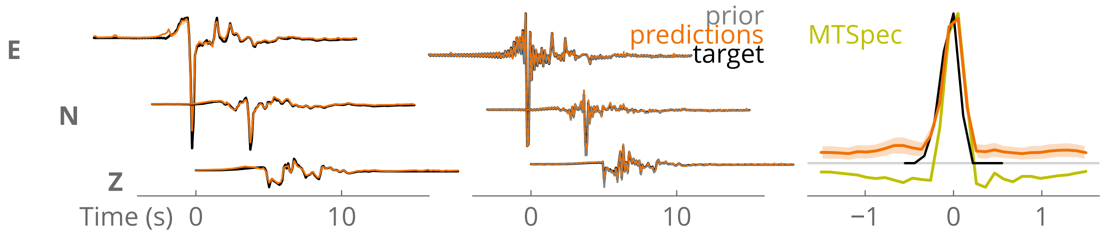
Figure S5 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **a0** to **a5**. Prior EGF is in gray, and the STF inferred with MTSpec in green.



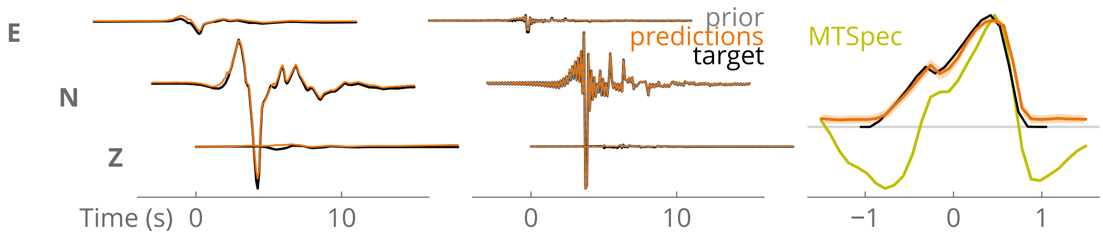
(a) Test a6



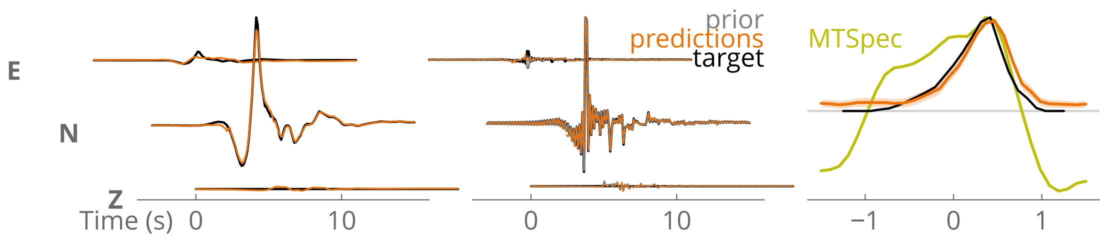
(b) Test b1



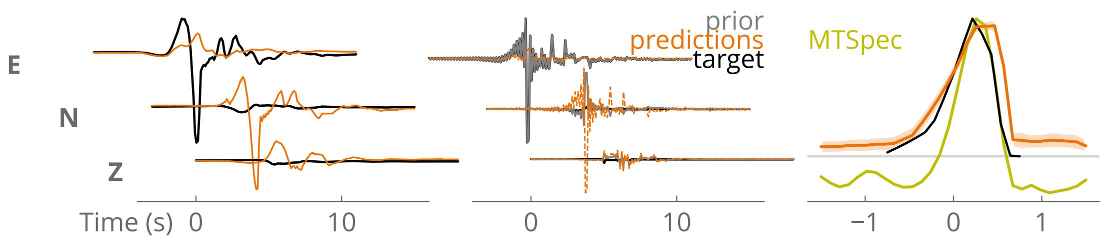
(c) Test b2



(d) Test b3

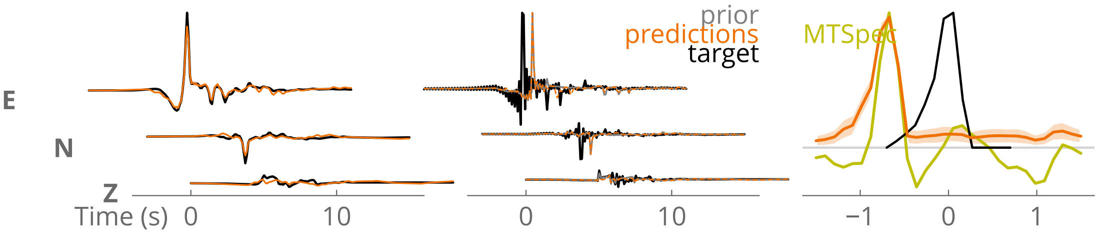


(e) Test b4

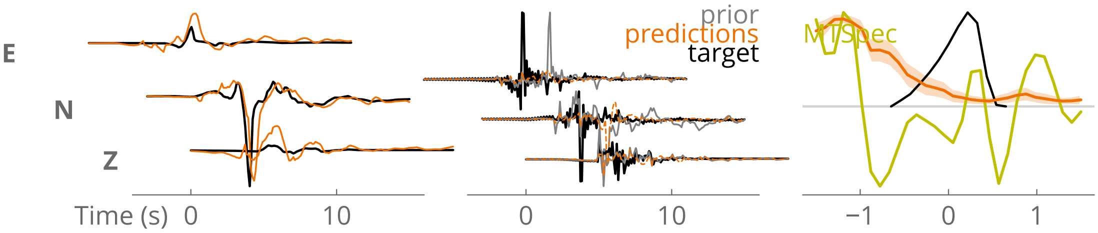


(f) Test b5

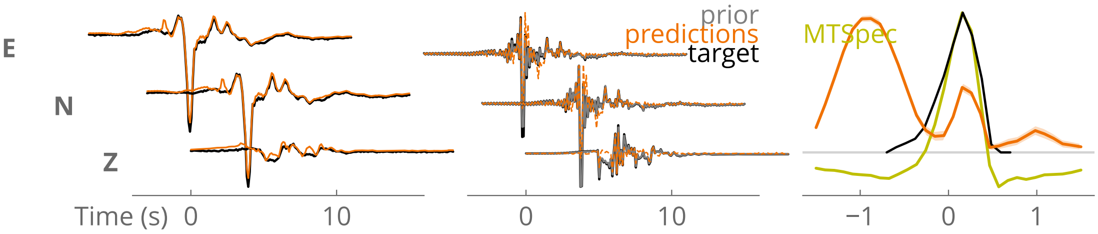
Figure S6 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **a6** to **b5**. Prior EGF is in gray, and the STF inferred with MTSpec in green.



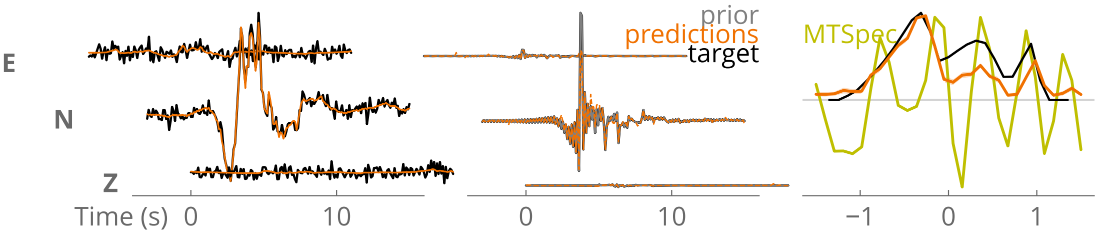
(a) Test c2



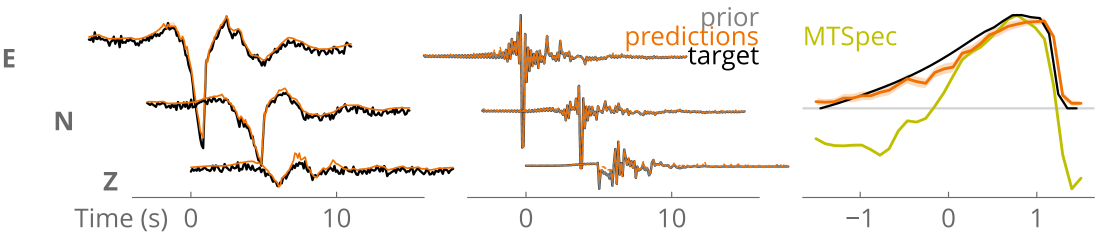
(b) Test c3



(c) Test d1

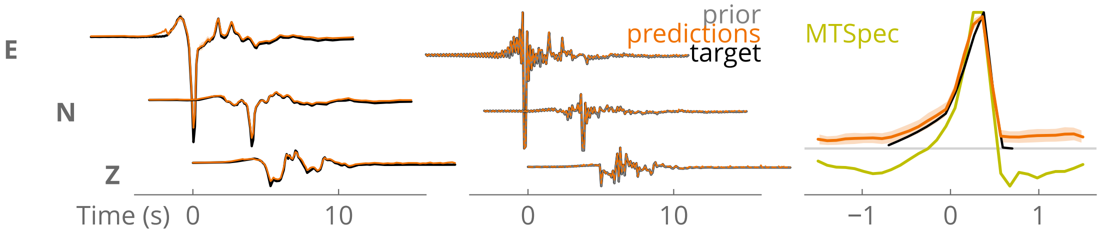


(d) Test d2

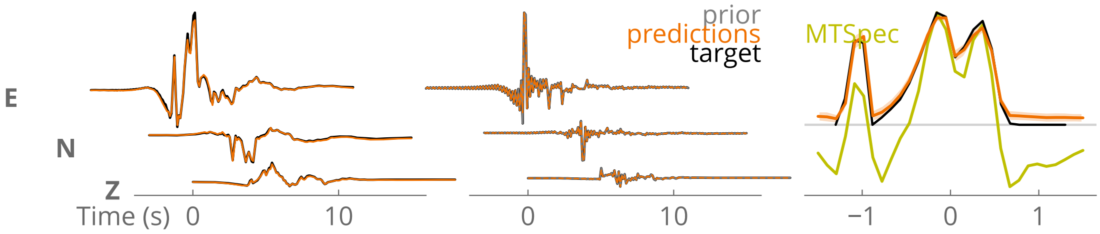


(e) Test d3

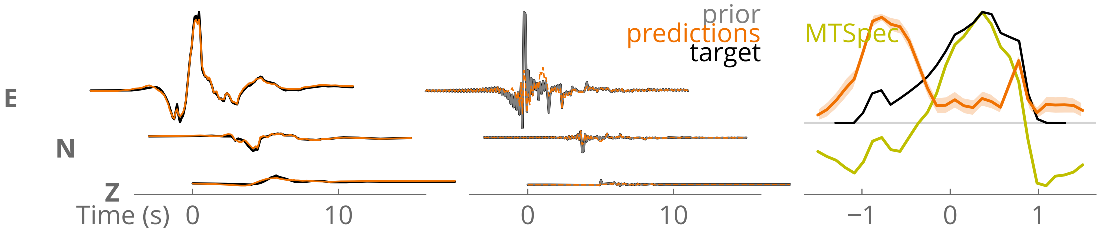
Figure S7 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **c2** to **d3**. Prior EGF is in gray.



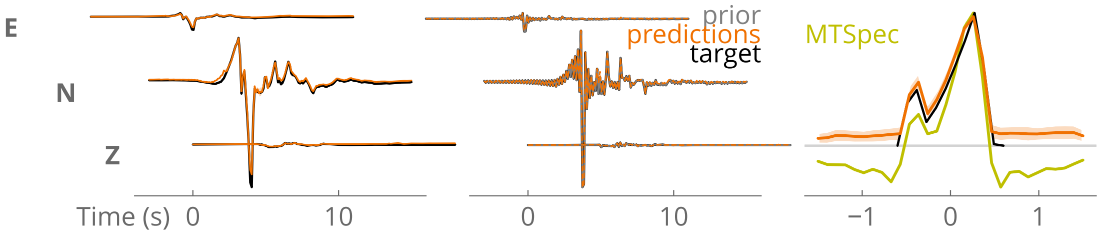
(a) Test e1



(b) Test e2

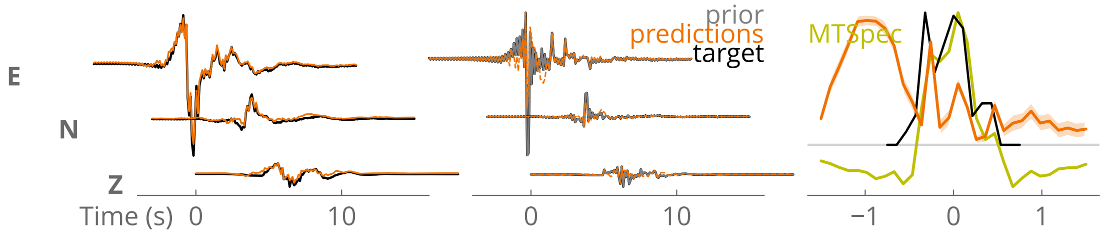


(c) Test e3

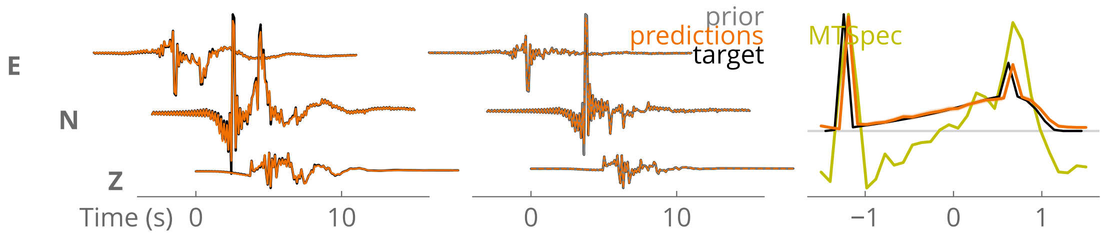


(d) Test e4

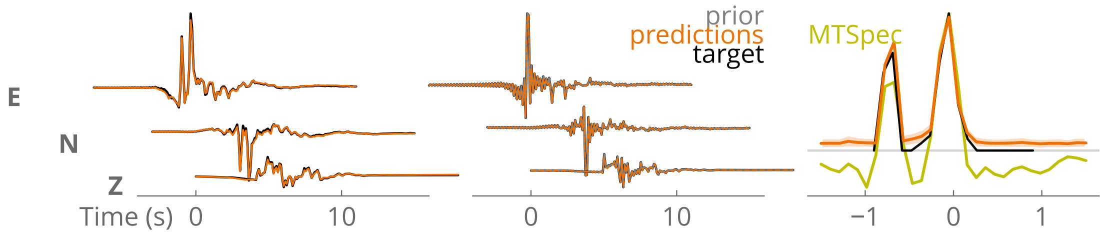
Figure S8 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **e1** to **e4**. Prior EGF is in gray.



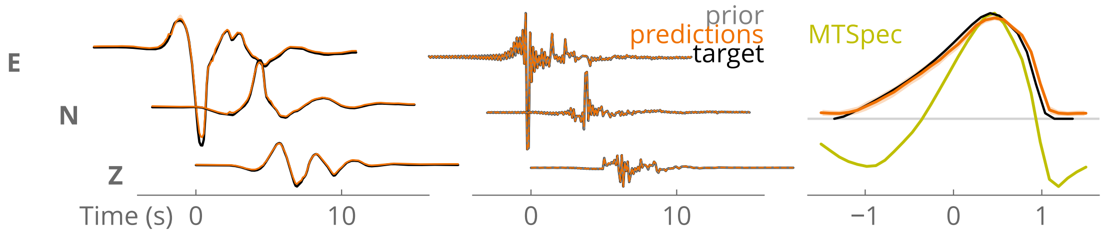
(a) Test f1



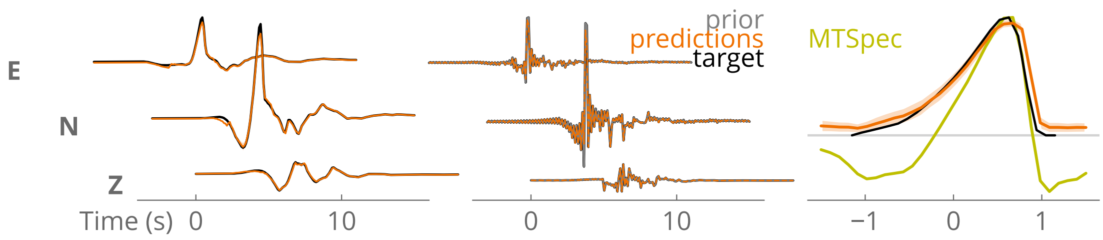
(b) Test f2



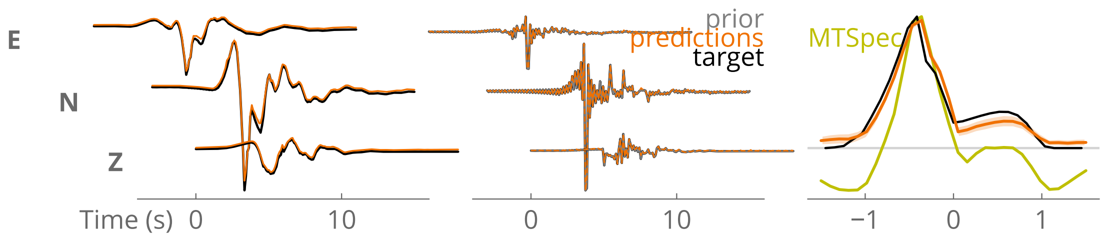
(c) Test f3



(d) Test f4

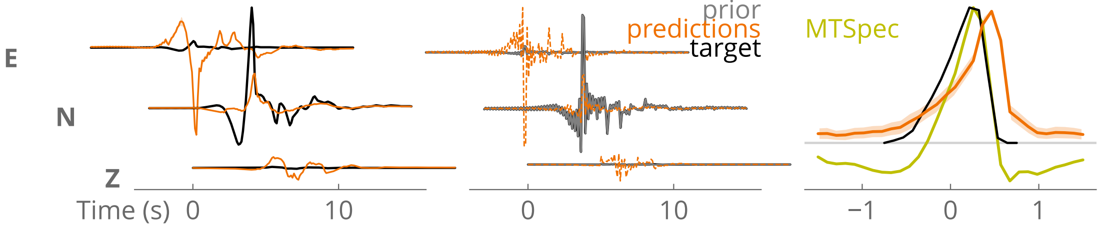


(e) Test f5

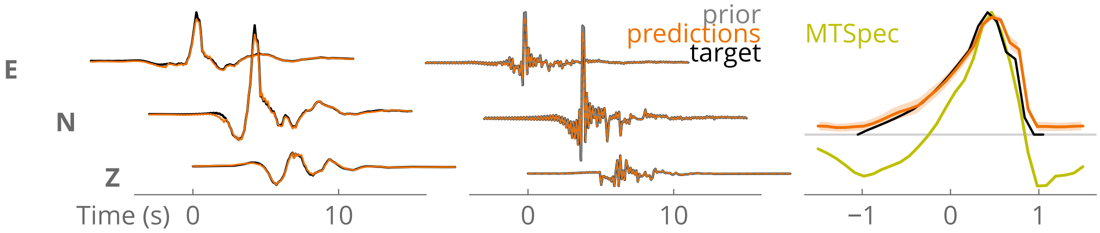


(f) Test f6

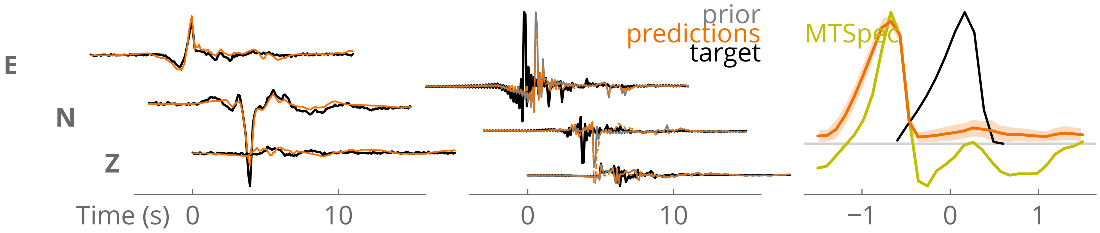
Figure S9 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **f1** to **f6**. Prior EGF is in gray, and the STF inferred with MTSpec in green.



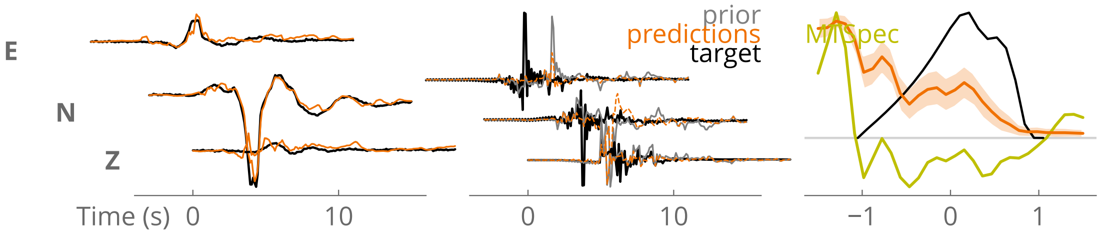
(a) Test f7



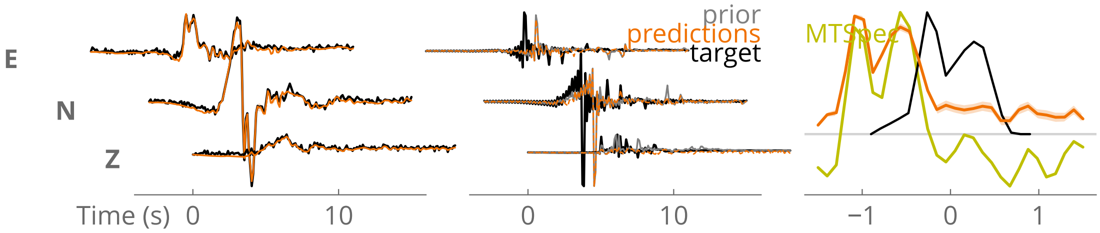
(b) Test f10



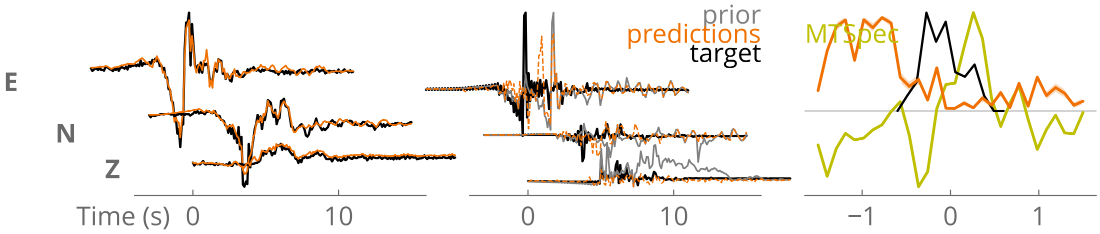
(c) Test g1



(d) Test g2

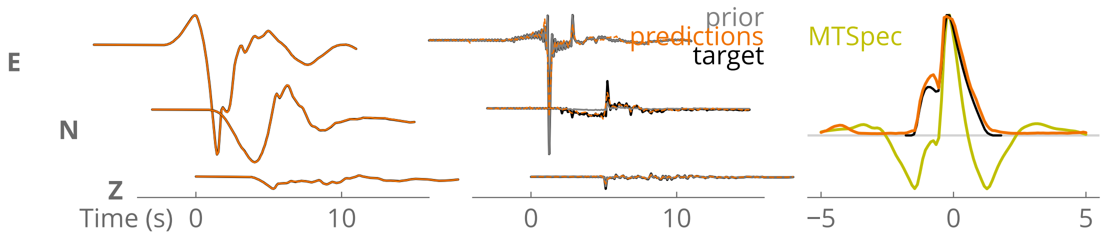


(e) Test g3

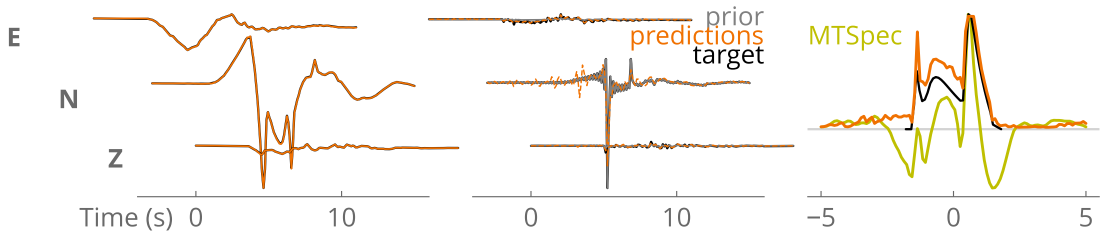


(f) Test g4

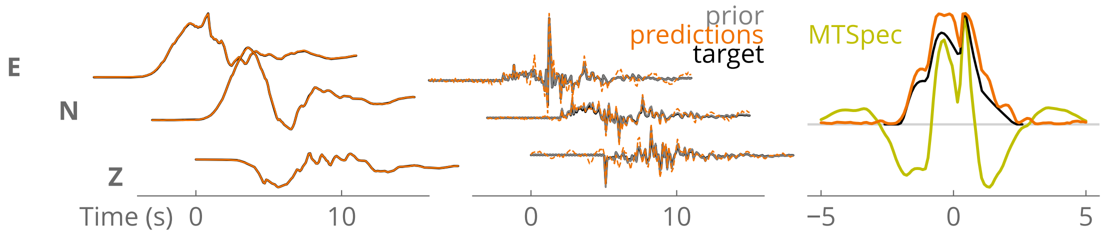
Figure S10 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **f7** to **g4**. Prior EGF is in gray, and the STF inferred with MTSpec in green.



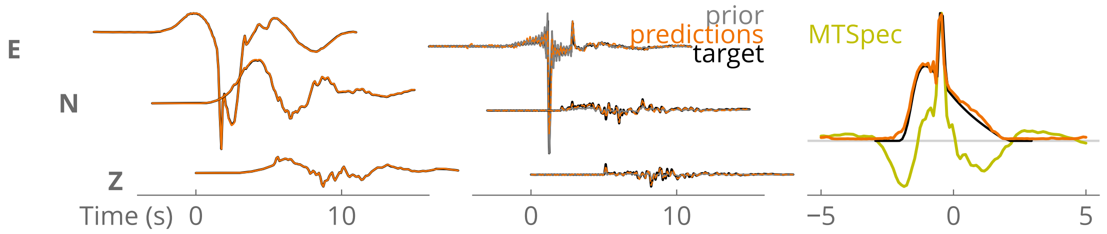
(a) Test 2a0



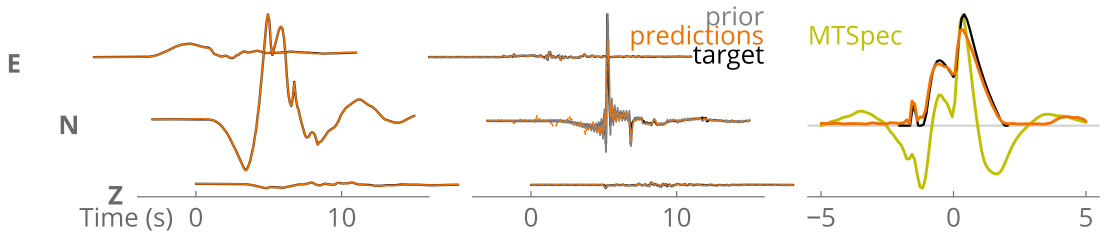
(b) Test 2a1



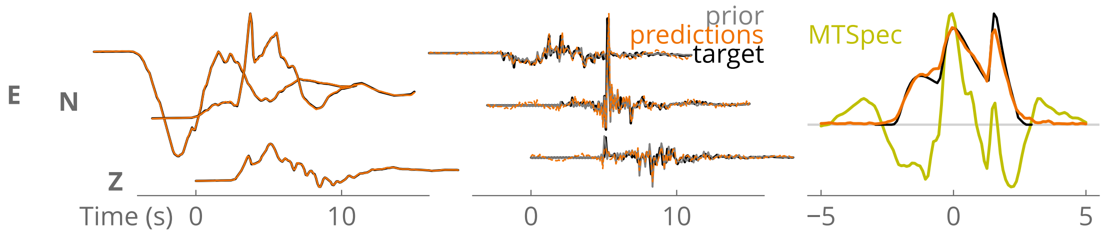
(c) Test 2a2



(d) Test 2a3

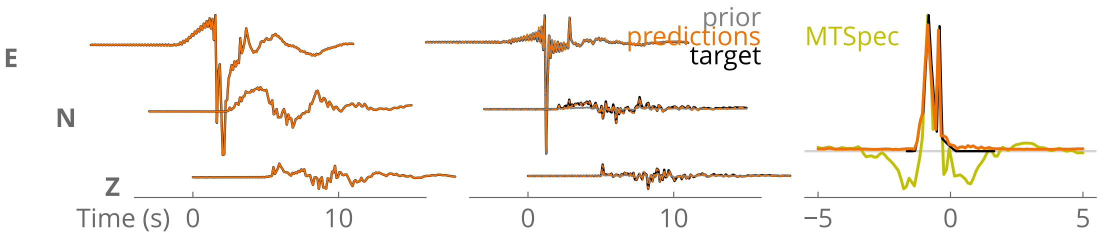


(e) Test 2a4

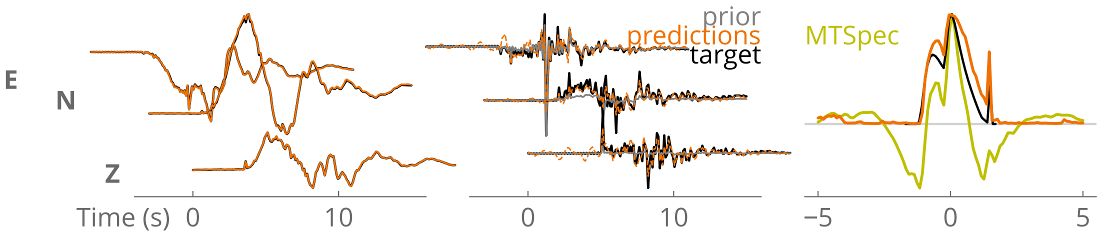


(f) Test 2a5

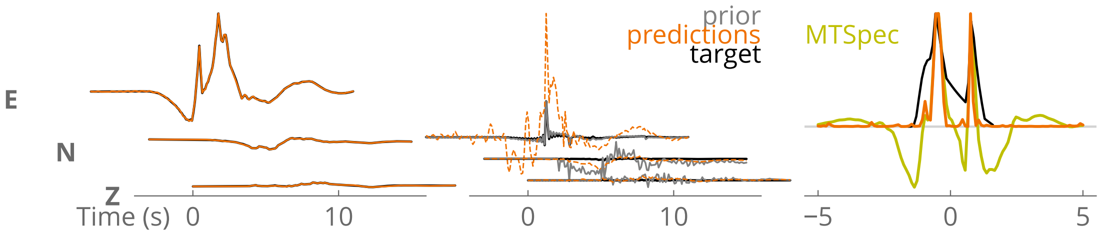
Figure S11 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **2a0** to **2a5**. Prior EGF is in gray, and the STF inferred with MTSpec in green.



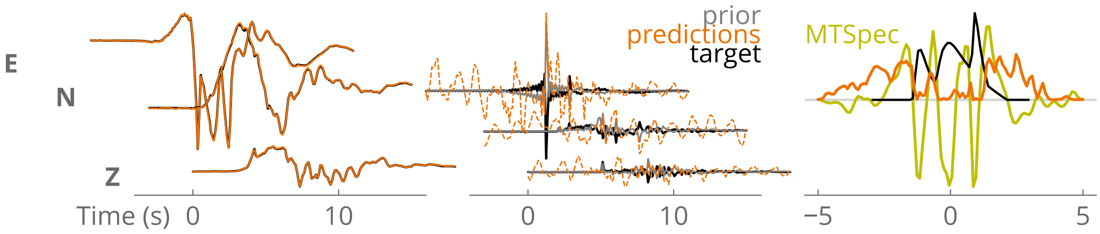
(a) Test 2b1



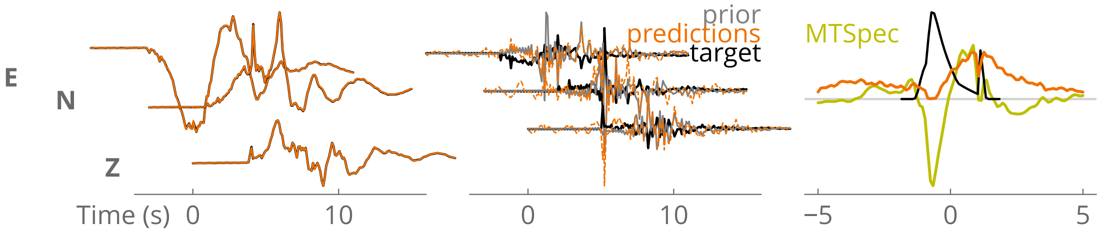
(b) Test 2b2



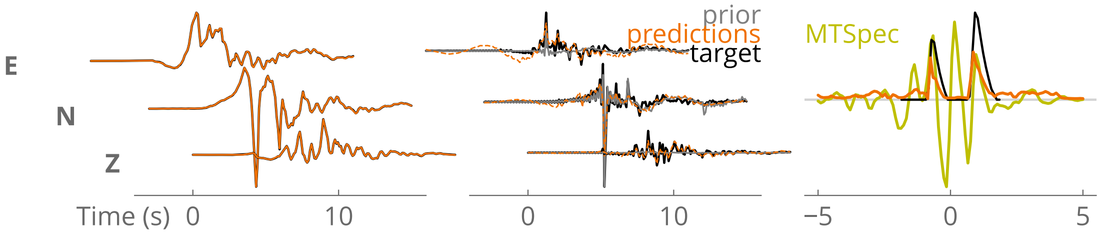
(c) Test 2b3



(d) Test 2b4

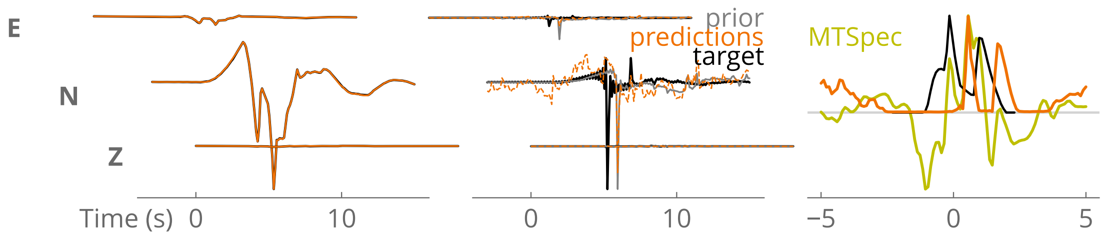


(e) Test 2b5

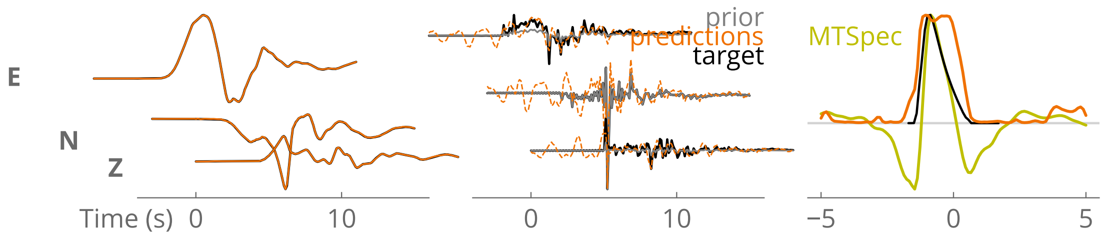


(f) Test 2b6

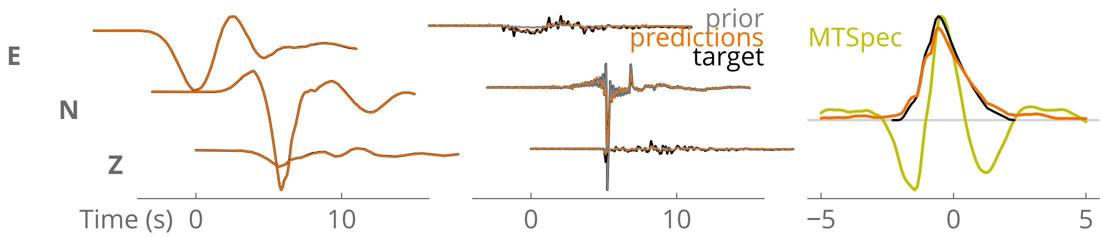
Figure S12 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **2b1** to **2b6**. Prior EGF is in gray, and the STF inferred with MTSpec in green.



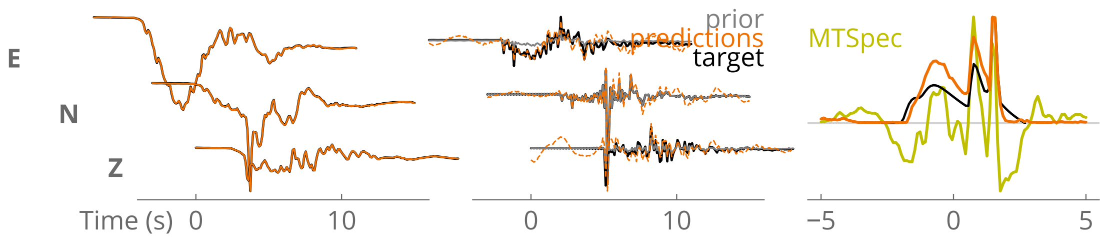
(a) Test 2c2



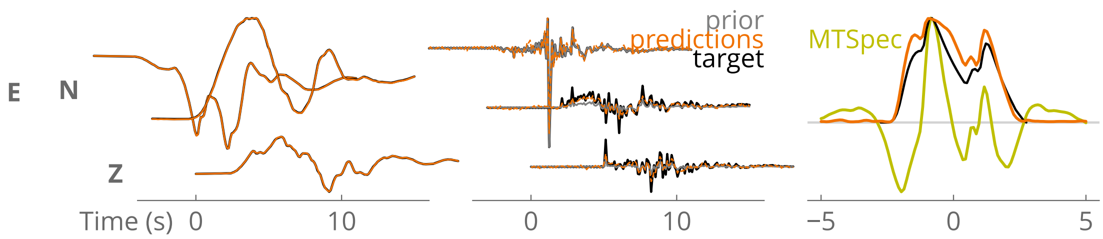
(b) Test 2e1



(c) Test 2e2

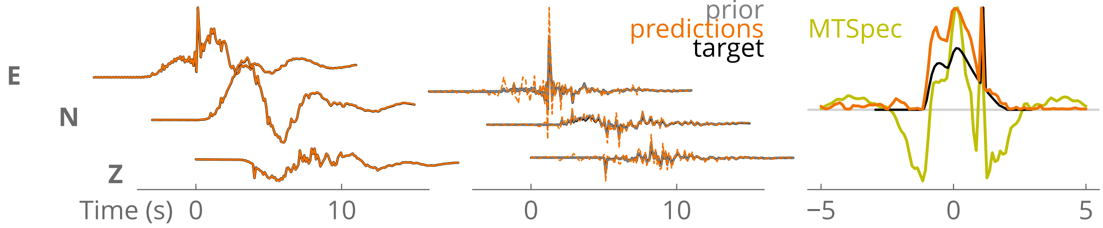


(d) Test 2e3

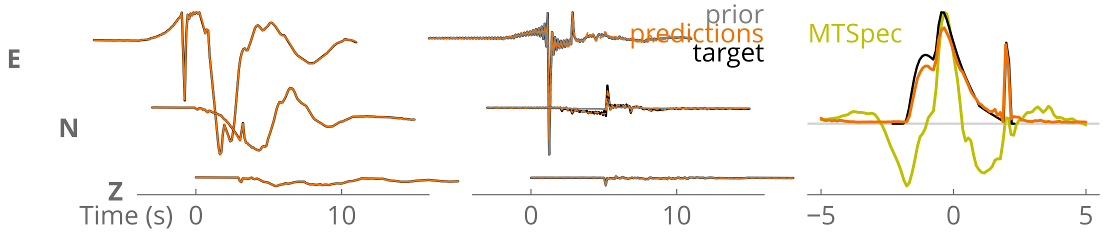


(e) Test 2e4

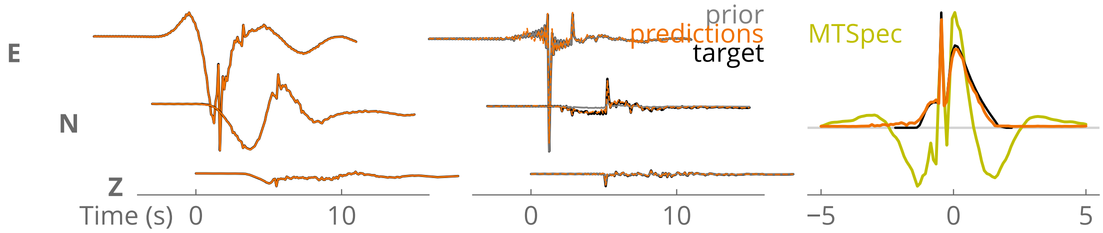
Figure S13 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **2c2** to **2e4**. Prior EGF is in gray.



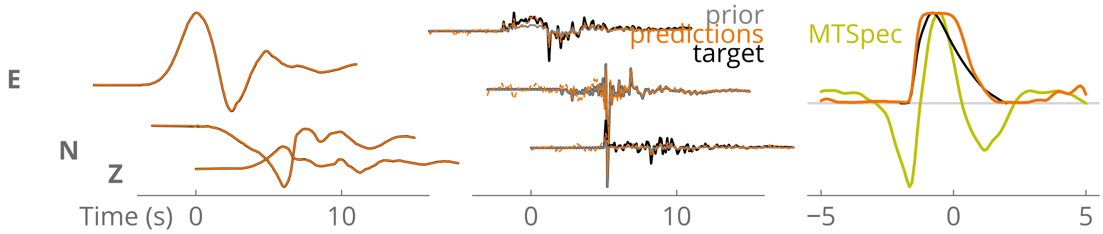
(a) Test 2f1



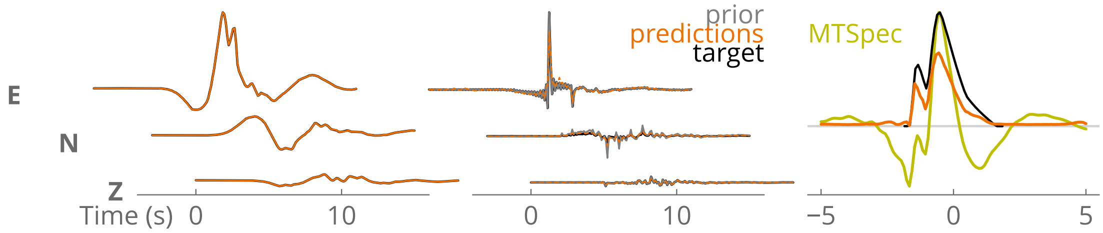
(b) Test 2f2



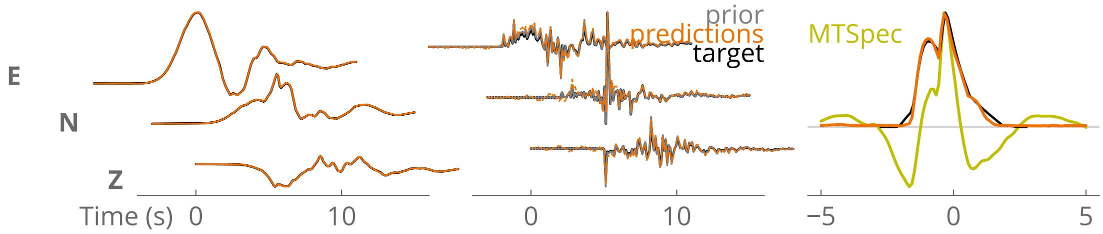
(c) Test 2f3



(d) Test 2f4

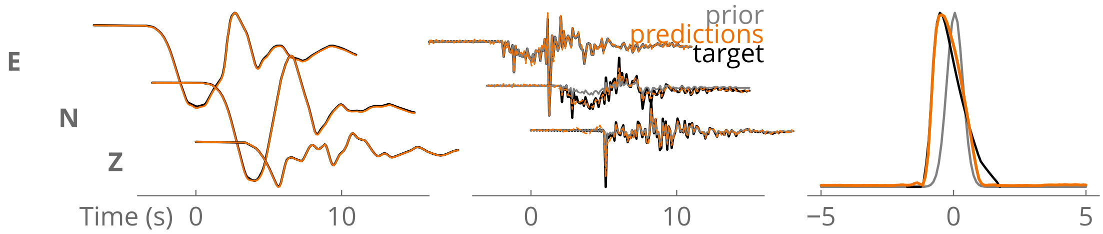


(e) Test 2f5

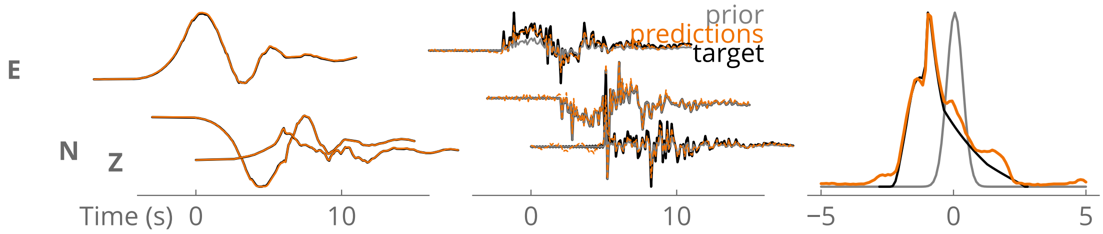


(f) Test 2f6

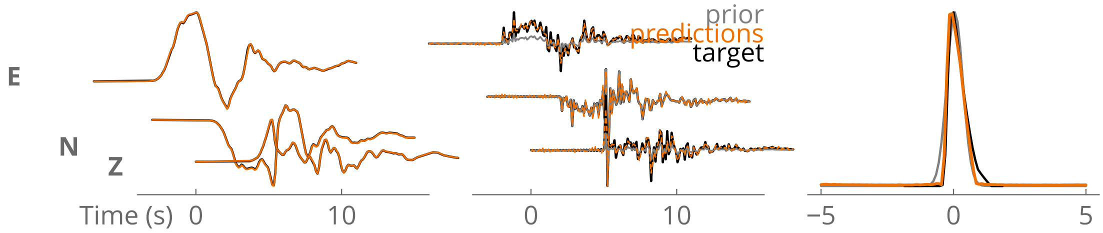
Figure S14 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **2f1** to **2f6**. Prior EGF is in gray, and the STF inferred with MTSpec in green.



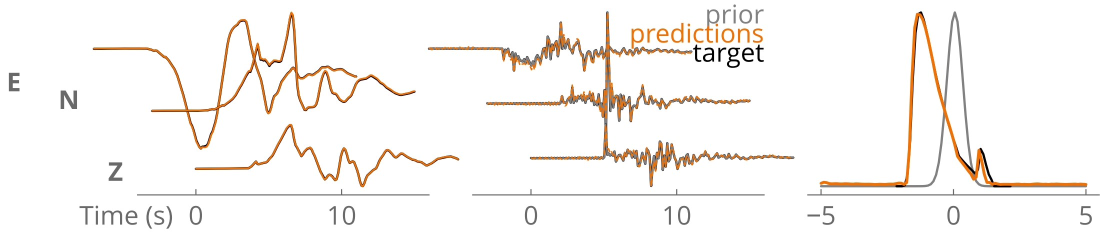
(a) Test 2f7



(b) Test 2f8

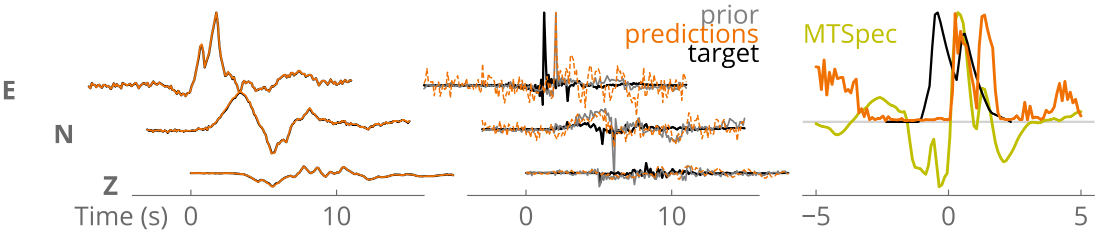


(c) Test 2f9

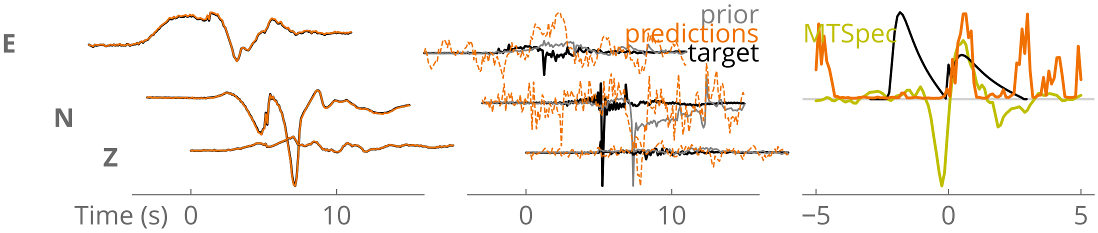


(d) Test 2f10

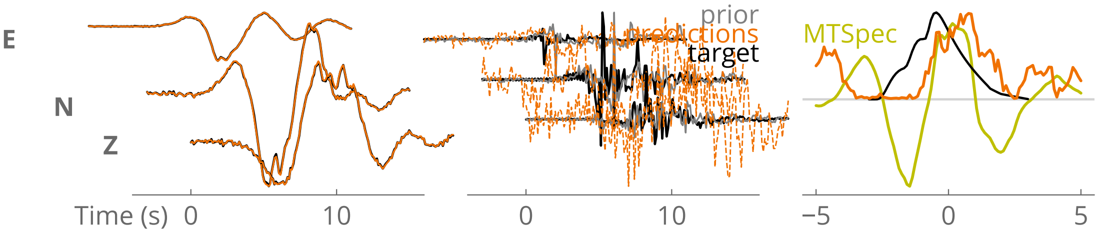
Figure S15 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **2f7** to **2f10**. Prior EGF is in gray.



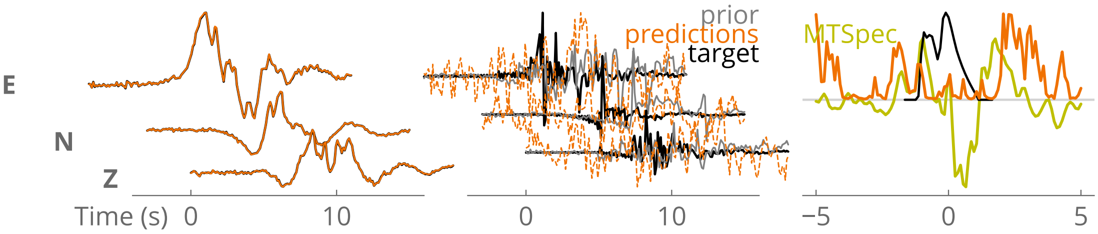
(a) Test 2g1



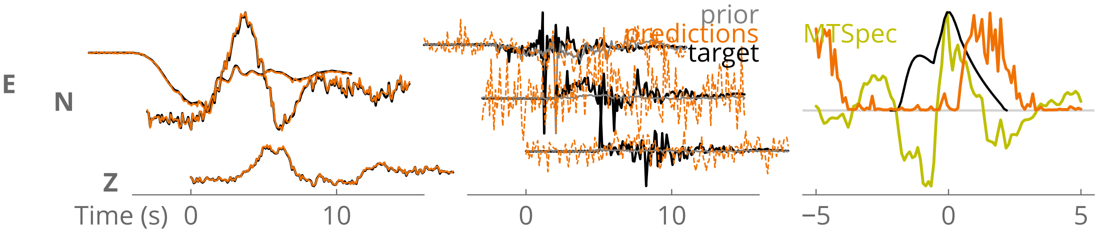
(b) Test 2g2



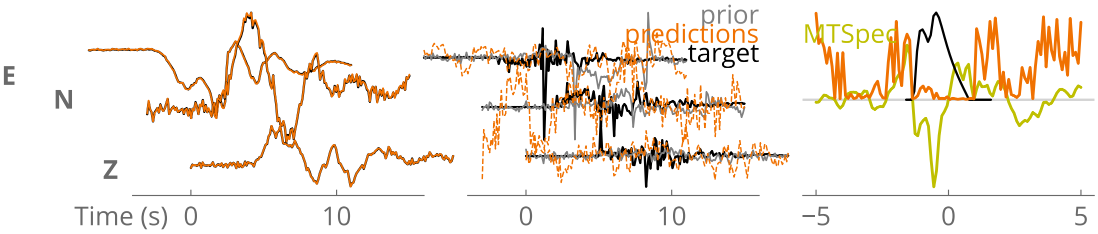
(c) Test 2g3



(d) Test 2g4

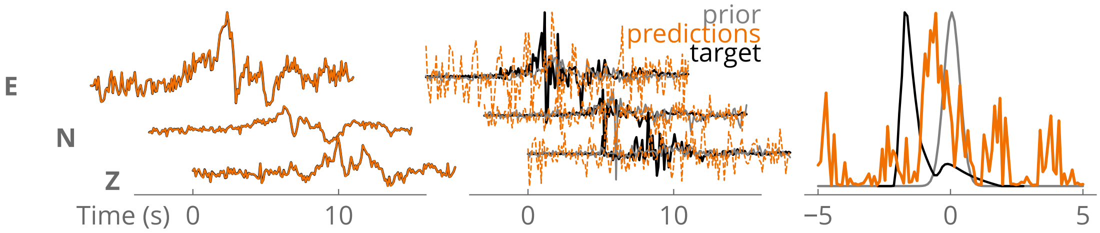


(e) Test 2g5

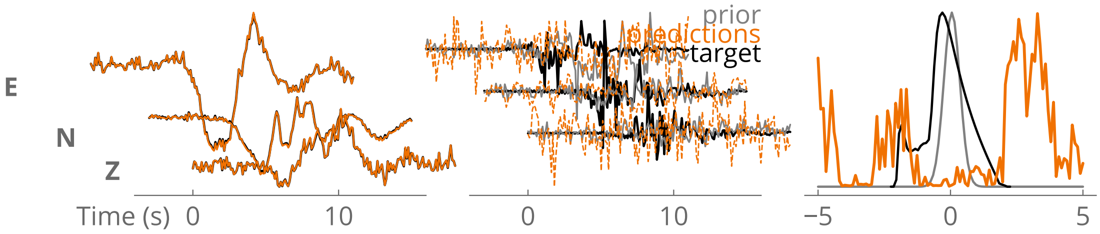


(f) Test 2g6

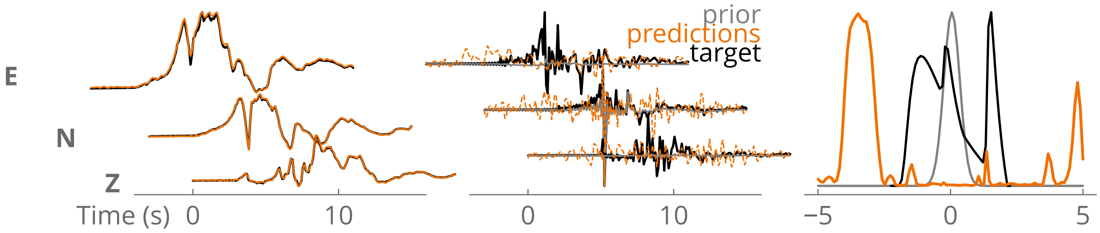
Figure S16 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **2g1** to **2g6**. Prior EGF is in gray, and the STF inferred with MTSpec in green.



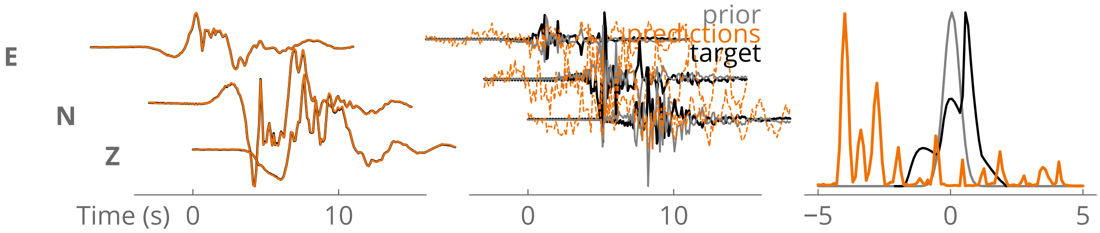
(a) Test 2g7



(b) Test 2g8



(c) Test 2b10



(d) Test 2b11

Figure S17 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for synthetic tests **2g7** to **2b11**. Prior EGF is in gray.

S3 Toy models with recorded waveforms: the 2016 Borrego Springs sequence, CA

S3.1 Data

We use seismic data recorded by the regional network (CI), plate boundary observatory (PB), ANZA network (AZ) and UCSB (SB) networks in Southern California for a ML 3.37 event that occurred on 17 July 2014 (SCSN-ID:15527617; 17 July 2014 14:24:34). We select stations within 100 km of this event, and we use both broadband and accelerometer data. We only present here a subset of the stations.

S3.2 Description of the forward model

We use the normalized waveforms of the ML 3.37 event as EGF, to which we add white noise (PSNR 3%, the noise is different for each component). To obtain the target waveforms of the main toy model event, we convolve this EGF with an STF whose characteristics are similar to the fully synthetic toy models. STFs either have $N_{STF} = 3$, $D_{STF} = 2s$ or $N_{STF} = 10$, $D_{STF} = 9s$. We add again white noise, PSNR 3%, to each of the components of the waveforms for the main toy model event.

We either use the full waveforms (both P and S arrivals, tests in Fig. S18) or the P arrivals only (tests in Figs. S19 and S20). For the later case, we trim the waveforms to just before the S waves arrivals. We use Phasenet (Zhu and Beroza, 2019) to determine phase arrivals. To decrease the computation time, we decimate the toy model waveforms (for both the EGF and main event) to 20 Hz (for broadband) or 25 Hz (for accelerometers) when using the full waveforms. We decimate the data to 40 or 50 Hz when using the P arrivals only (tests in Fig. S18).

Prior assumptions for DeepGEM

We used the following non-default parameters for DeepGEM:

```
num_epochs = 100
EMFull = True
stf_dur = 9
Elr = 8e-3
Mlr = 5e-6
data_sigma = 5e-6
```

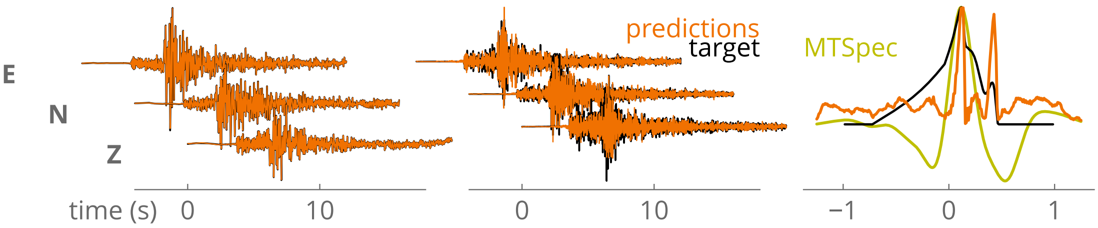
Prior assumptions for the Landweber approach

For some tests, we compare DeepGEM inferences with a frequency-domain deconvolution using the approach proposed by Bertero et al. (1997). We use the same downsampling as with DeepGEM. We first fix the duration of the STF and optimize its time shift with a least-square approach. We impose 500 iterations. We estimate apparent STFs for each component and each EGF, and then either visually select the best fitting STF.

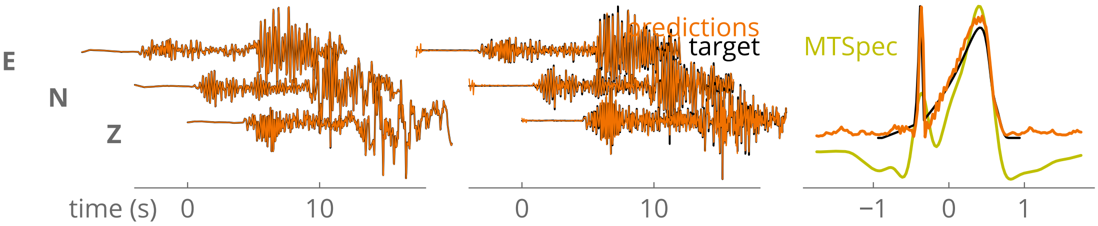
S3.3 Results

List of figures:
- Fig. S18: full waveforms, $N_{STF} = 3$
- Fig. S19, P waves arrivals, $N_{STF} = 10$
- Fig. S20, P waves arrivals, $N_{STF} = 10$

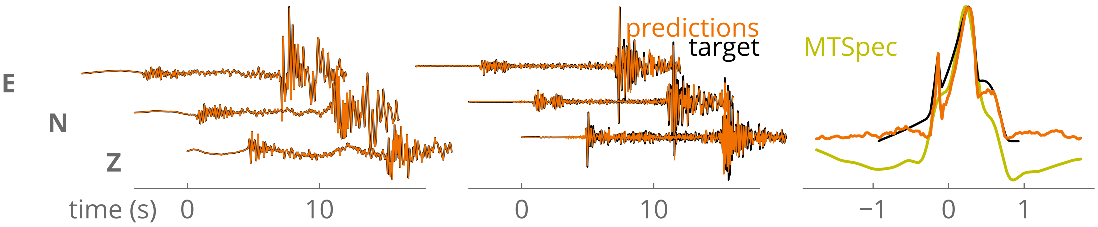
The average run time for these toy models is of 8 minutes.



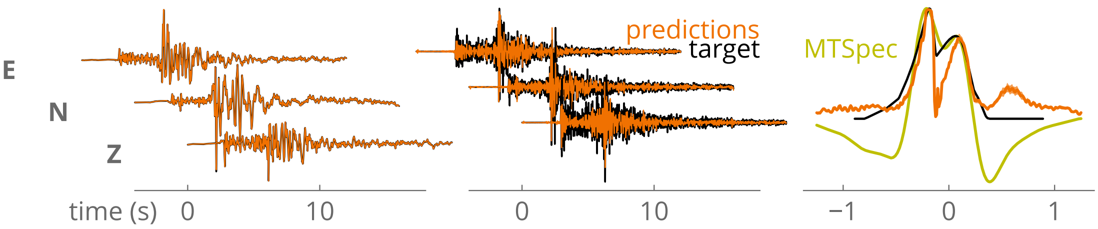
(a) Test BOR



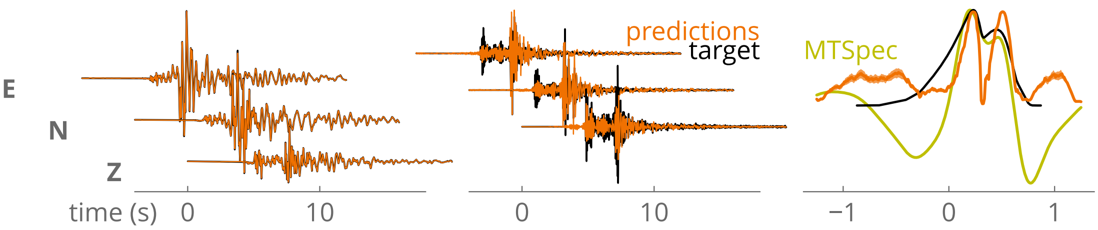
(b) Test MUR



(c) Test CPE

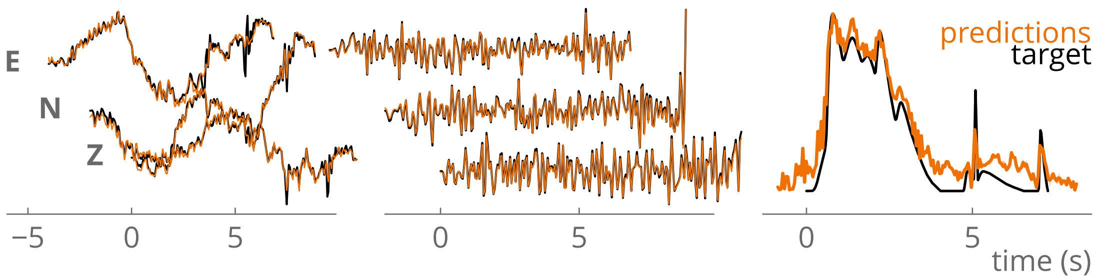


(d) Test TOR

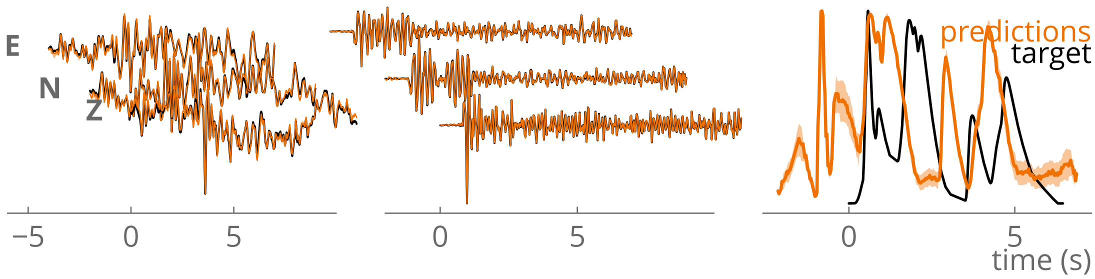


(e) Test TRO

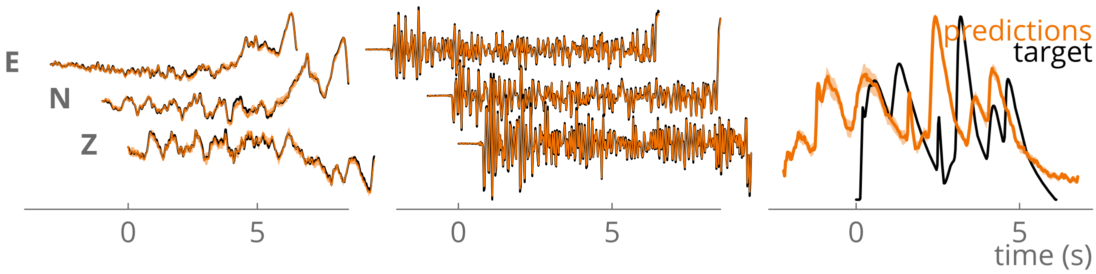
Figure S18 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for toy models designed with full waveforms for a M 3.37 event that occured in 2017 near Borrego Springs, CA.



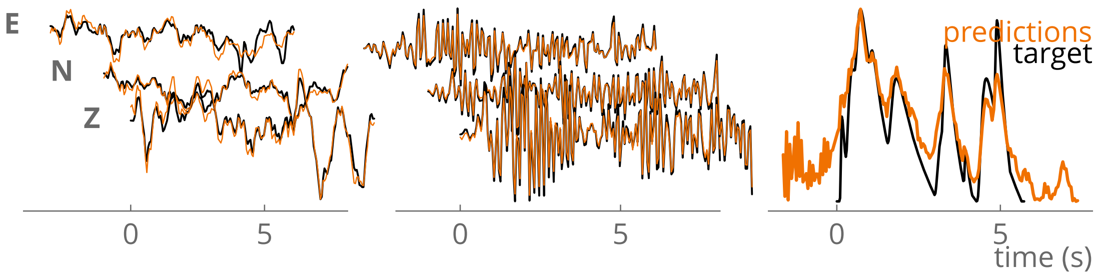
(a) Test BAR



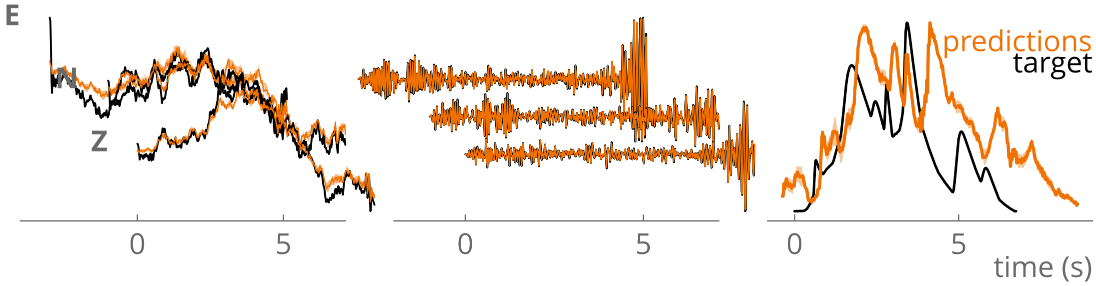
(b) Test CPE



(c) Test BLA2

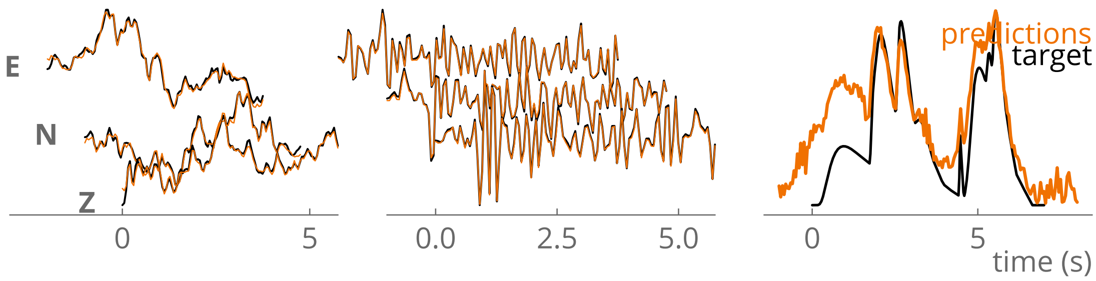


(d) Test SMER

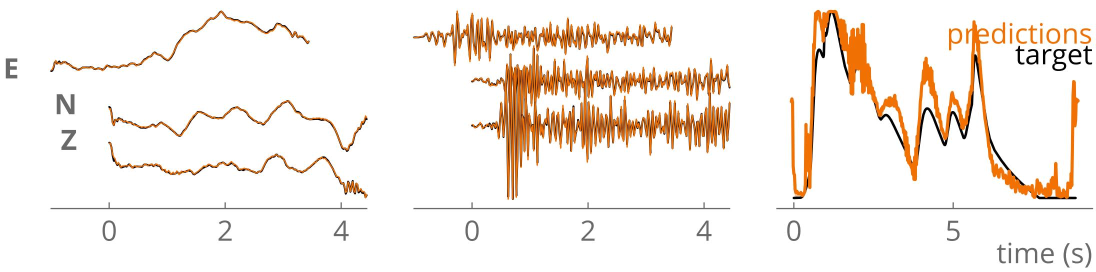


(e) Test BAC

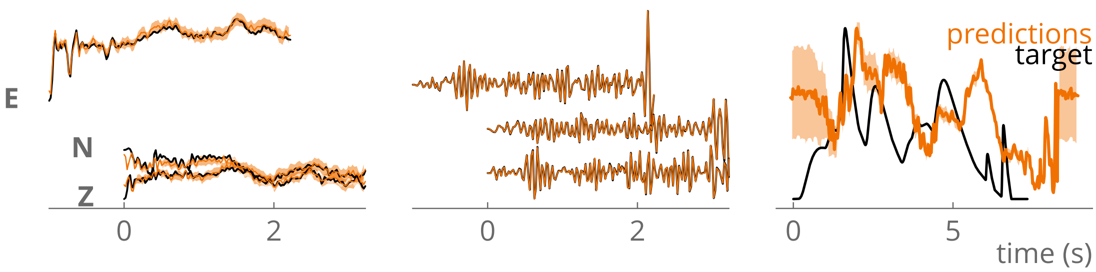
Figure S19 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for toy models shown in Figure 2, designed with P arrivals for a M 3.37 event that occured in 2017 near Borrego Springs, CA.



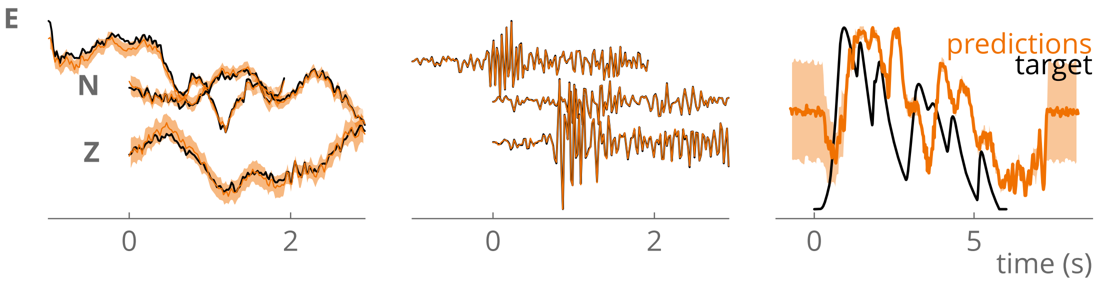
(a) Test KNW



(b) Test CRY



(c) Test BOR



(d) Test TRO

Figure S20 Inferred (orange) and target (black) waveforms (left), EGF (middle) and STF (right) for toy models shown in Figure 2, designed with P arrivals for a M 3.37 event that occured in 2017 near Borrego Springs, CA.

S4 Case study: the 2019 Cahuilla swarm, CA

S4.1 Data

We use broadband seismic data recorded by the regional network (CI), plate boundary observatory (PB), ANZA network (AZ) and UCSB (SB) networks in Southern California for the 2018 Mw 4.41 mainshock (SCSN-ID:38245496; August 15, 2018, 01:24:26) and several M∼2-2.5 events that occurred during the Cahuilla swarm (Ross et al., 2020). We use stations located within 100 km of the mainshock. Stations locations are shown in Figs 2 and 4 of the main text. We either use the full waveforms (both P and S arrivals), the P arrivals only, or the S arrivals. For the later cases, we trim the waveforms to just before the S waves arrivals. We use Phasenet (Zhu and Beroza, 2019) to determine phase arrivals. To decrease computation time, we decimate the waveforms to 20 Hz.

The selection of prior EGFs is described separately for the toy models and results.

Table S9 Four potential EGFs selected for the Cahuilla case study.

event ID	date	Mw	Relocated distance to mainshock (km)
38050943	2018-09-07	2.44	0.306
38242792	2018-08-11	2.33	0.307
38245688	2018-08-15	2.11	0.347
38038871	2018-08-29	2.05	0.354

S4.2 Toy models with recorded waveforms

Description of the forward model

We select prior EGFs, with a $2 <$Mw< 2.5, from their distance to the mainshock (Table S9), based on the relocated catalog from Ross et al. (2020). We only use stations which recorded the 4 (or 3) selected EGFs.

Target EGFs are calculated as a weighted sum of the normalized waveforms recorded for three or four of M∼2 events, to which we add white noise with a PSNR of 3%. To obtain the target waveforms of the main toy model event, we convolve the target EGFs with a randomly calculated STF. The STF is a stack of N_{STF} (3 or 10) Gaussian STFs, each of the Gaussian STFs being characterized by a random risetime, a random amplitude, and a random padding, while the total duration D_{STF} ranges from 5 to 7 s. We add again white noise with a PSNR of 3% to each of the components of the waveforms for the main toy model event.

We design two series of tests. In the first one (Table S10), the target EGF consists in a sum of three M∼2 events (event ID:37195604 discarded), while the STF has $N_{STF} = 3$ and $D_{STF} = 5$s. The full waveforms are used. We also compute frequency-domain deconvolution for each prior EGF. Results are compiled in Fig. S21 and plotted below for each test.

In the second serie of tests (Table S11), whose results are displayed in the main text in Fig. 3, the target EGF consists of a sum of the four M∼2 events, and the STF has $N_{STF} = 10$ and $D_{STF} = 7$s. We only use the P-wave arrivals. Results are plotted below for each test. Additionally, we also perform two tests with 8 EGFs for station TOR. In one case, the additional four waveforms are weighted sums of the initial four prior EGFs (Figs. S38 and S40), and in another the additional four waveforms are the target ones with 10% of random weighted sum (Fig. S39).

Prior assumptions for DeepGEM

In this case, we use multiple prior EGFs. The prior EGFs are the ones used for calculation of the synthetic Green's functions. The waveforms are normalized and we only solve for the shape of the STF, not its amplitude.

We used the following non-default parameters for DeepGEM:

```
num_epochs = 150
EMFull = False
stf_dur = 9
Elr = 1e-3
Mlr = 1e-4
stf_init_weight = 1e0
data_sigma = 5e-6
```

Table S10 Weights (α) used for toy models using a weighted sum of 3 EGFs. For those, the STF is characterized by $N_{STF} = 3$ and $D_{STF} = 5$s.

name	station	α1, ID:38194264	α2, ID:37949151	α3, ID:Z38242792
CSH	CSH	0.1	0.3	0.6
DGR	DGR	0.8	0.1	0.1
PALA	PALA	0.3	0.3	0.4
PLM	PLM	0.6	0.3	0.1
POB2	POB2	0.5	0.4	0.1
CSH_2_2	CSH	0.8	0.1	0.1
DGR_2_2	DGR	0.3	0.3	0.4
PALA_2	PALA	0.6	0.3	0.1
PLM_2	PLM	0.5	0.4	0.1
POB2_2_2	POB2	0.1	0.3	0.6
CSH_3	CSH	0.4	0.35	0.25
PLM_3	PLM	0.35	0.4	0.25

Table S11 Weights (α) used for toy models using a weighted sum of 4 EGFs, shown in Fig. 3. For those, the STF is characterized by $N_{STF} = 10$ and $D_{STF} = 7$s. We only use the P-wave arrivals.

name	station	α0, ID:37195604	α1, ID:38194264	α2, ID:37949151	α3, ID:38242792
CTW	CTW	0.37335196	0.33257028	0.1458018	0.14827596
TOR	TOR	0.77052845	0.05954214	0.08736548	0.08256393
PSD	PSD	0.50688547	0.05116649	0.29047711	0.15147093
LMH	LMH	0.45428515	0.26398319	0.04305582	0.23867585

Results

List of figures:
First set of tests (Table S10), STF with $N_{STF} = 3$:
- Fig. S22
- Fig. S23
- Fig. S24
- Fig. S25
- Fig. S26
- Fig. S27
- Fig. S28
- Fig. S29
- Fig. S30
- Fig. S31
- Fig. S32
- Fig. S33

Second set of tests (Table S11), STF with $N_{STF} = 10$:
- Fig. S34
- Fig. S35
- Fig. S36
- Fig. S37
- Fig. S38 station TOR, test A with 4 EGFs (to compare with tests B and C at same station)
- Fig. S40 station TOR, test B with 8 EGFs, 4 additional EGFS are random
- Fig. S39 station TOR, test C with 8 EGFs, 4 additional EGFS are close to target

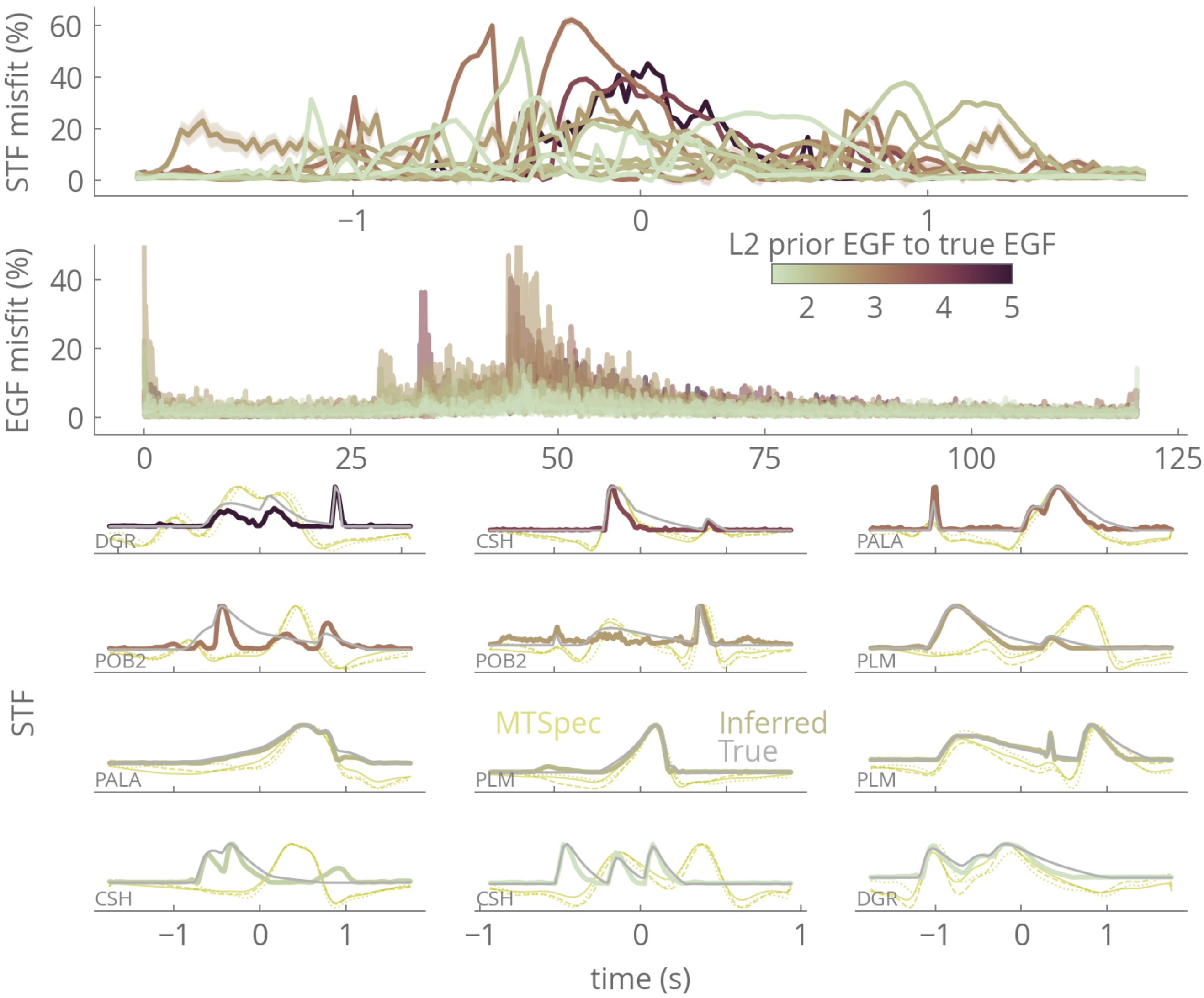


Figure S21 Goodness of fit for the STFs and EGFs for synthetic tests designed for the Cahuilla case study. (first row) Misfit (in % of amplitude) against time (s) between the inferred STF and the true STF used for calculation of the waveforms of reference. The misfit is color-coded from the average distance between the prior EGF and the true Green's function used for calculation of the waveforms of reference. (second row) Misfit (in % of amplitude) against time (s) between the best inferred EGF and the true GF used for calculation of the waveforms of reference. (bottom) True (gray), inferred STF (color), and STFs inferred with MTSpec (green). The name of the station is shown in gray.

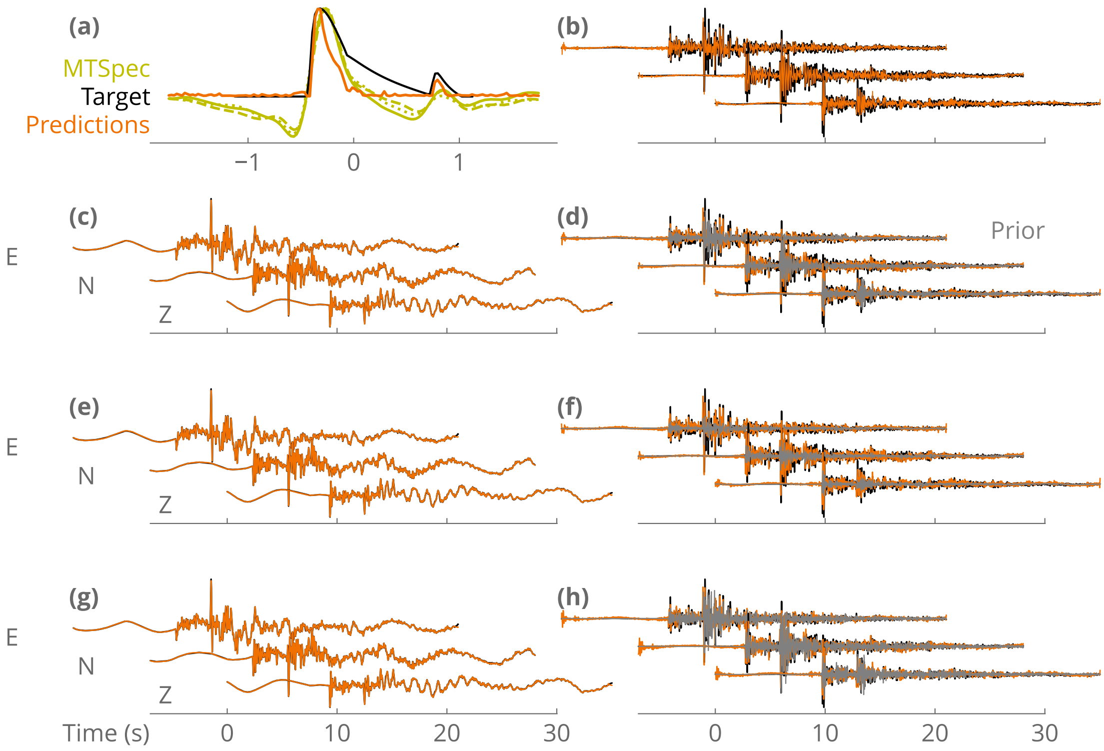


Figure S22 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **CSH** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

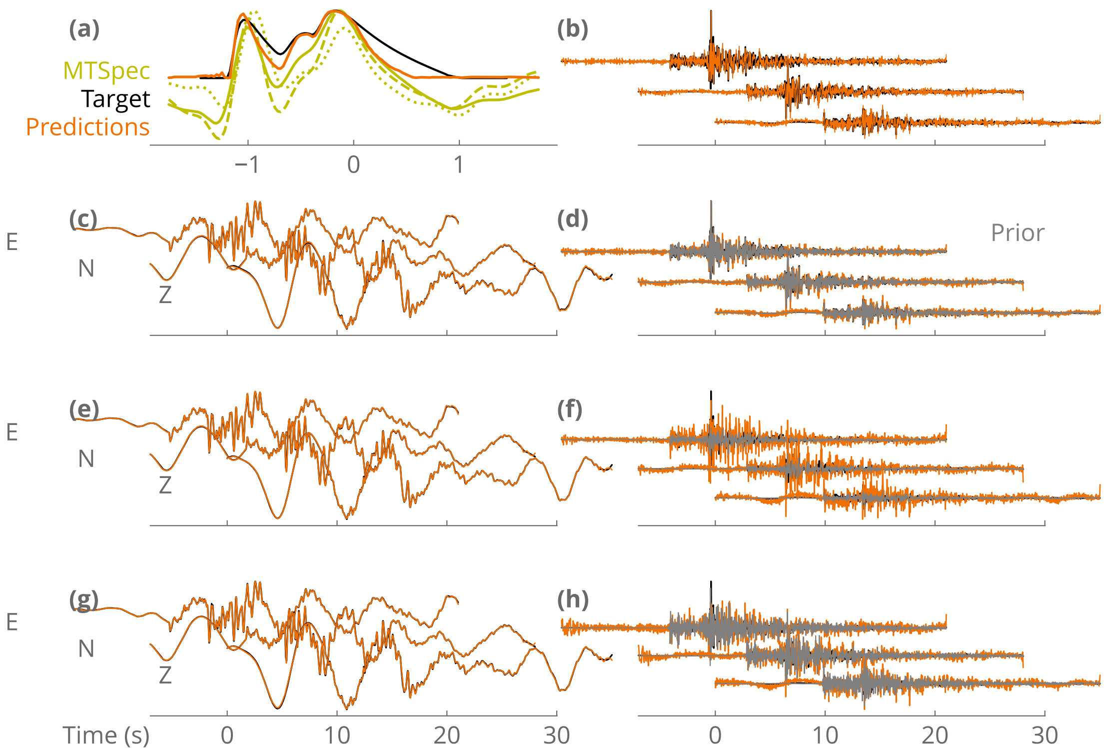


Figure S23 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **DGR** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

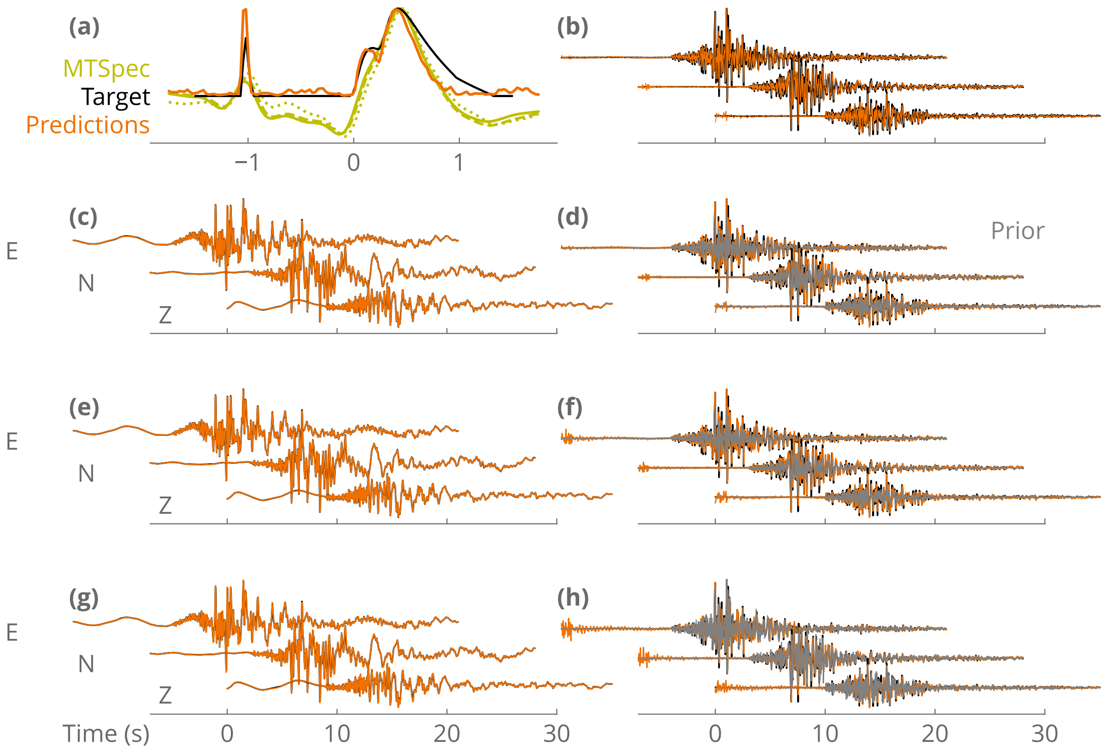


Figure S24 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **PALA** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

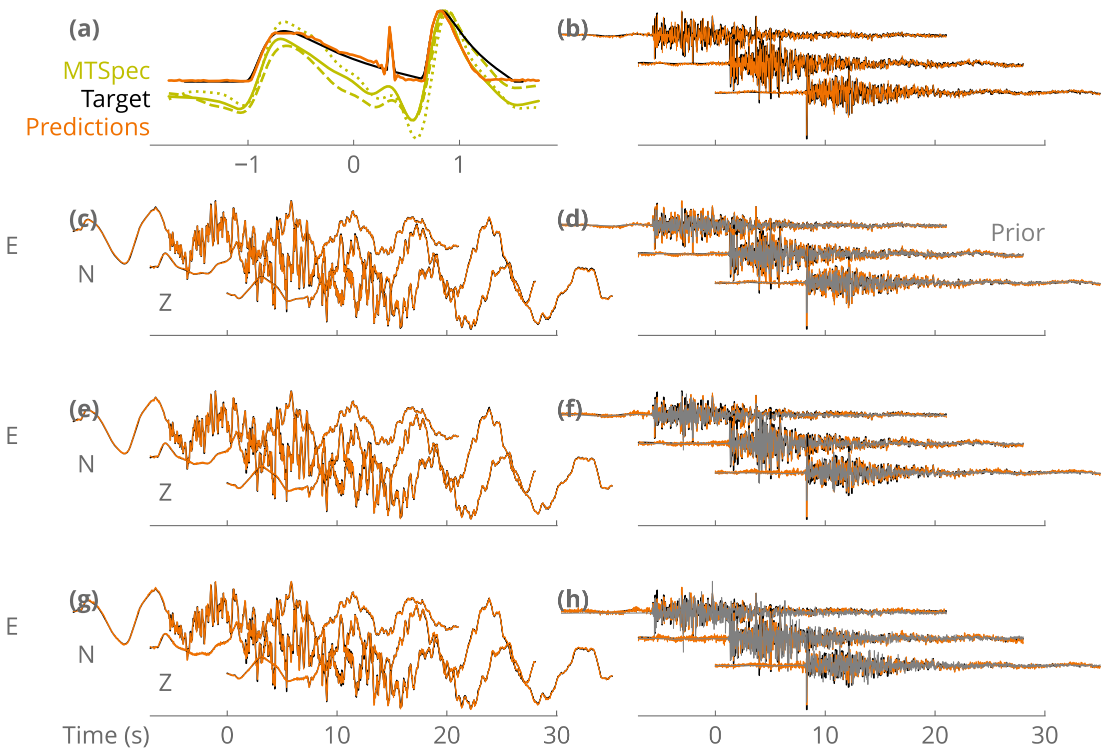


Figure S25 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **PLM** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

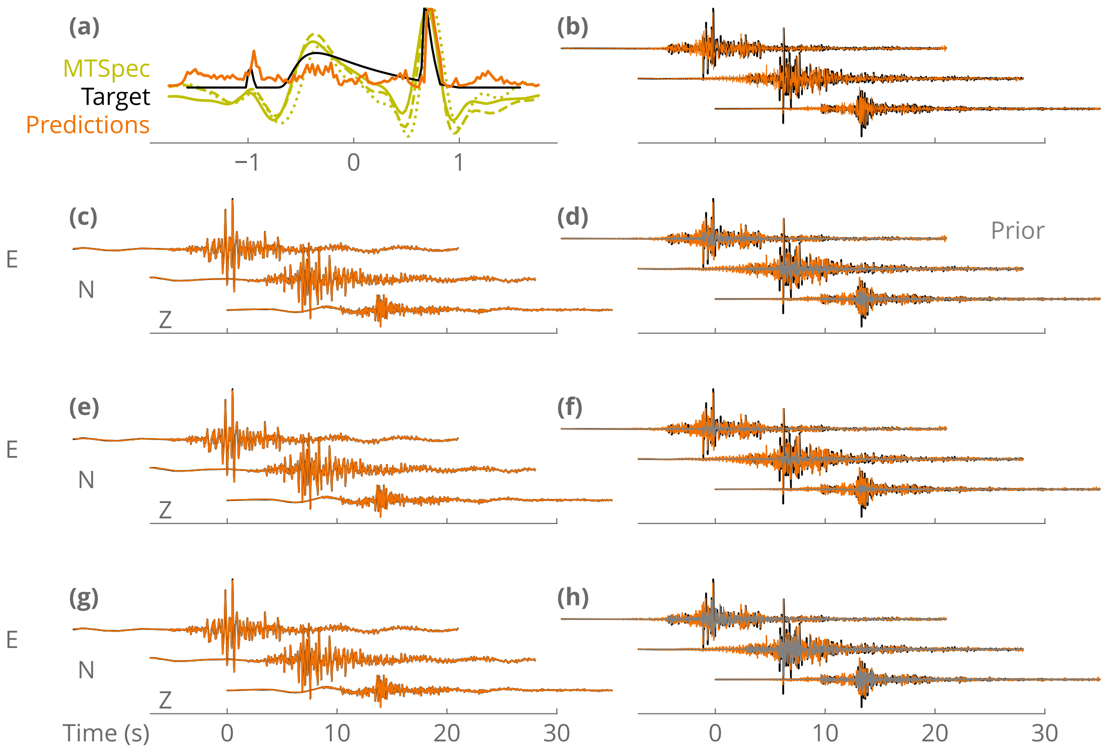


Figure S26 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **POB2** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

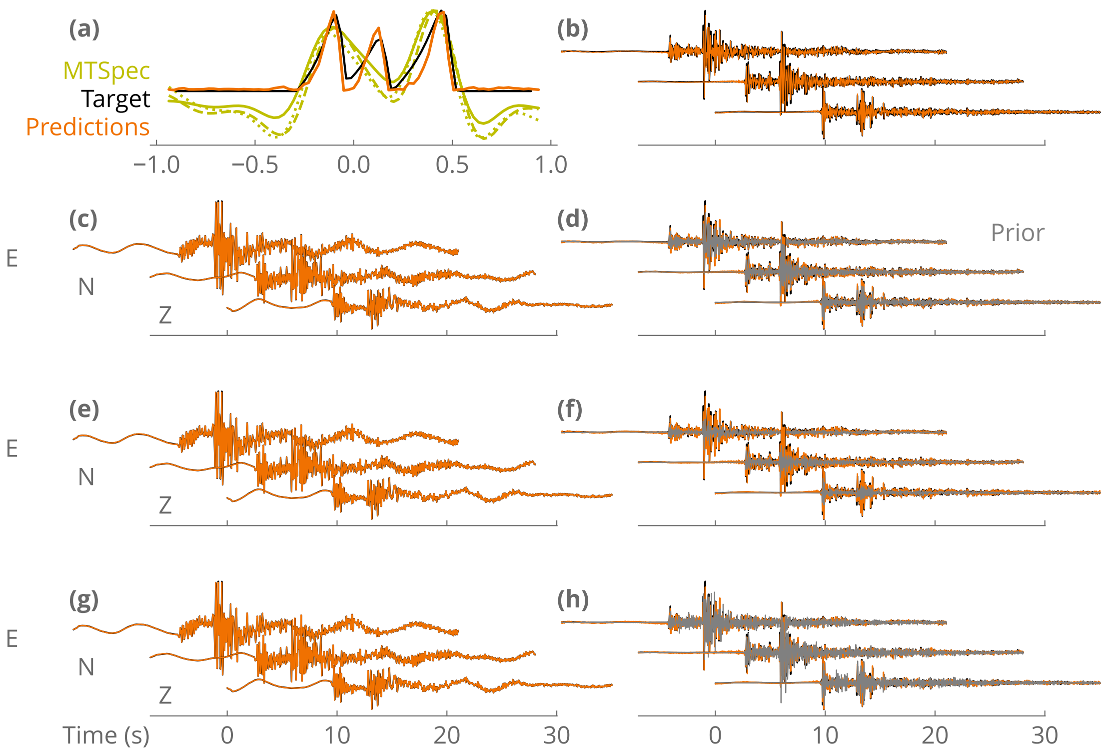


Figure S27 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **CSH_2_2** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

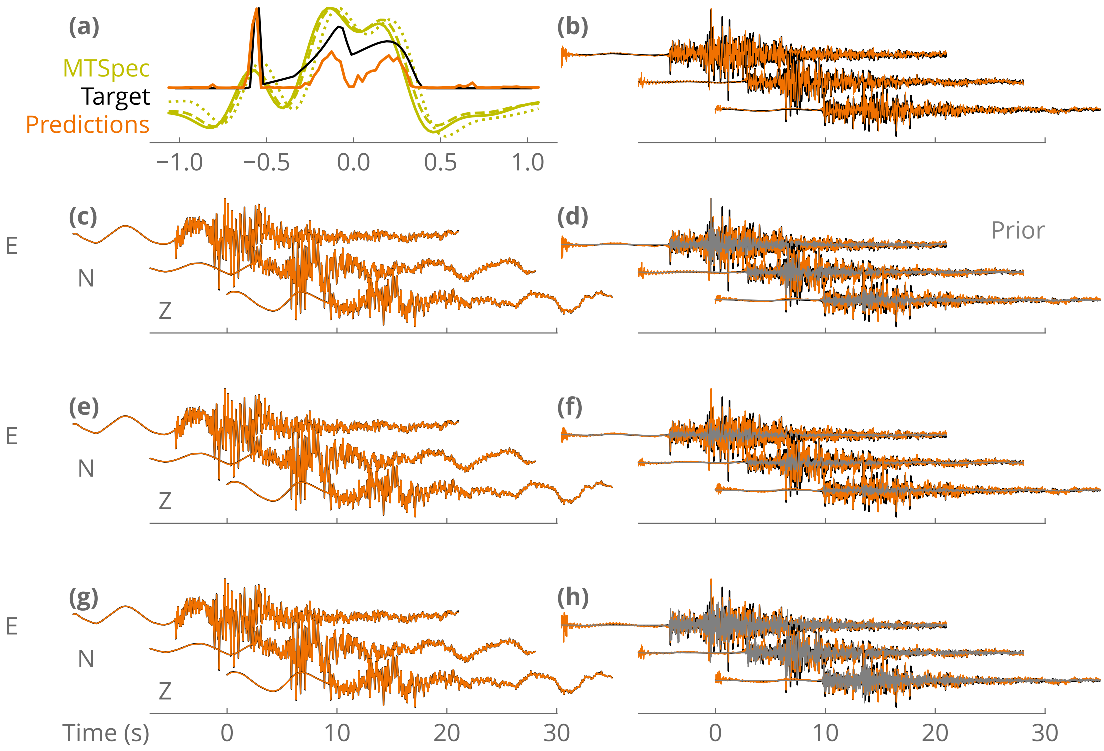


Figure S28 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **DGR_2_2** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

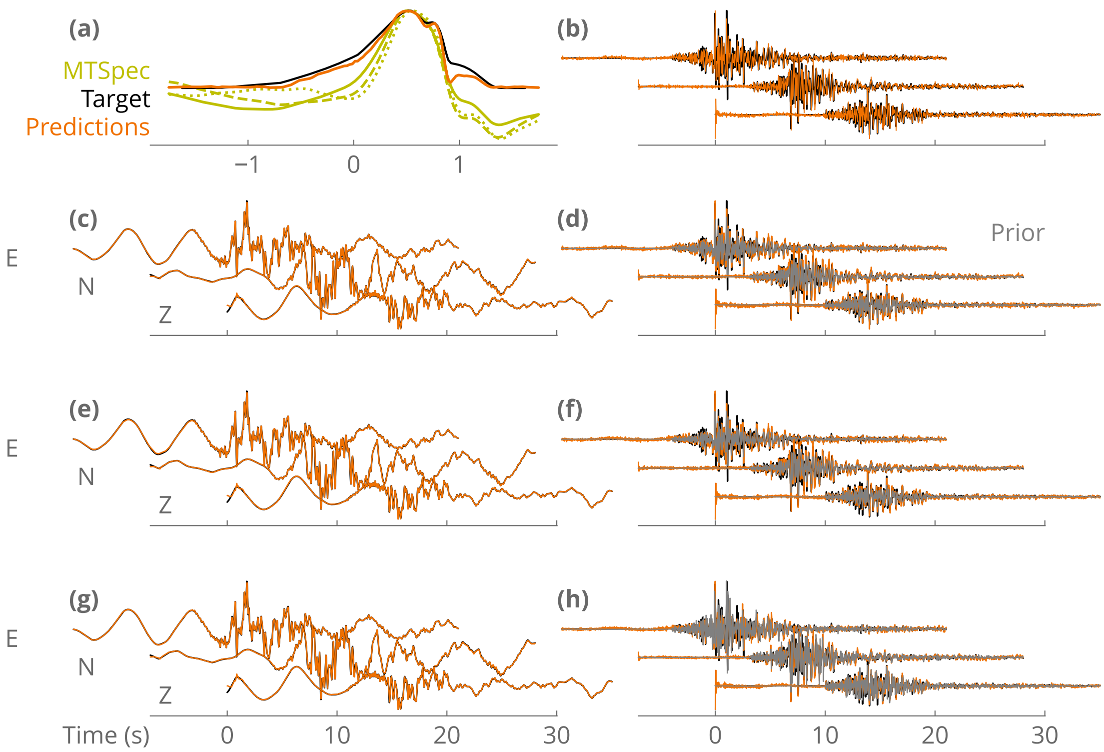


Figure S29 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **PALA_2** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

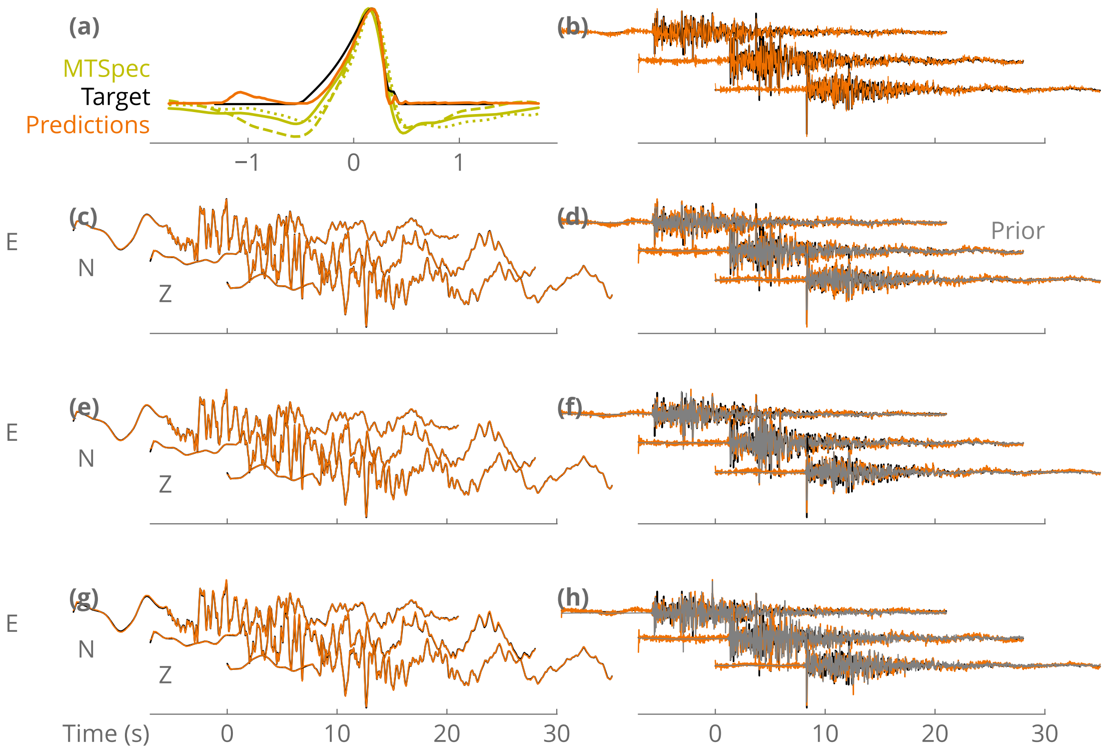


Figure S30 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **PLM_2** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

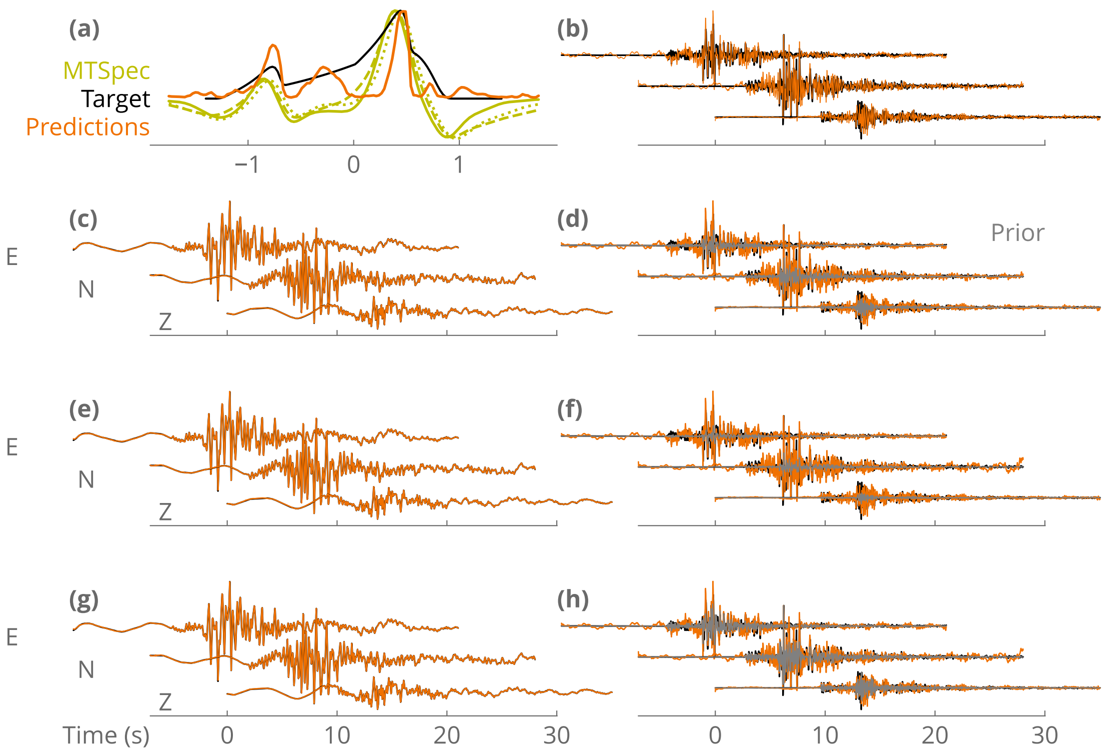


Figure S31 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **POB2_2_2** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

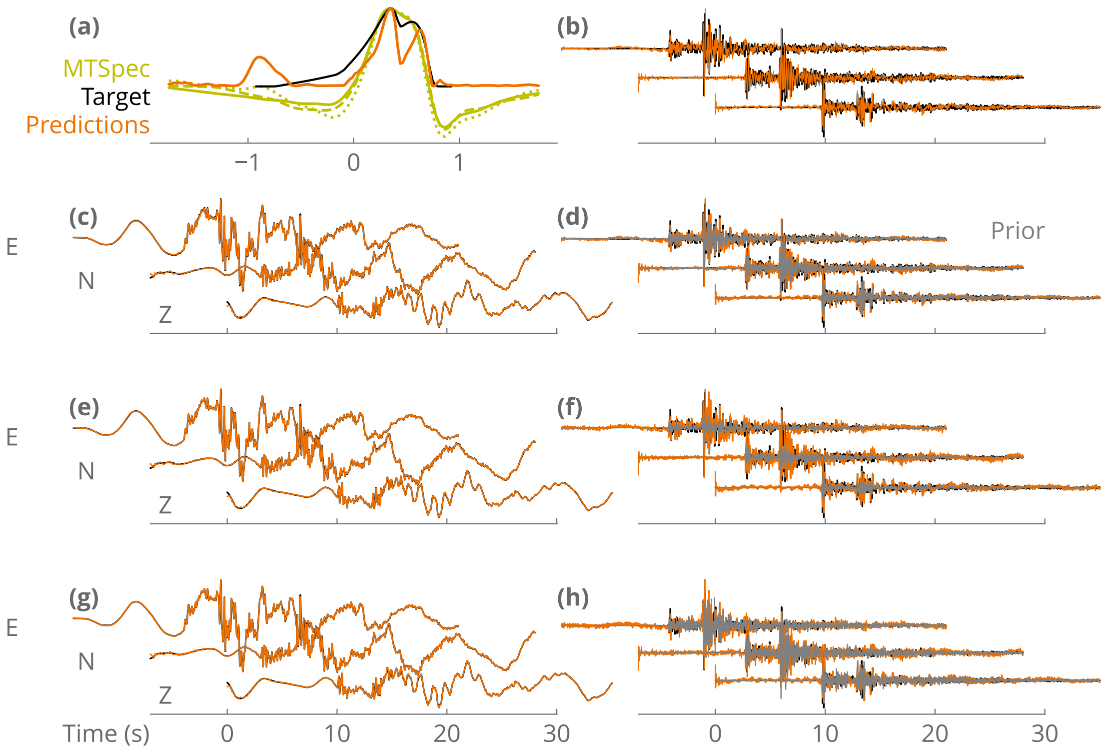


Figure S32 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **CSH_3** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

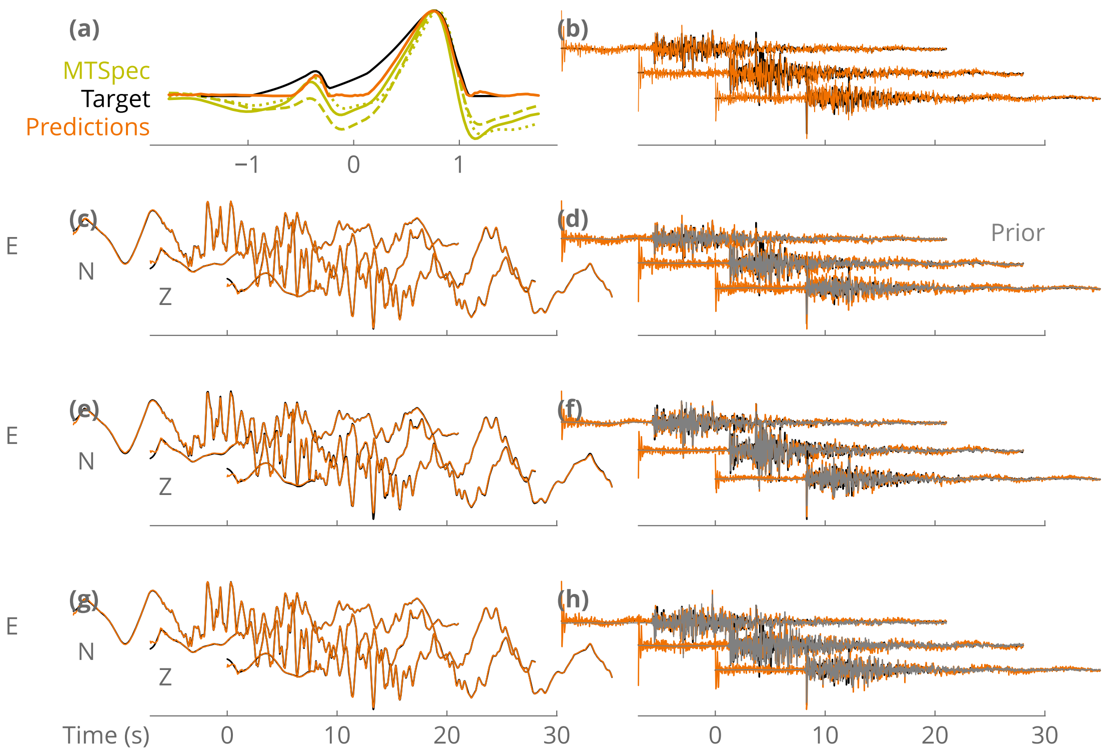


Figure S33 Inferred (orange) and target (black) STFs (a) and best inferred EGF (b) for toy model **PLM_3** whose characteristics are summarized in Table S10. In (d,f,h) and (c,e,g) are shown the prior (gray), inferred and target EGFs and waveforms for the main toy model event. In (a) the STF estimated in the frequency-domain is shown in green.

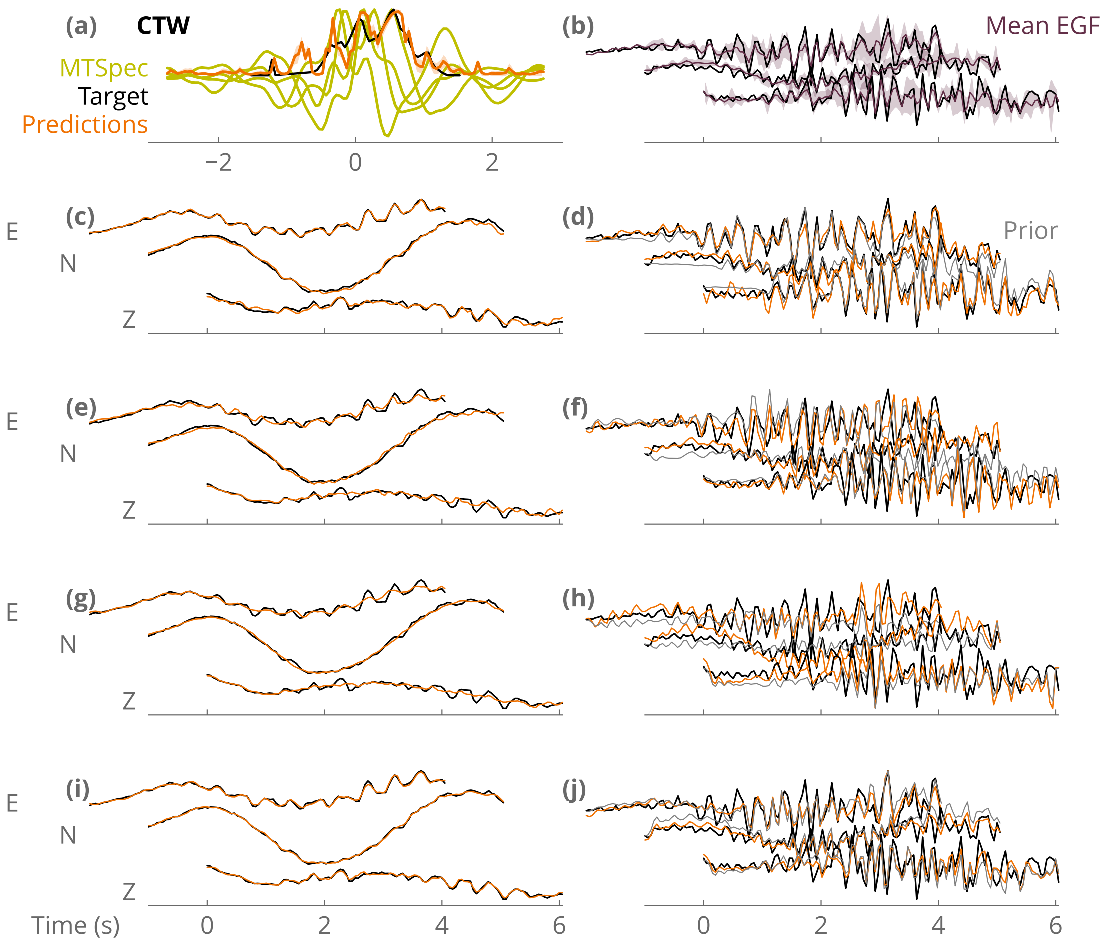


Figure S34 Inferred (orange) and target (black) STFs (a), EGFs (b,d,f,h,j) and waveforms of the main event (c,e,g,i) for toy model **CTW** whose characteristics are summarized in Table S11. In (a) the STFs estimated in the frequency-domain, assuming each EGF separately, are shown in green. In (b) the mean EGF and its standard deviation are in purple. In (d,f,h,j) the prior EGF is in gray.

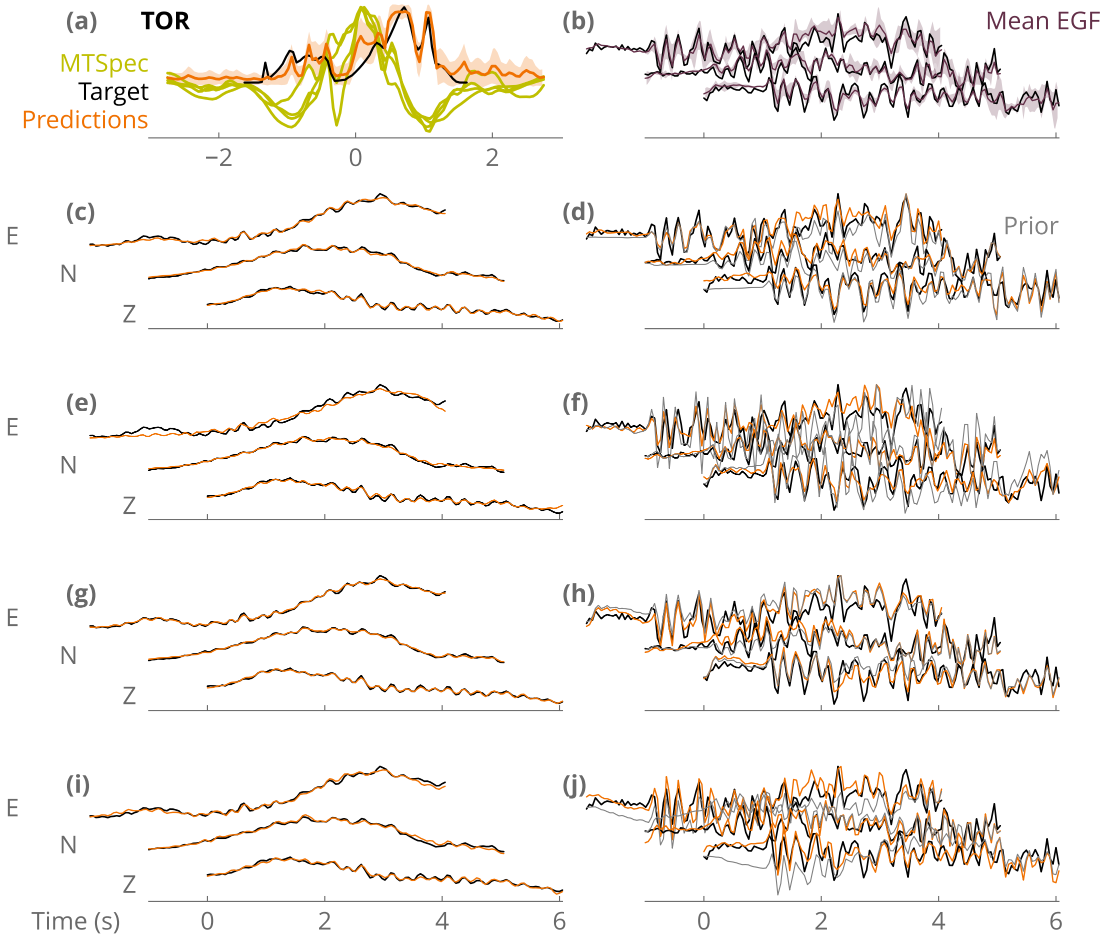


Figure S35 Inferred (orange) and target (black) STFs (a), EGFs (b,d,f,h,j) and waveforms of the main event (c,e,g,i) for toy model **TOR** whose characteristics are summarized in Table S11. In (a) the STFs estimated in the frequency-domain, assuming each EGF separately, are shown in green. In (b) the mean EGF and its standard deviation are in purple. In (d,f,h,j) the prior EGF is in gray.

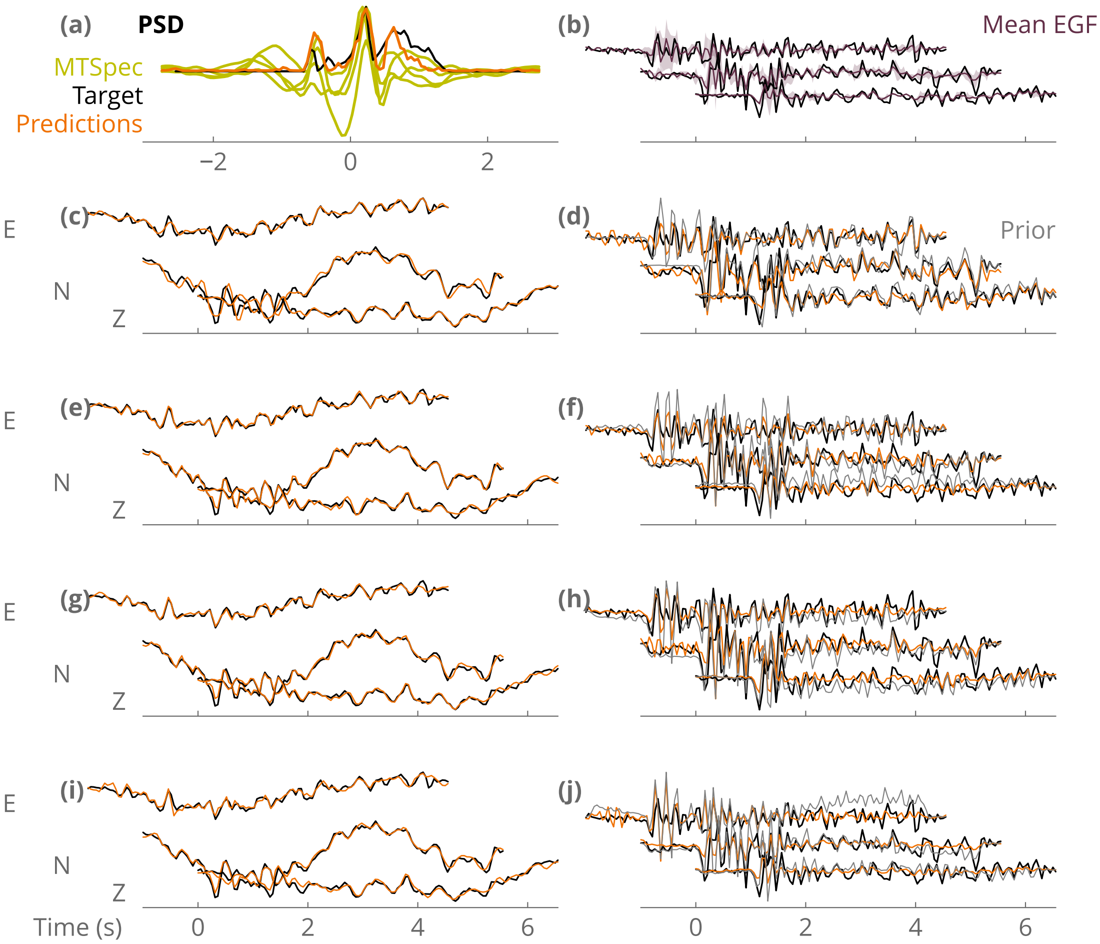


Figure S36 Inferred (orange) and target (black) STFs (a), EGFs (b,d,f,h,j) and waveforms of the main event (c,e,g,i) for toy model **PSD** whose characteristics are summarized in Table S11. In (a) the STFs estimated in the frequency-domain, assuming each EGF separately, are shown in green. In (b) the mean EGF and its standard deviation are in purple. In (d,f,h,j) the prior EGF is in gray.

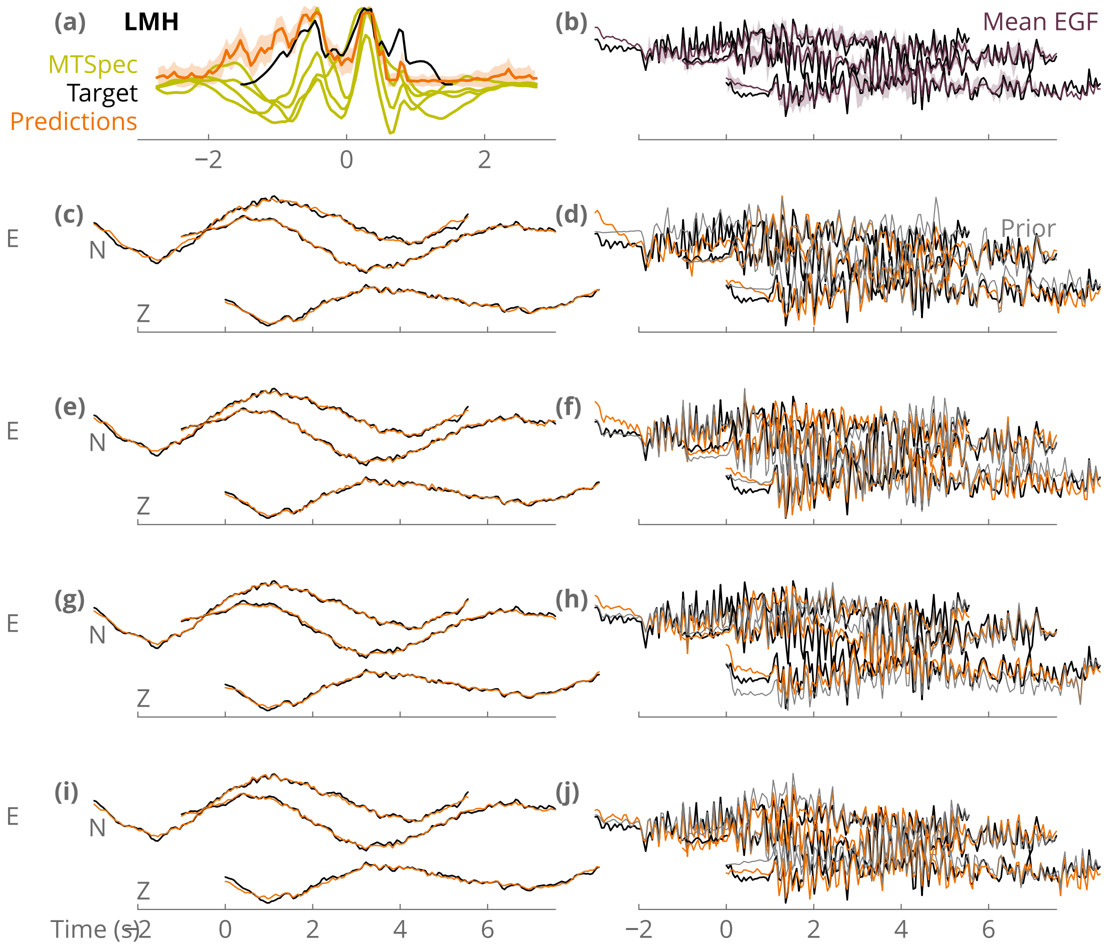


Figure S37 Inferred (orange) and target (black) STFs (a), EGFs (b,d,f,h,j) and waveforms of the main event (c,e,g,i) for toy model **LMH** whose characteristics are summarized in Table S11. In (a) the STFs estimated in the frequency-domain, assuming each EGF separately, are shown in green. In (b) the mean EGF and its standard deviation are in purple. In (d,f,h,j) the prior EGF is in gray.

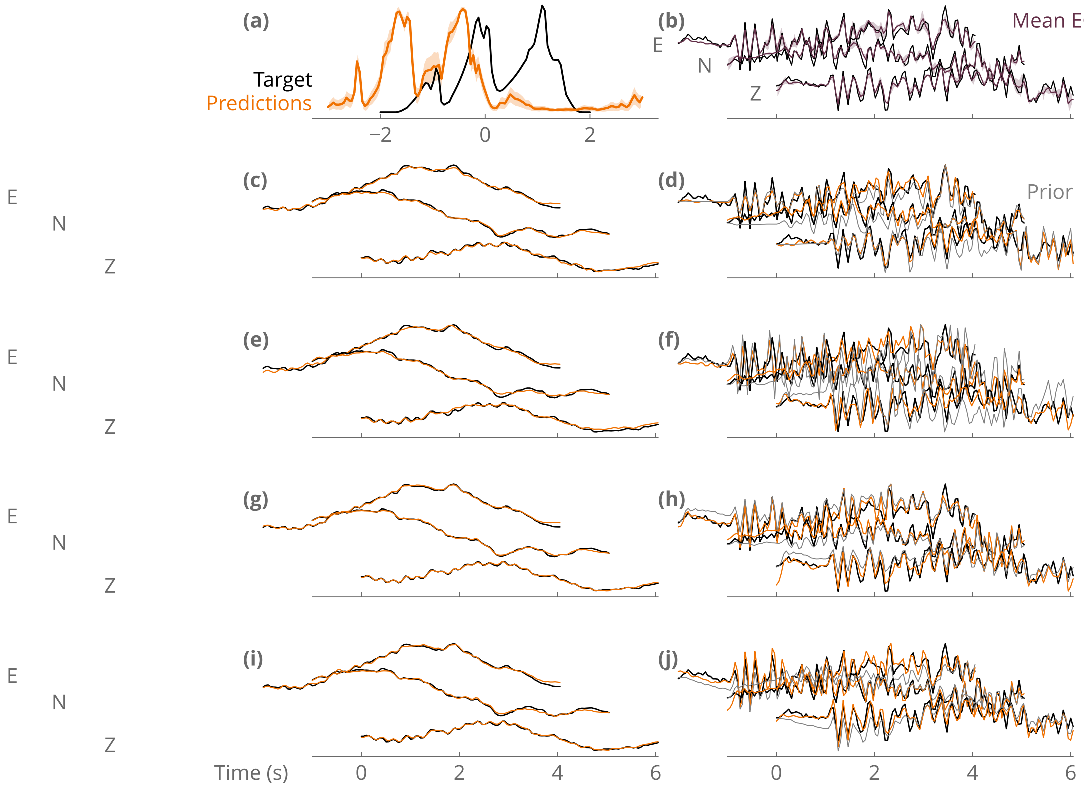


Figure S38 Inferred (orange) and target (black) STFs (a), EGFs (right) and waveforms of the main event (left) for station TOR, test **A with 4 EGFs**. In (a) the STFs estimated in the frequency-domain, assuming each EGF separately, are shown in green. In (b) the mean EGF and its standard deviation are in purple. The prior EGF is in gray.

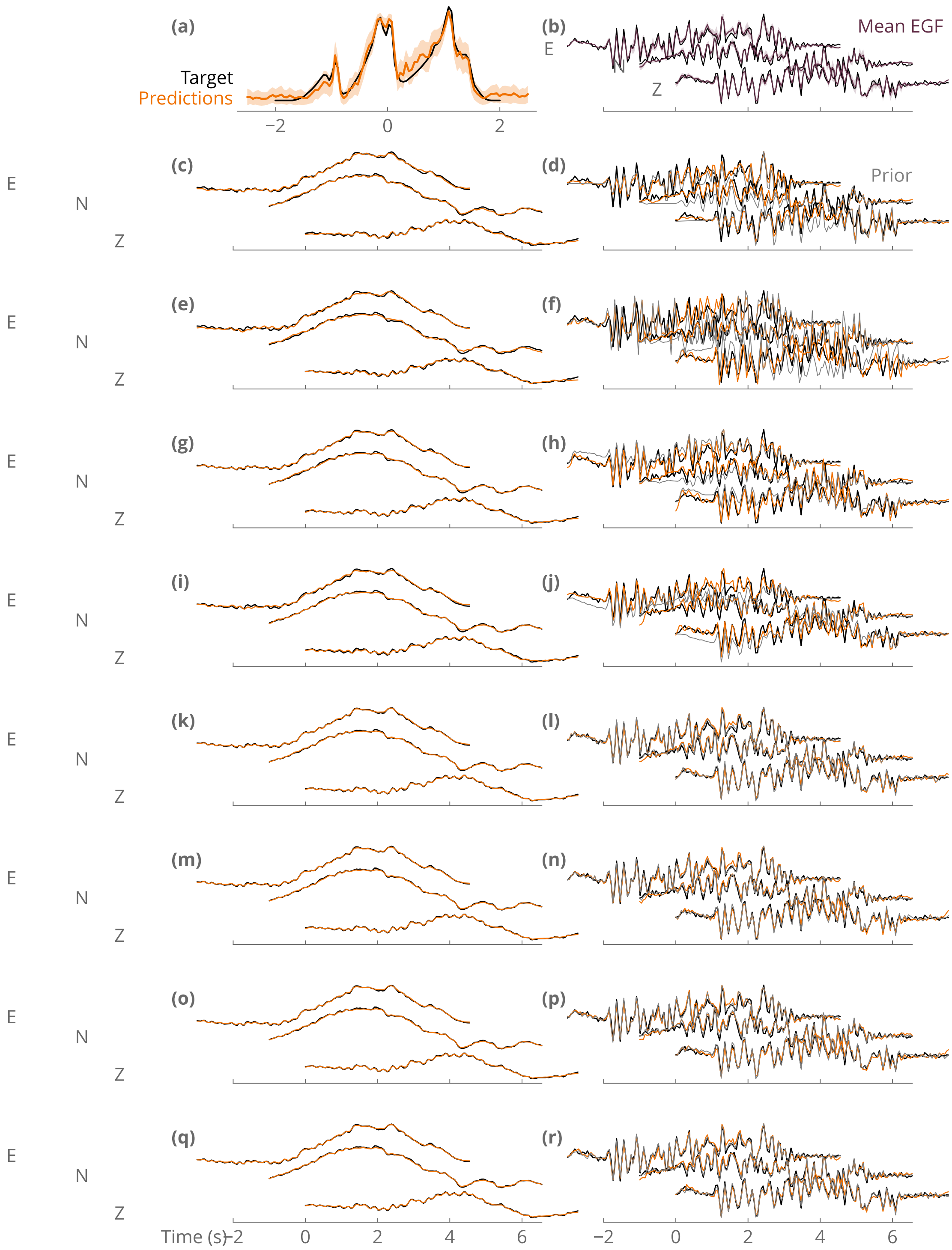


Figure S39 Inferred (orange) and target (black) STFs (a), EGFs (right) and waveforms of the main event (left) for station TOR, test **B with 8 EGFs**. In (a) the STFs estimated in the frequency-domain, assuming each EGF separately, are shown in green. In (b) the mean EGF and its standard deviation are in purple. The prior EGF is in gray.

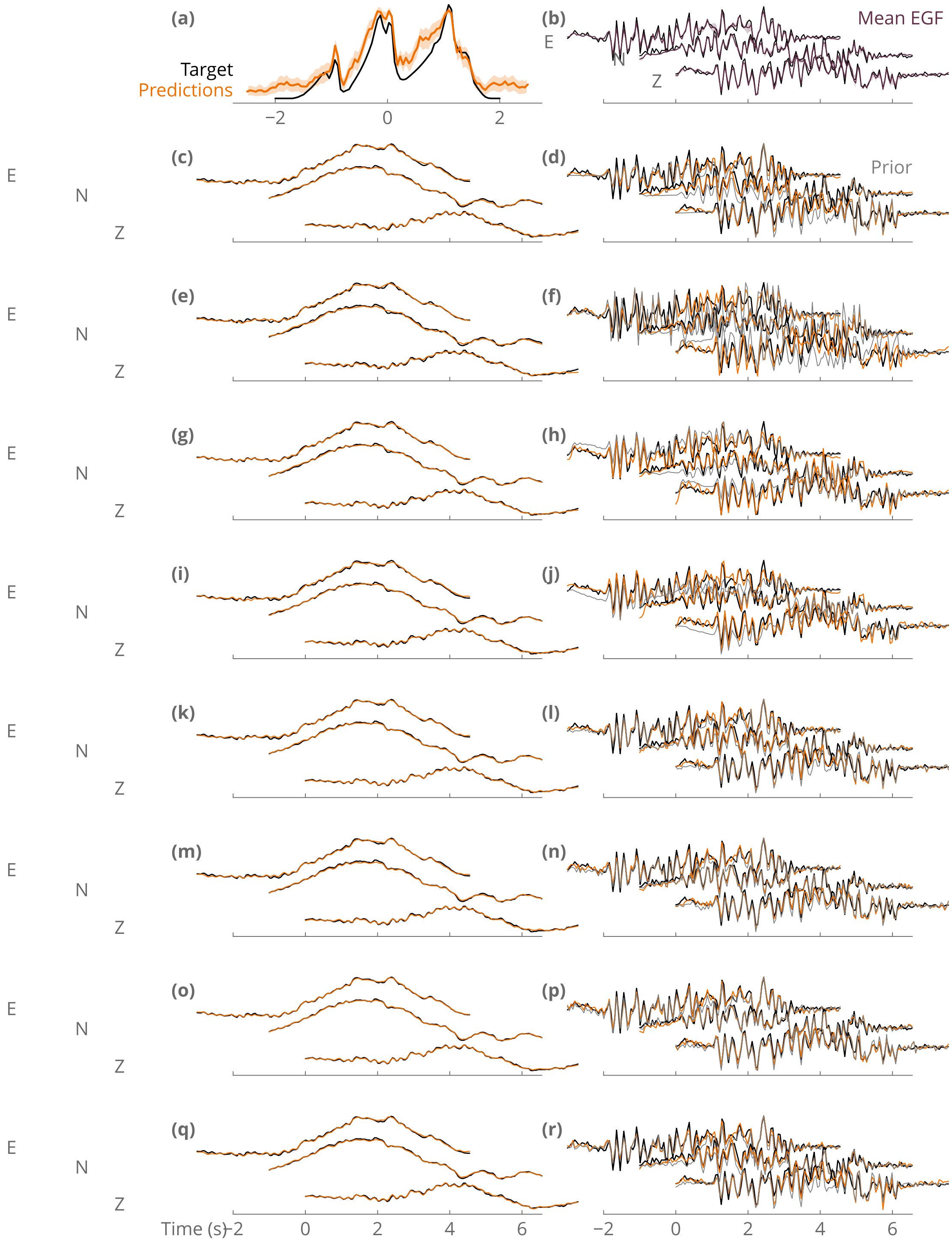


Figure S40 Inferred (orange) and target (black) STFs (a), EGFs (right) and waveforms of the main event (left) for station TOR, test **C with 8 EGFs**. In (a) the STFs estimated in the frequency-domain, assuming each EGF separately, are shown in green. In (b) the mean EGF and its standard deviation are in purple. The prior EGF is in gray.

Table S12 Four potential EGFs for the Cahuilla case study, selected based on their cross-corelation with the mainshock waveforms at station PLM.

event ID	date	Mw	Relocated distance to mainshock (km)	Cross-correlation
38049295	2018-09-06	2.35	0.909	0.563
38243232	2018-08-12	2.29	0.928	0.612
38245472	2018-08-15	2.03	0.924	0.641
37195604	2018-09-07	2.16	0.918	0.686

S4.3 Description of the forward model

We assume three different sets of prior EGFs, with P arrivals only (3 sec.) or S arrivals only (13 sec.):

- **set A, P waves**: 4 EGFs, distance-based, similar to toy models, EGFs listed in Table S9.
- **set B, P waves**: 4 EGFs, based on their cross-correlation with the mainshock waveforms at station PLM, that are located at less than 1 km from the mainshock. Listed in Table S12. The choice of the station is based on the quality of the recordings.
- **set C, P waves**: We select 1 to 4 events for each station. The choice is based on the cross-correlation of their waveforms with the mainshock waveforms at each station (P or S arrivals waveforms only). EGFs are at a distance of less than 1 km from the mainshock. The number of assumed EGFs depends on their SNR that should be larger than 2. This amounts to a total of 69 single events.

Prior assumptions for the Landweber approach

We compare DeepGEM inferences with the approach proposed by Bertero et al. (1997). We use the same downsampling as with DeepGEM. We first fix the duration of the STF and then optimize its time shift with a least-square approach. We impose 500 iterations. We estimate apparent STFs for each component and each EGF, and then derive mean and standard deviation from those multiple estimates.

S4.4 Results

We only provide here a subset of the results for a few key stations to allow for comparison. STFs at all stations are plotted in Fig. 4 in the main text.

at station BOR:
- Fig. S41 : set A, P waves
- Fig. S42 : set B, P waves
- Fig. S43 : set C, P waves
- Fig. S44 : set C, S waves

at station BLA2:
- Fig. S45 : set A, P waves
- Fig. S46 : set B, P waves
- Fig. S47 : set C, P waves
- Fig. S48 : set C, S waves

at station PLS:
- Fig. S49 : set A, P waves
- Fig. S50 : set B, P waves
- Fig. S51 : set C, P waves
- Fig. S52 : set C, S waves

at station LMH:
- Fig. S53 : set A, P waves
- Fig. S54 : set B, P waves
- Fig. S55 : set C, P waves
- Fig. S56 : set C, S waves

at station PLM:
- Fig. S57 : set A, P waves
- Fig. S58 : set B, P waves
- Fig. S59 : set C, P waves

- Fig. S60 : set C, S waves

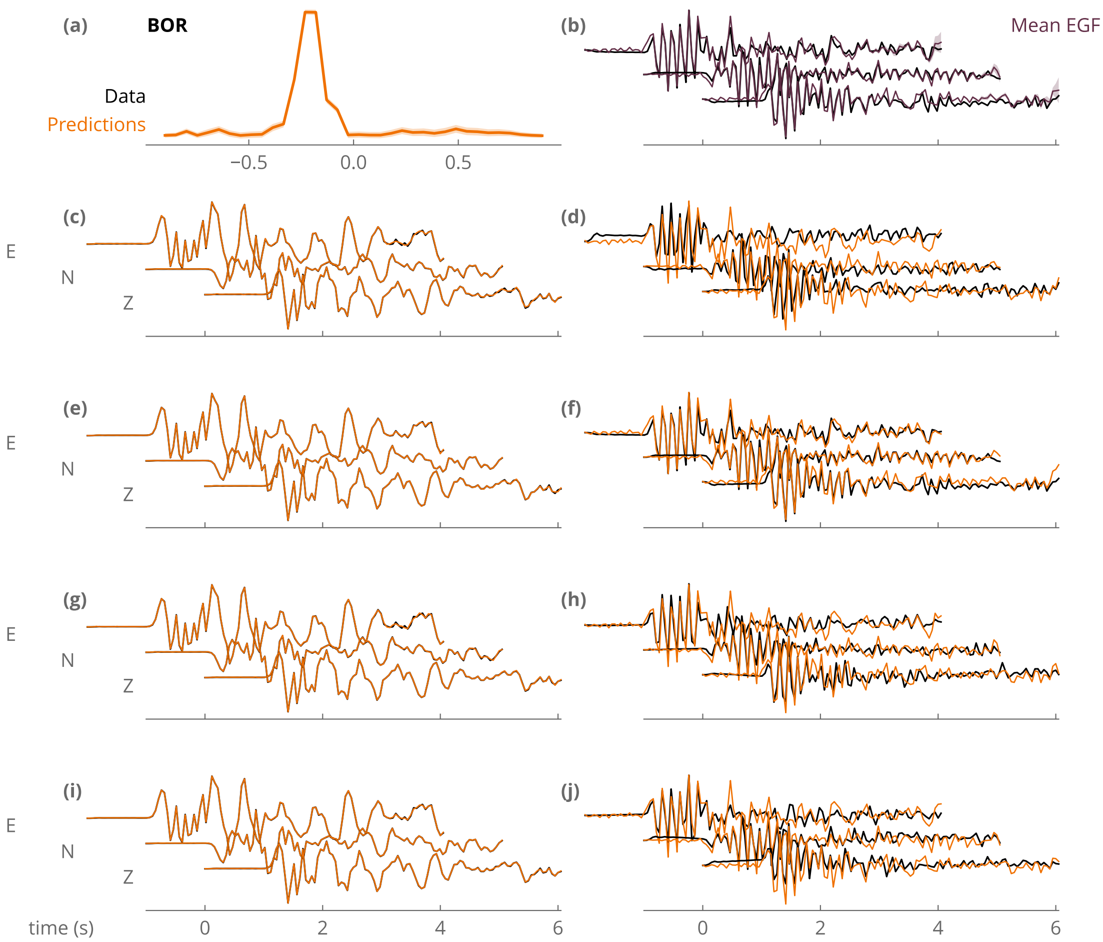


Figure S41 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **BOR** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(A)**.

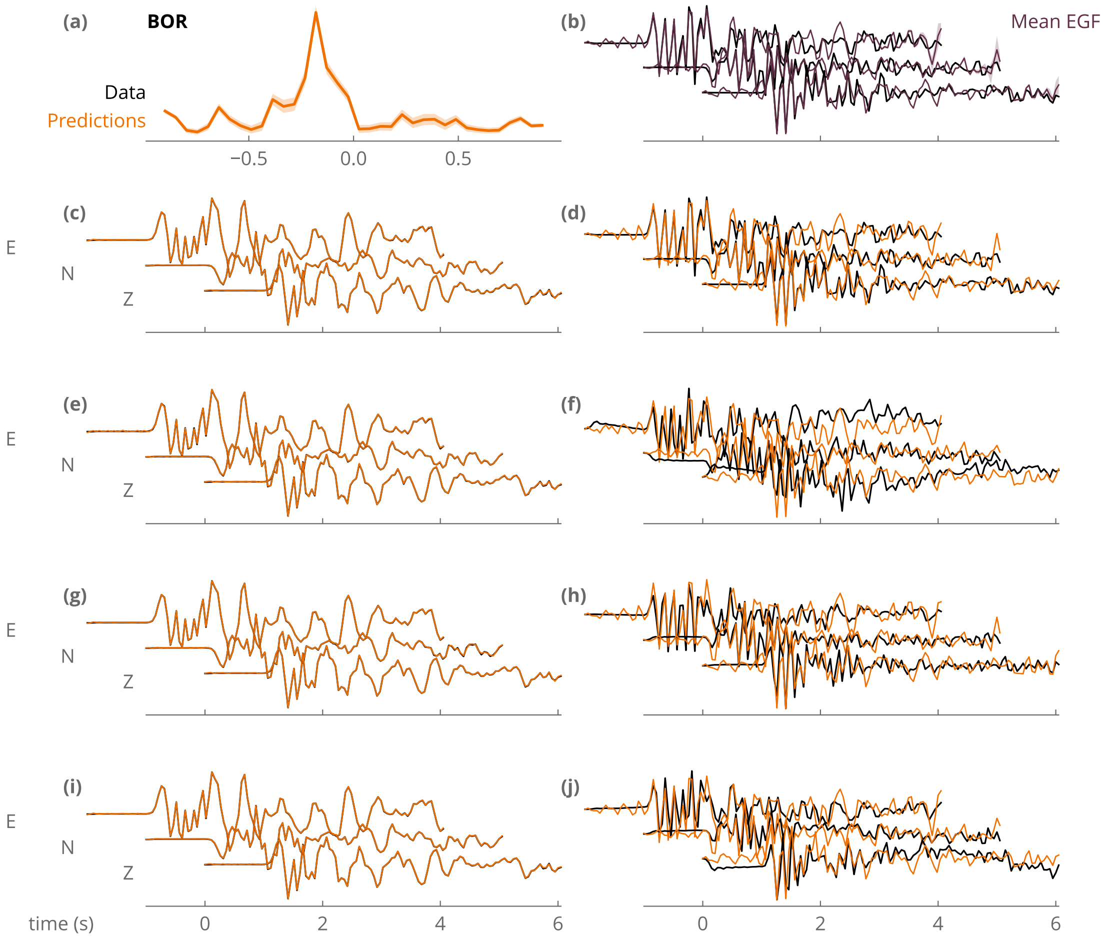


Figure S42 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **BOR** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(B)**.

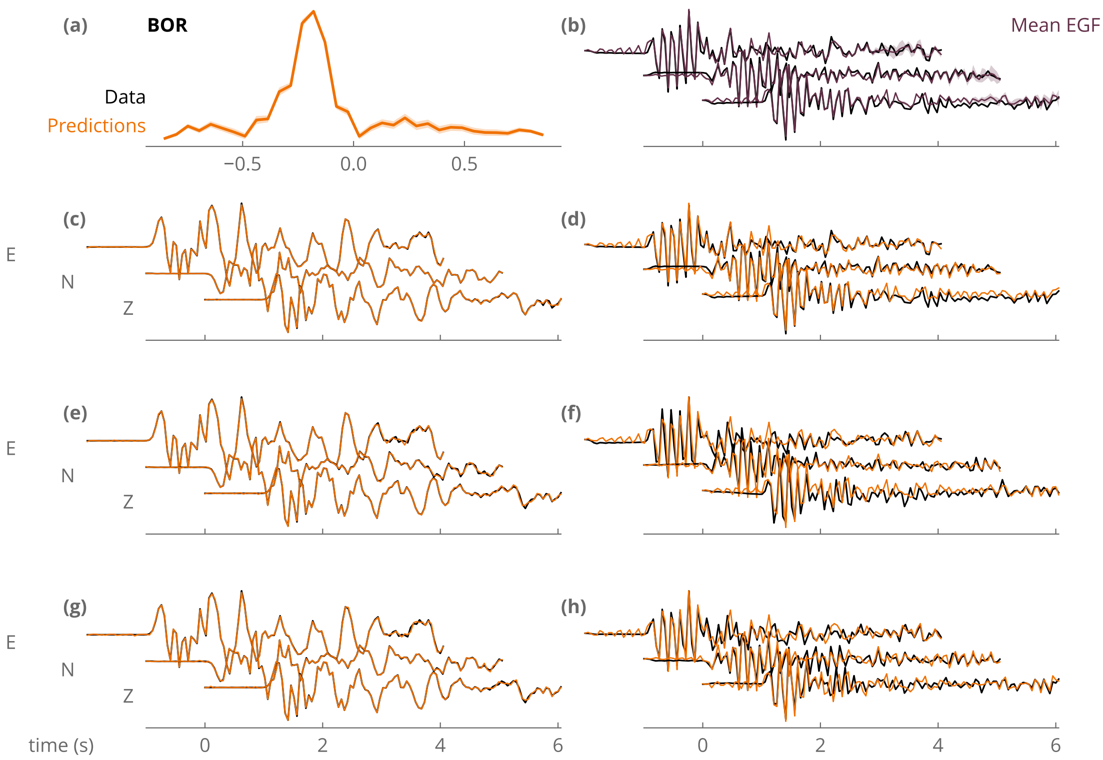


Figure S43 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **BOR** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(C)**.

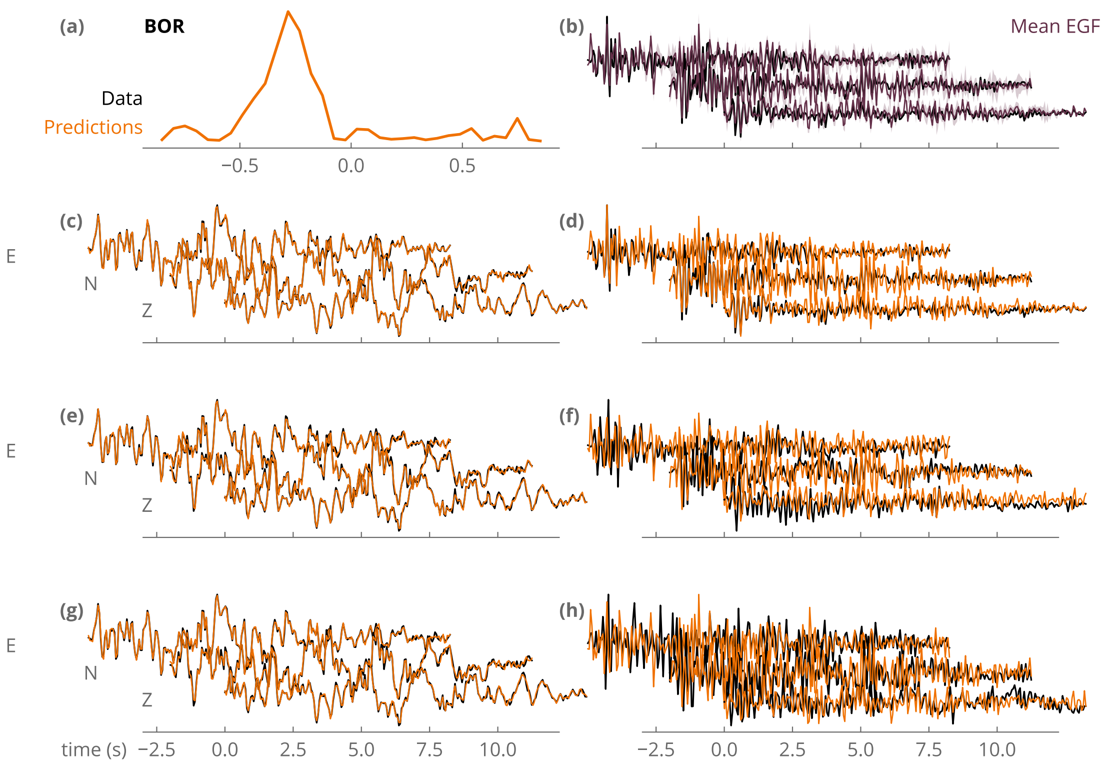


Figure S44 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **BOR** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(S)**.

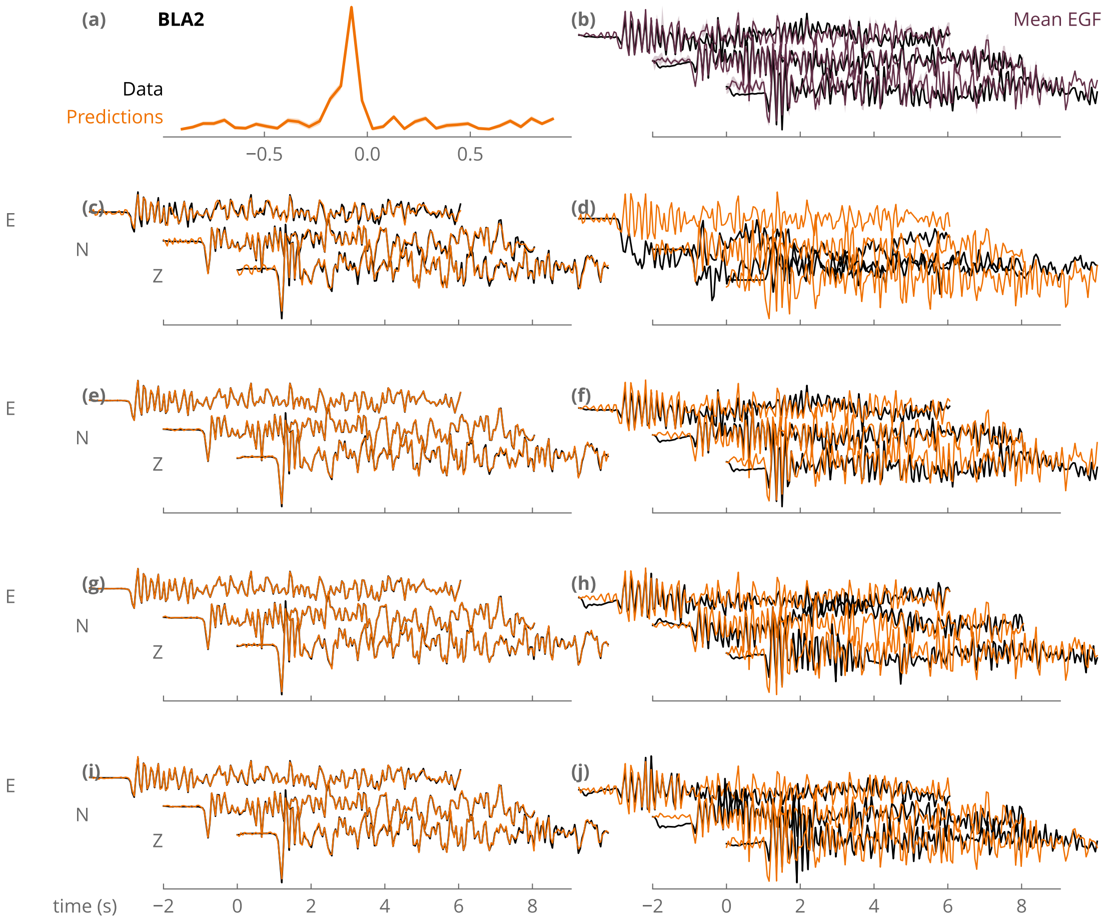


Figure S45 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **BLA2** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(A)**.

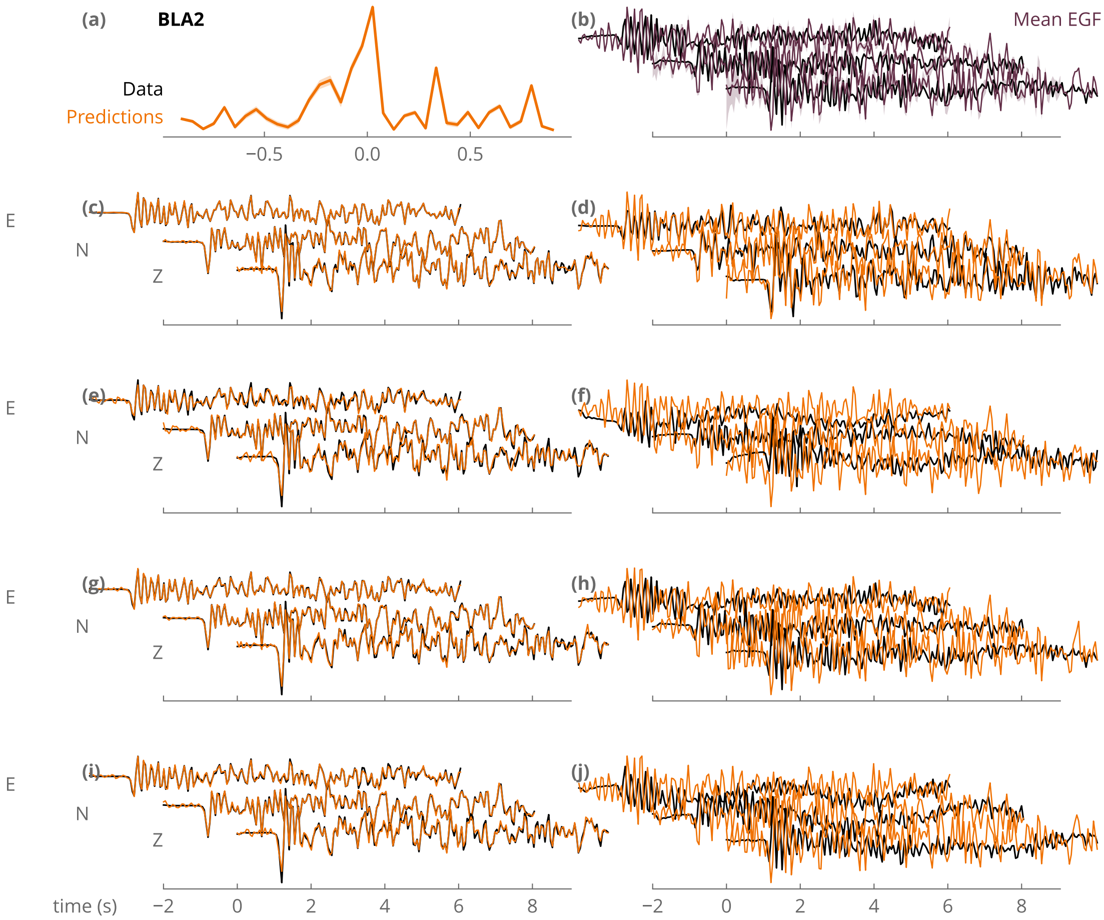


Figure S46 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **BLA2** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(B)**.

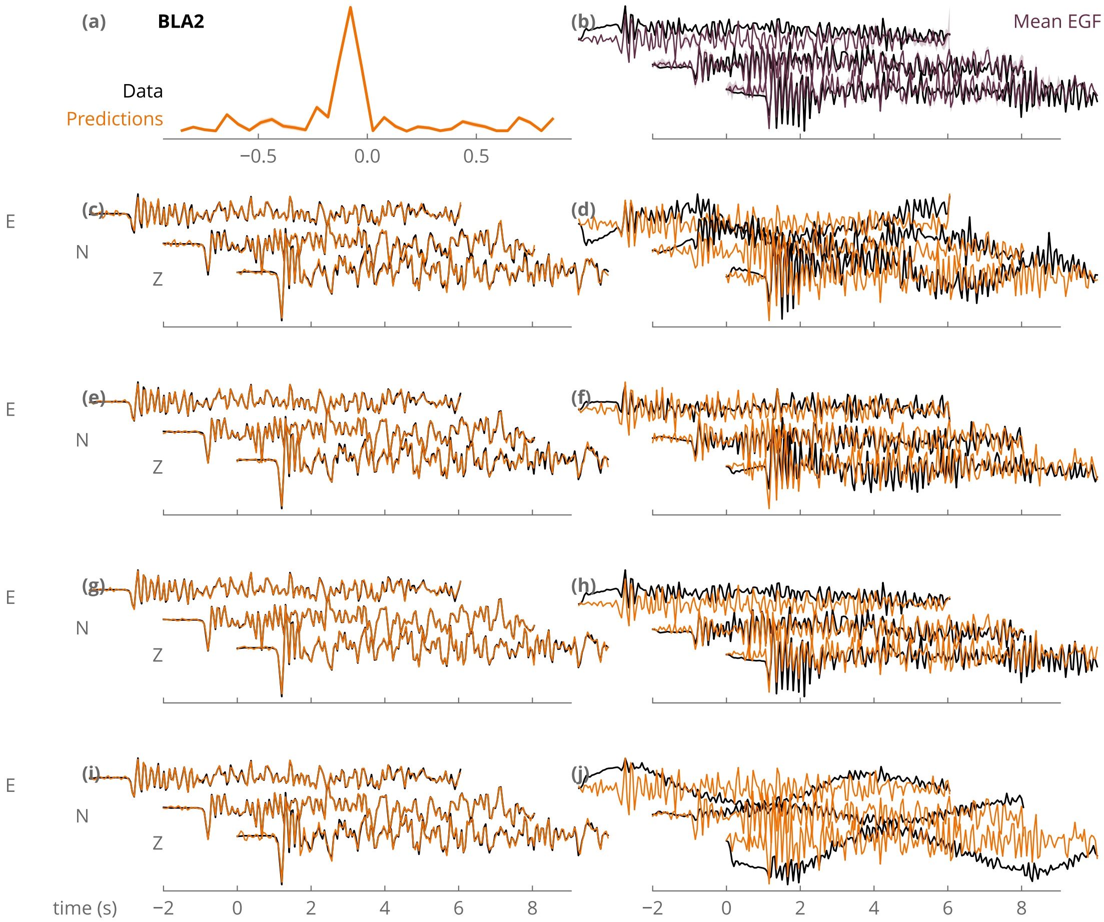


Figure S47 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **BLA2** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(C)**.

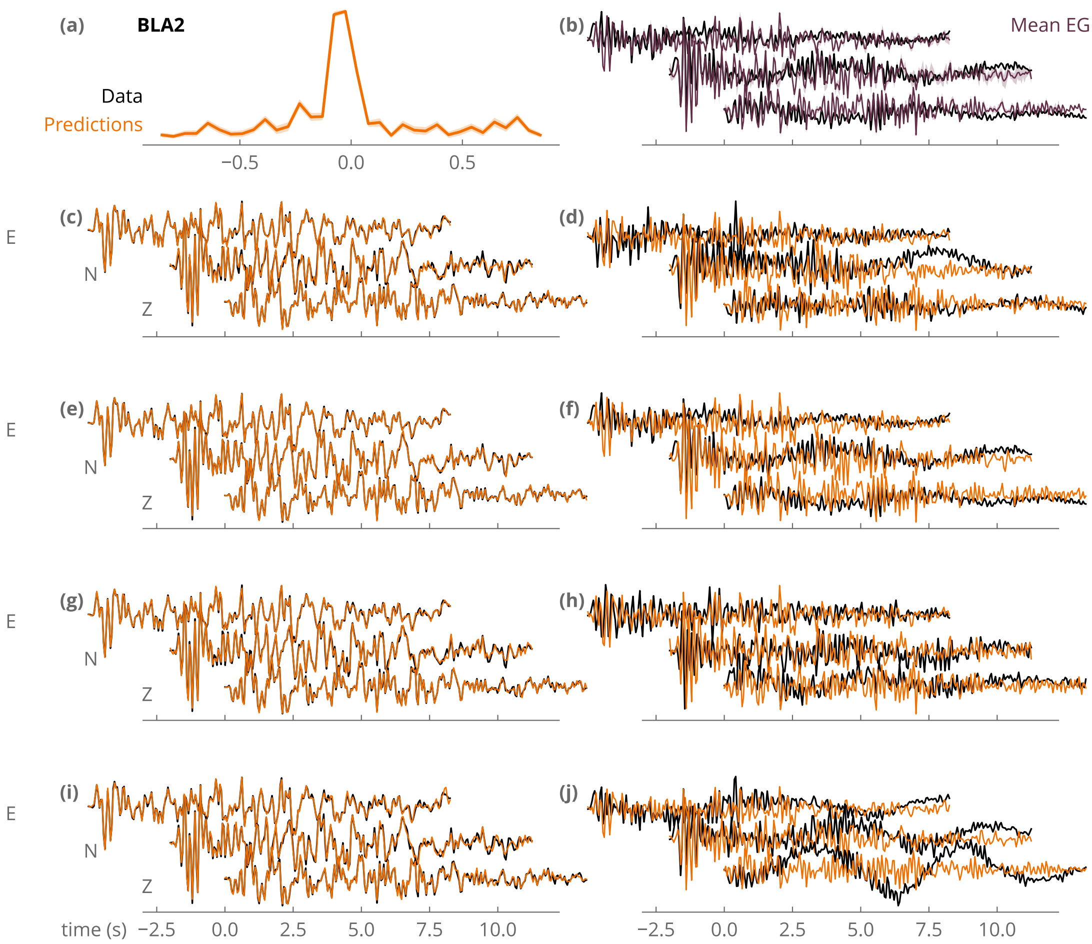


Figure S48 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **BLA2** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(S)**.

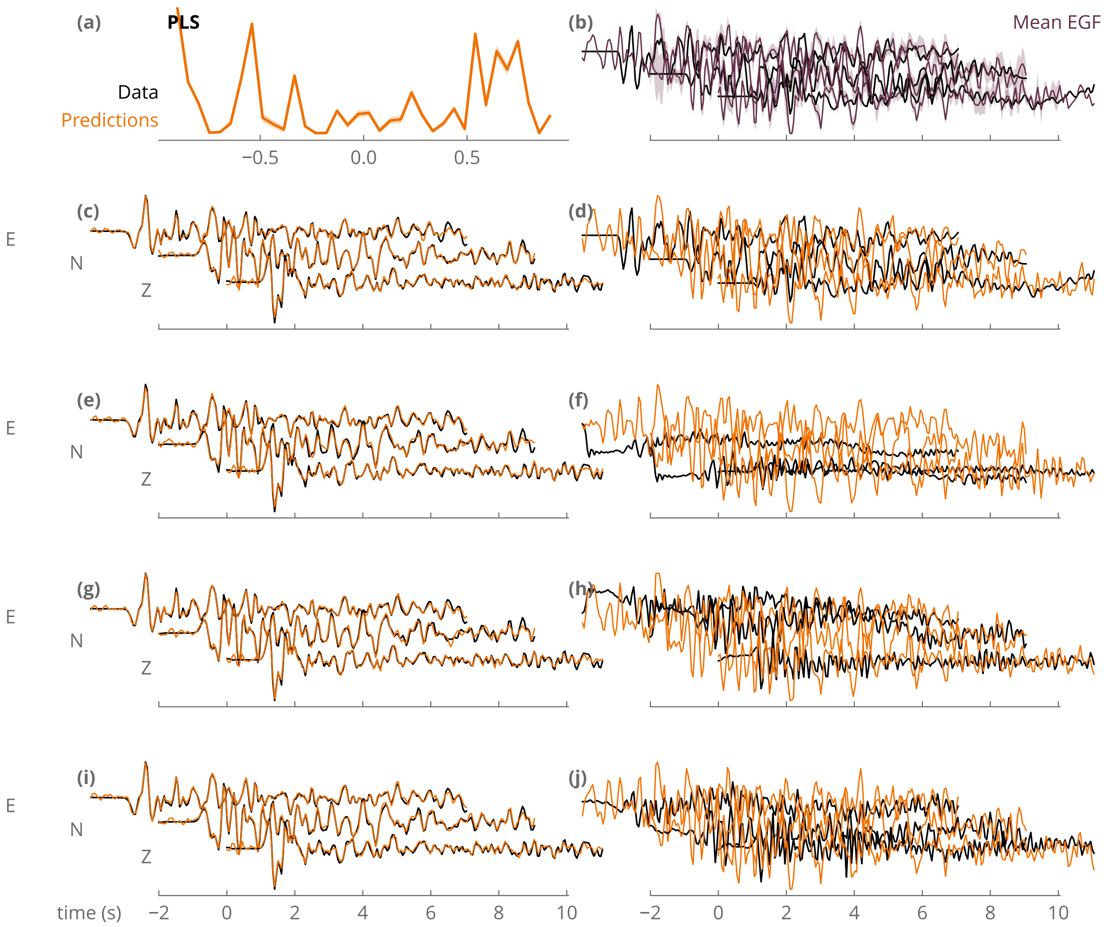


Figure S49 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **PLS** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(A)**.

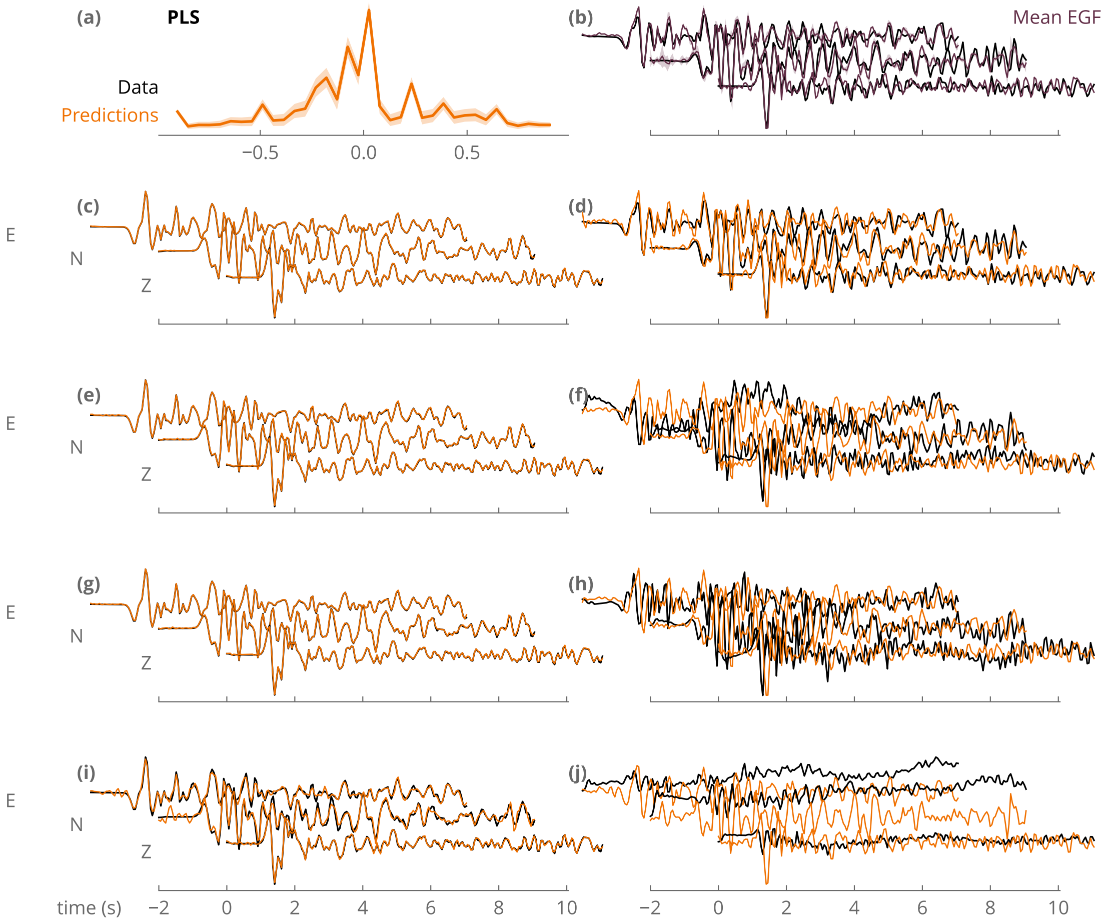


Figure S50 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **PLS** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(B)**.

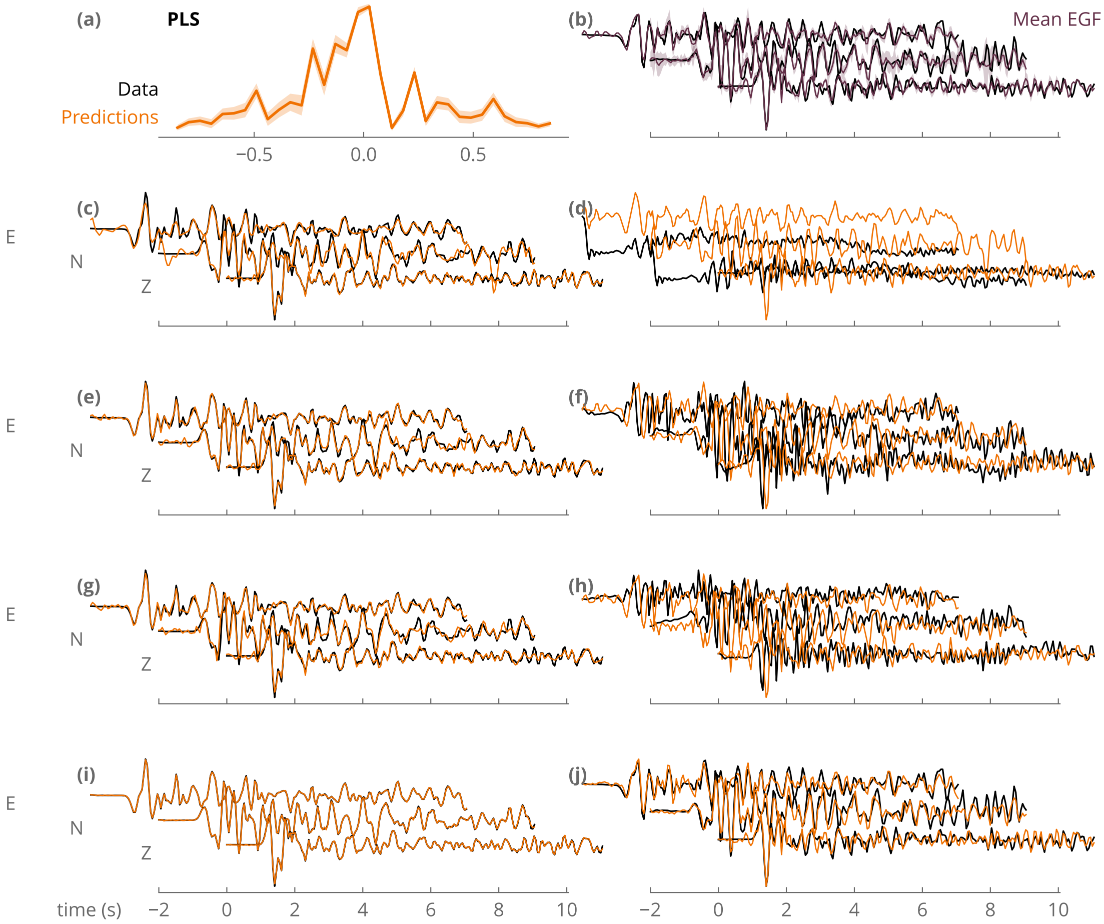


Figure S51 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **PLS** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(C)**.

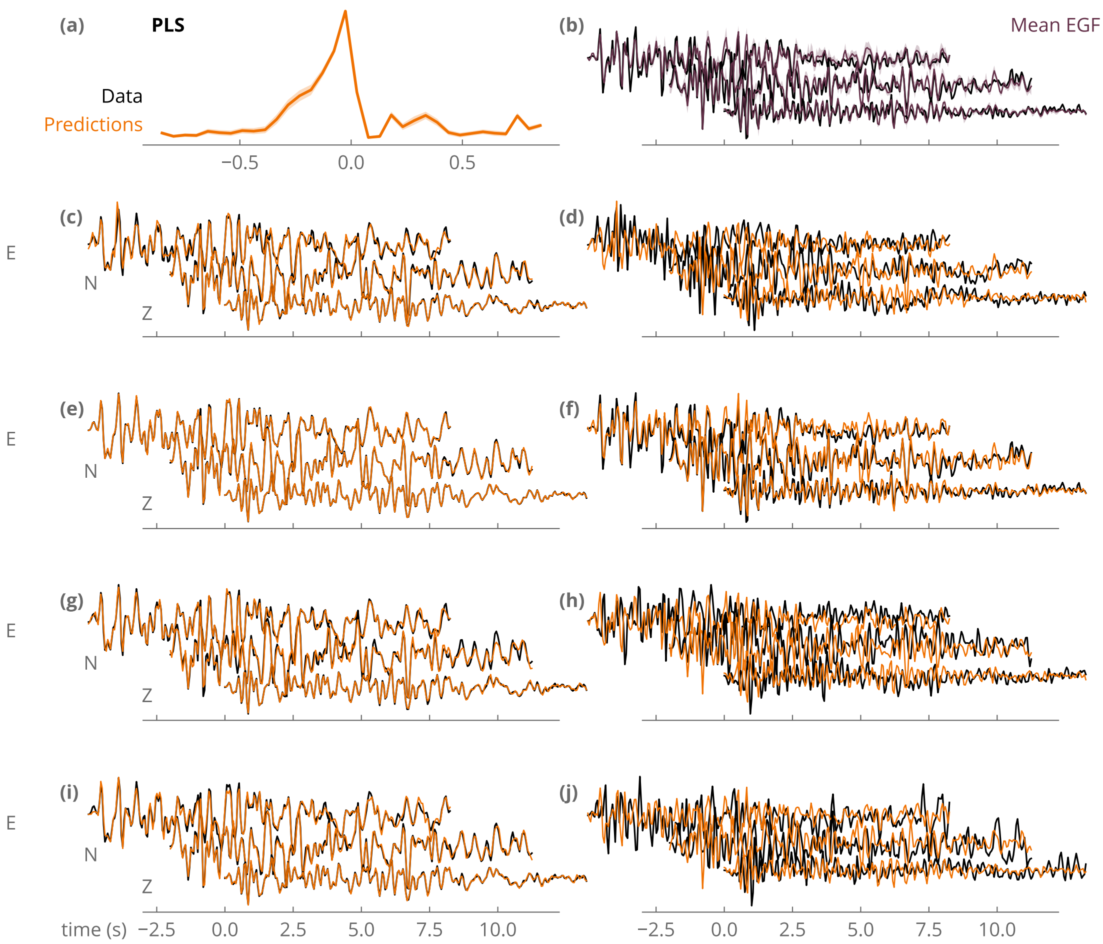


Figure S52 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **PLS** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(S)**.

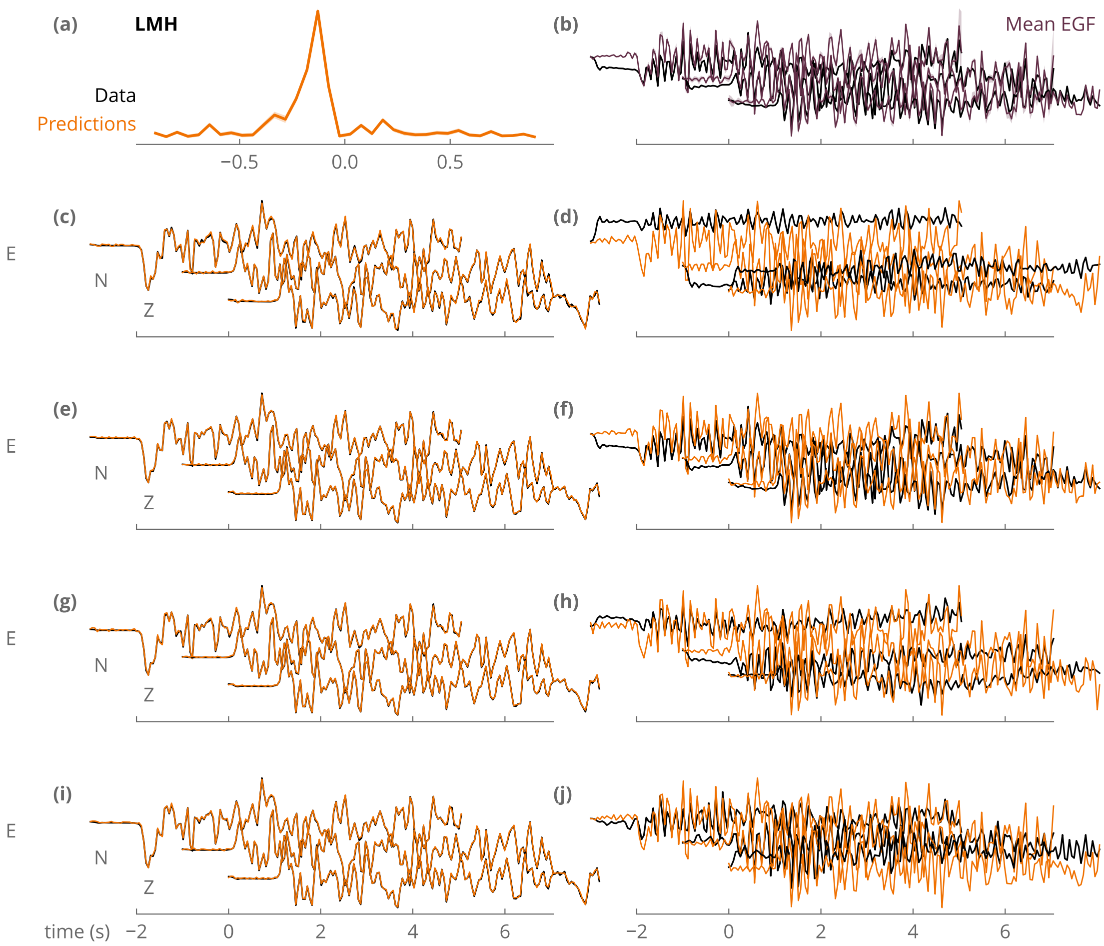


Figure S53 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **LMH** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(A)**.

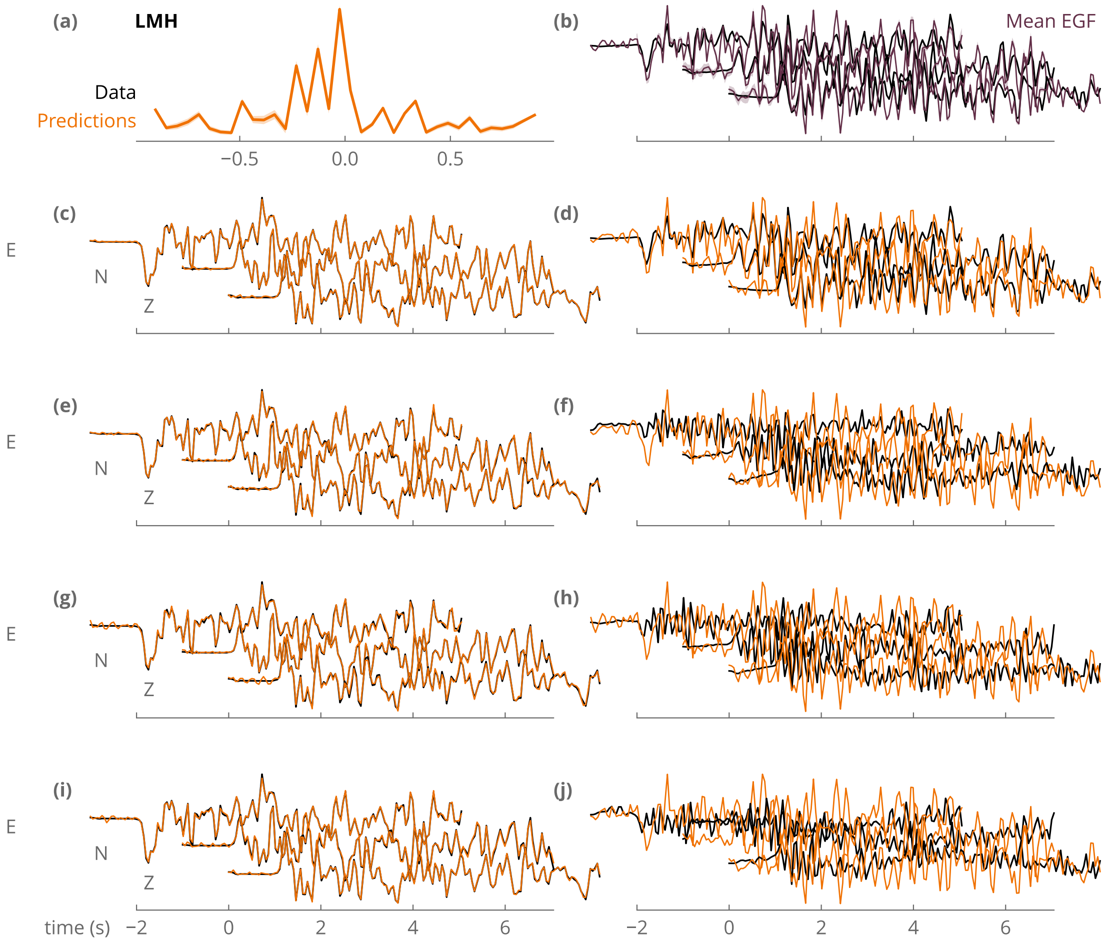


Figure S54 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **LMH** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(B)**.

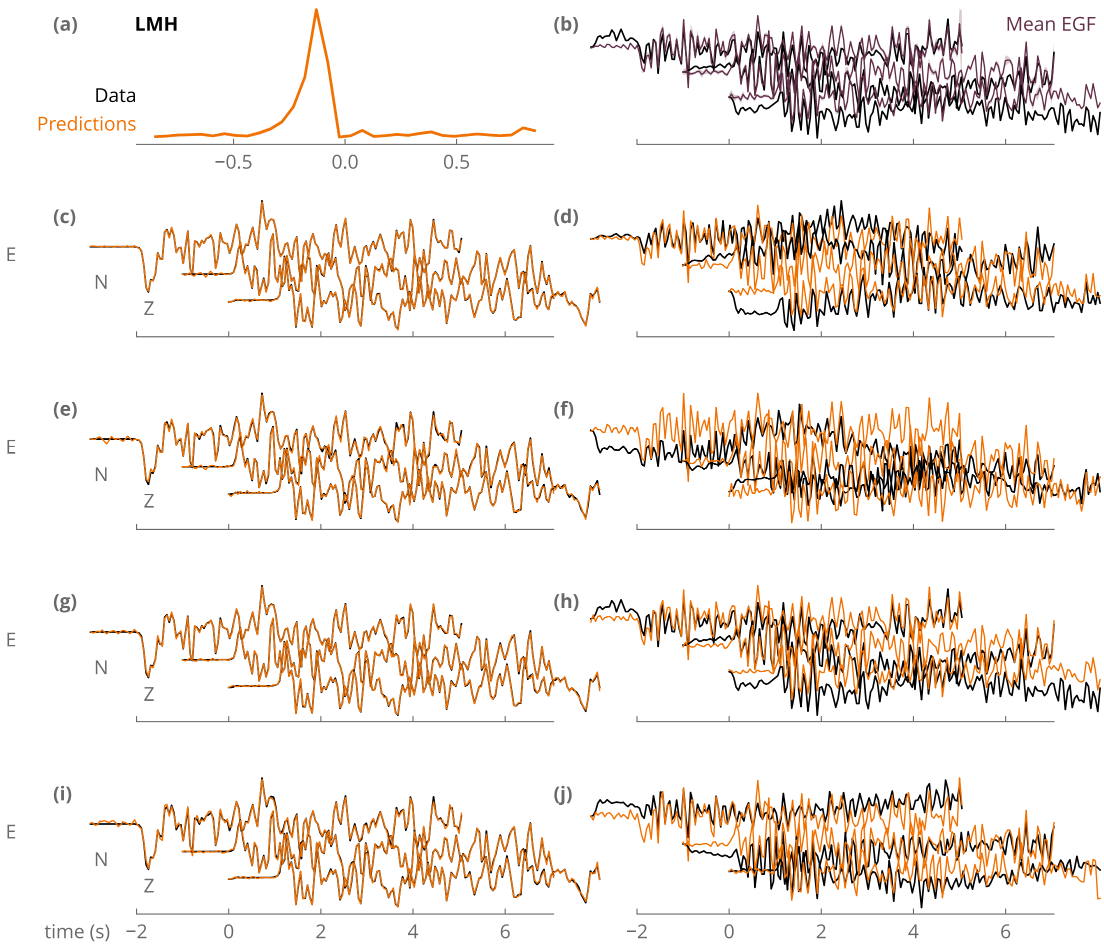


Figure S55 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **LMH** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(C)**.

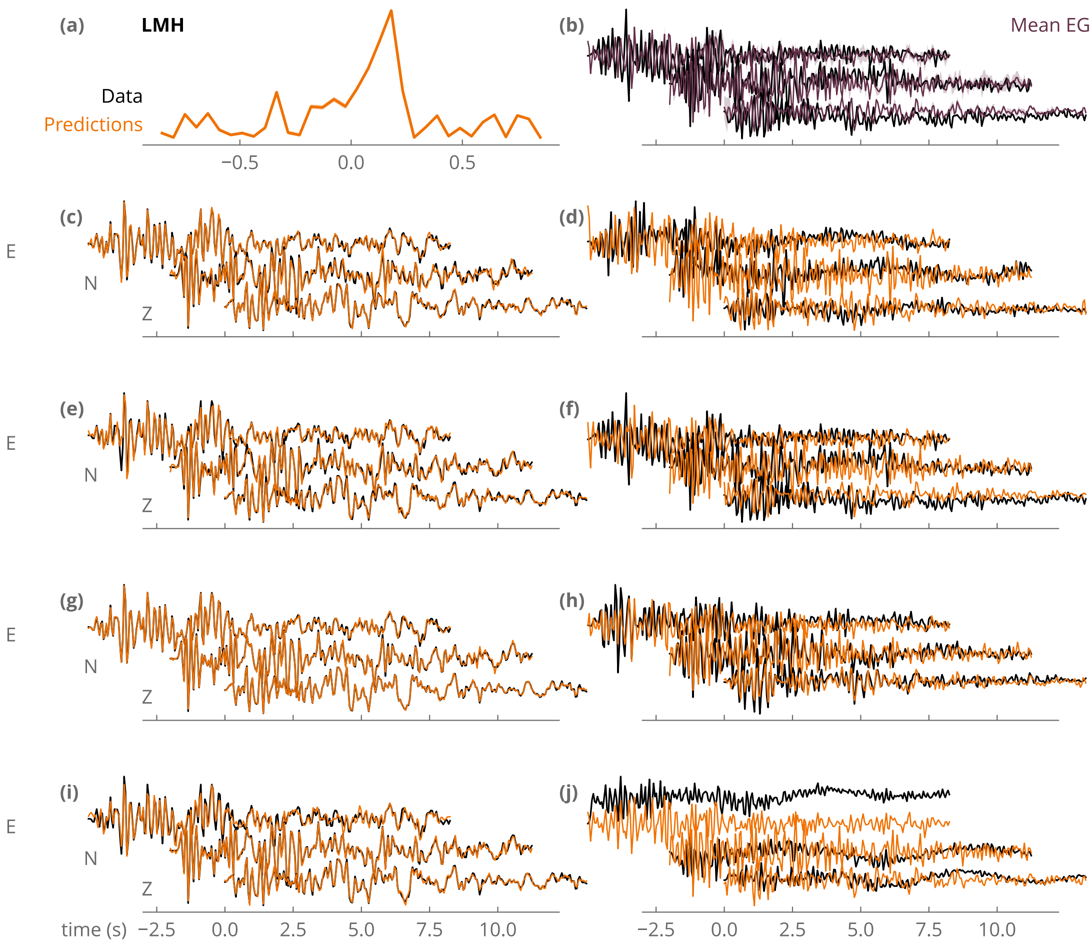


Figure S56 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **LMH** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(S)**.

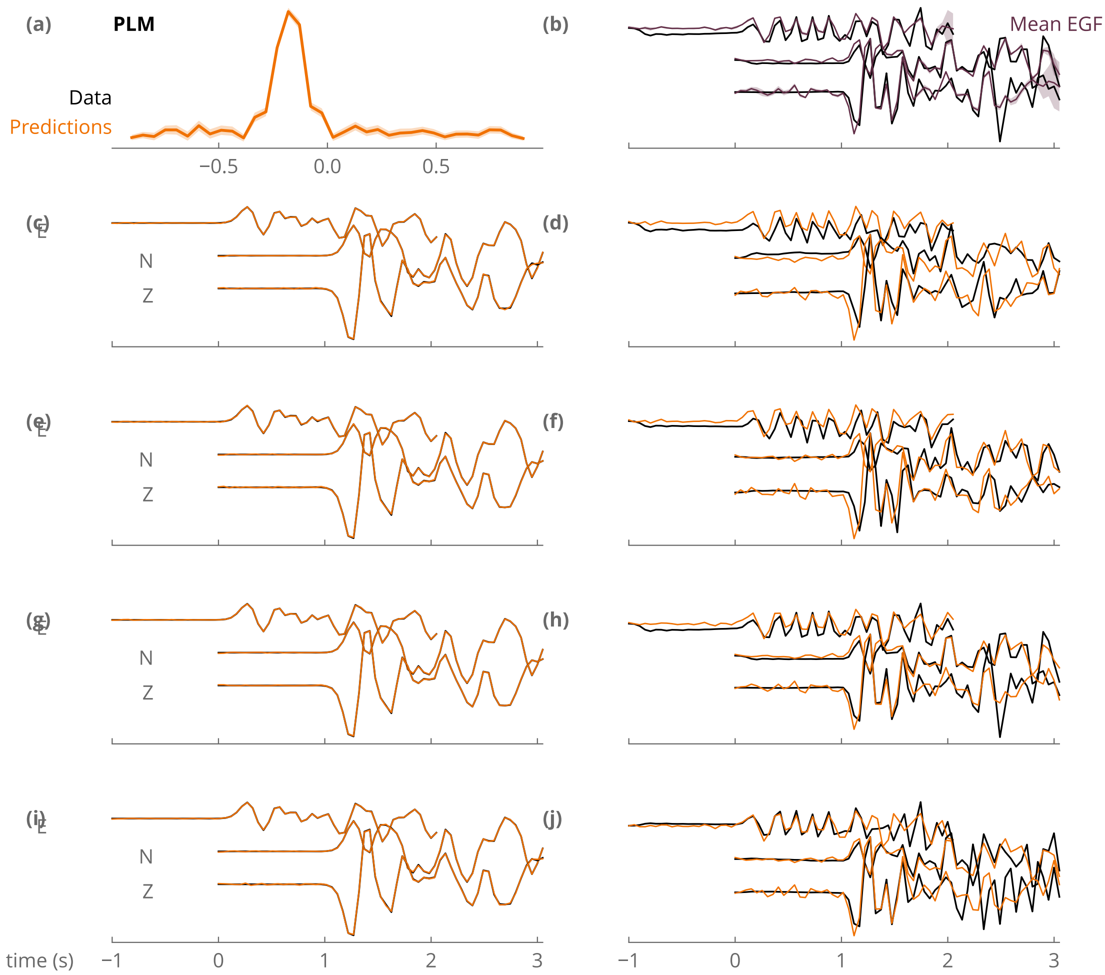


Figure S57 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **PLM** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(A)**.

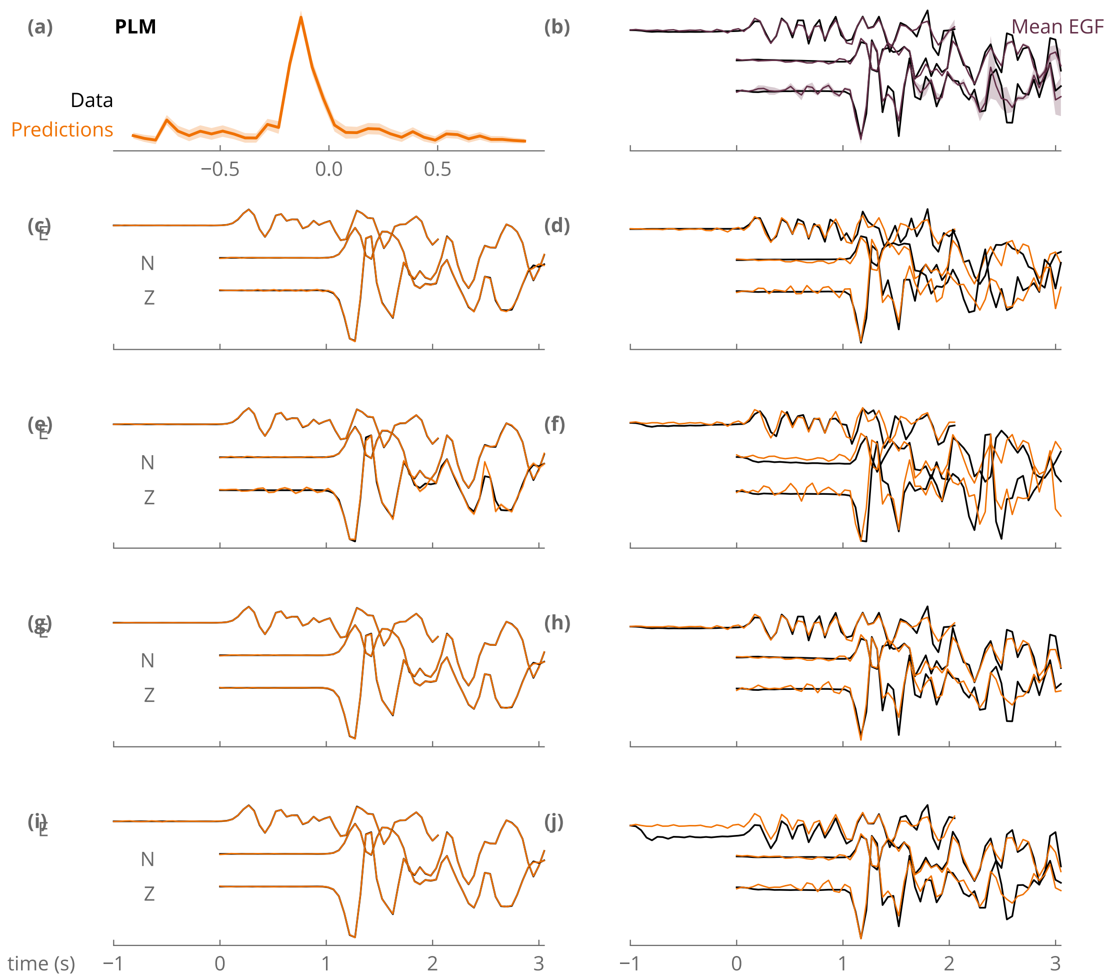


Figure S58 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **PLM** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(B)**.

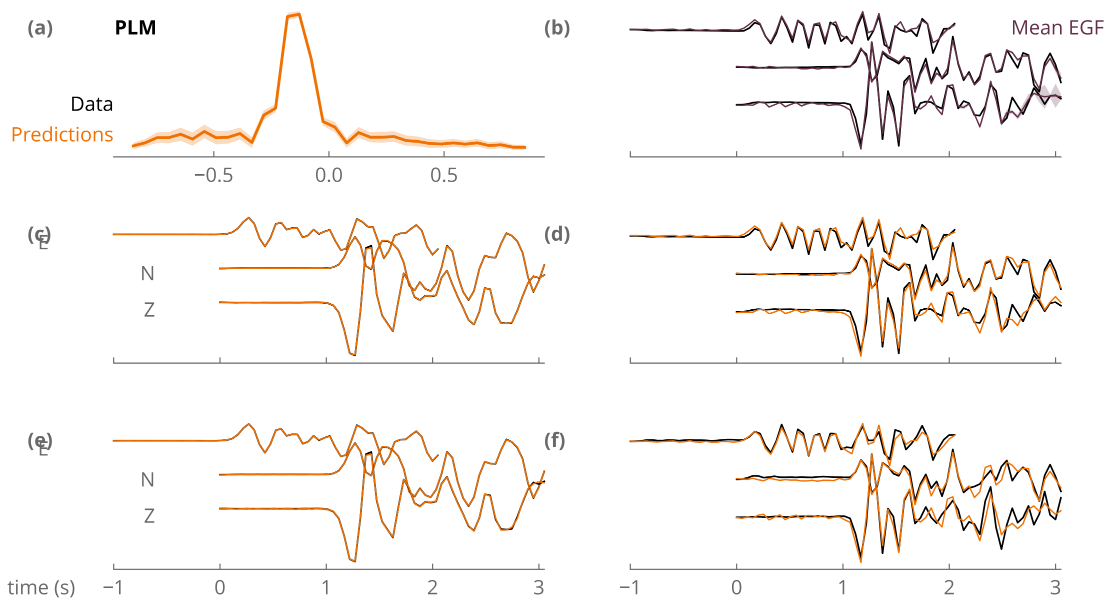


Figure S59 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **PLM** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(C)**.

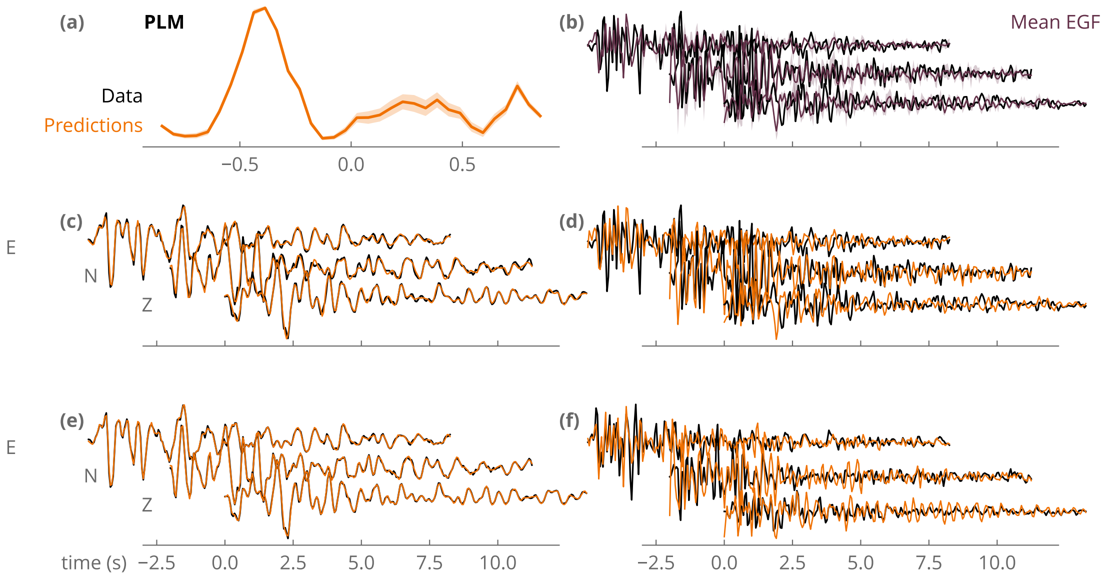


Figure S60 Inferred mean STF (a, orange) and EGF (b, purple) and their standard deviation (lighter) at station **PLM** for the Cahuilla case study. Inferred (orange) and observed (black) waveforms for the mainshock and EGFs are plotted on the left or right, respectively. (right) Prior EGFs are from set **(S)**.

References

Bertero, M., Bindi, D., Boccacci, P., Cattaneo, M., Eva, C., and Lanza, V. (1997). Application of the projected Landweber method to the estimation of the source time function in seismology. *Inverse Problems*, 13(2):465. 27, 48

Heimann, S., Steinberg, A., Sudhaus, H., Vasyura-Bathke, H., Dahm, T., and Isken, M. (2017). Pyrocko: A Versatile Software Framework for Seismology. 4

Ross, Z. E., Cochran, E. S., Trugman, D. T., and Smith, J. D. (2020). 3D fault architecture controls the dynamism of earthquake swarms. *Science*, 368(6497):1357–1361. 31

Zhu, W. and Beroza, G. C. (2019). PhaseNet: A deep-neural-network-based seismic arrival-time picking method. *Geophysical Journal International*, 216(1):261–273. 27, 31