Challenges and developments arising from 2D FWI of a land VSP dataset in the Permian Basin

Brendan Smithyman*
Bas Peters

SLIM
University of British Columbia

*currently at Western University, Canada

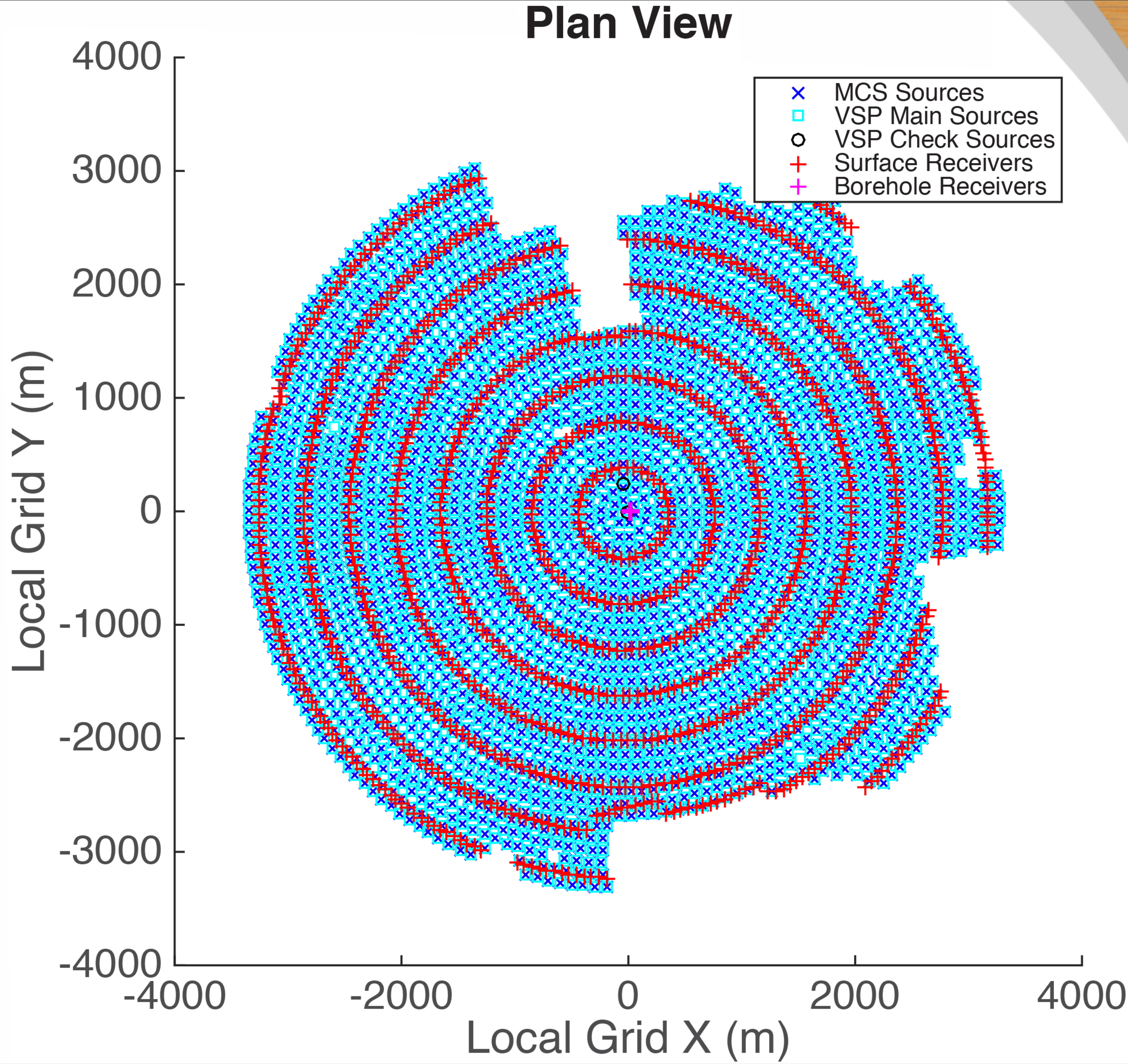
Goals

Evaluate standard SLIM FWI codes on real data.

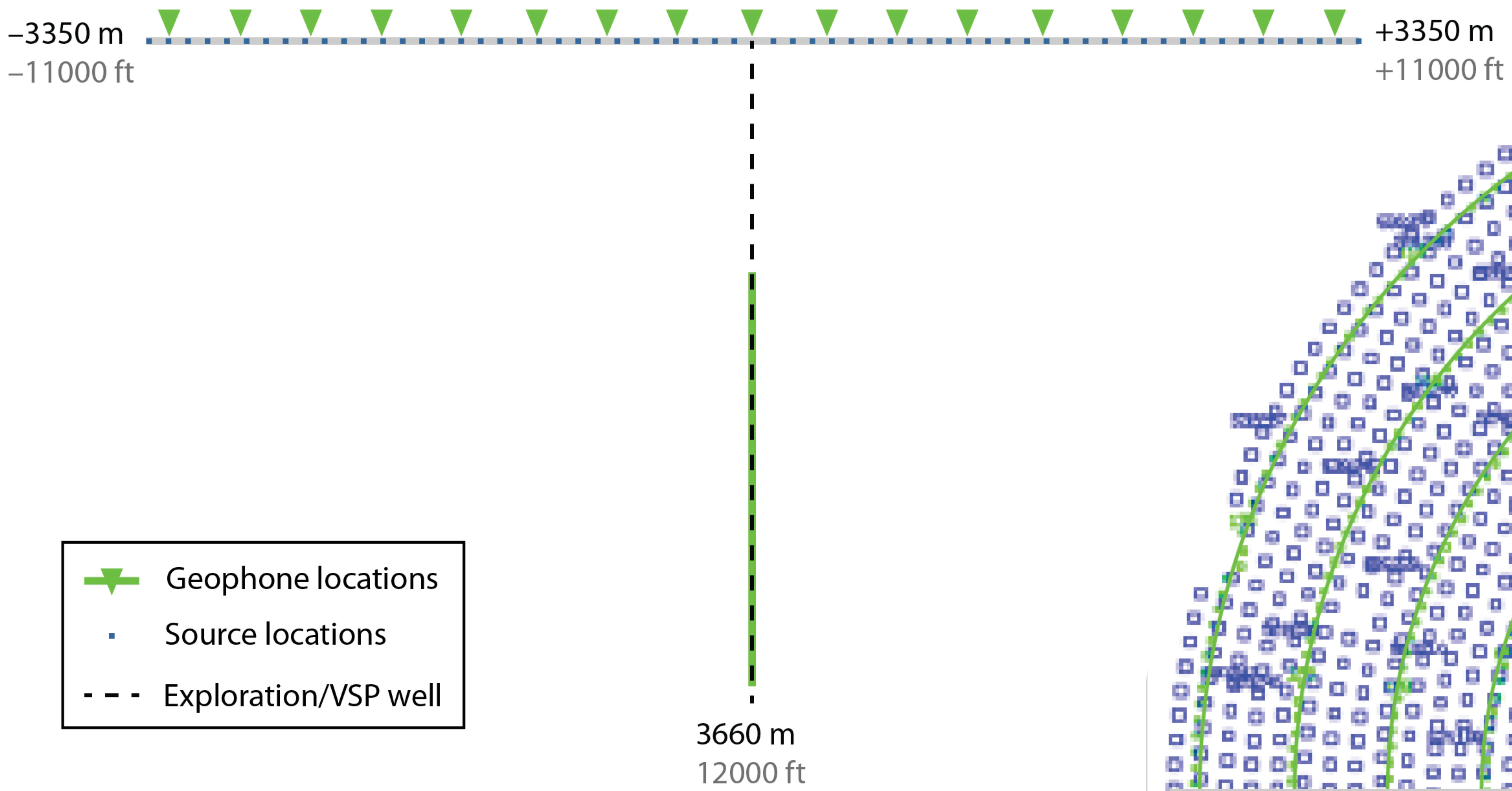
Develop new algorithms/codes required for real data.

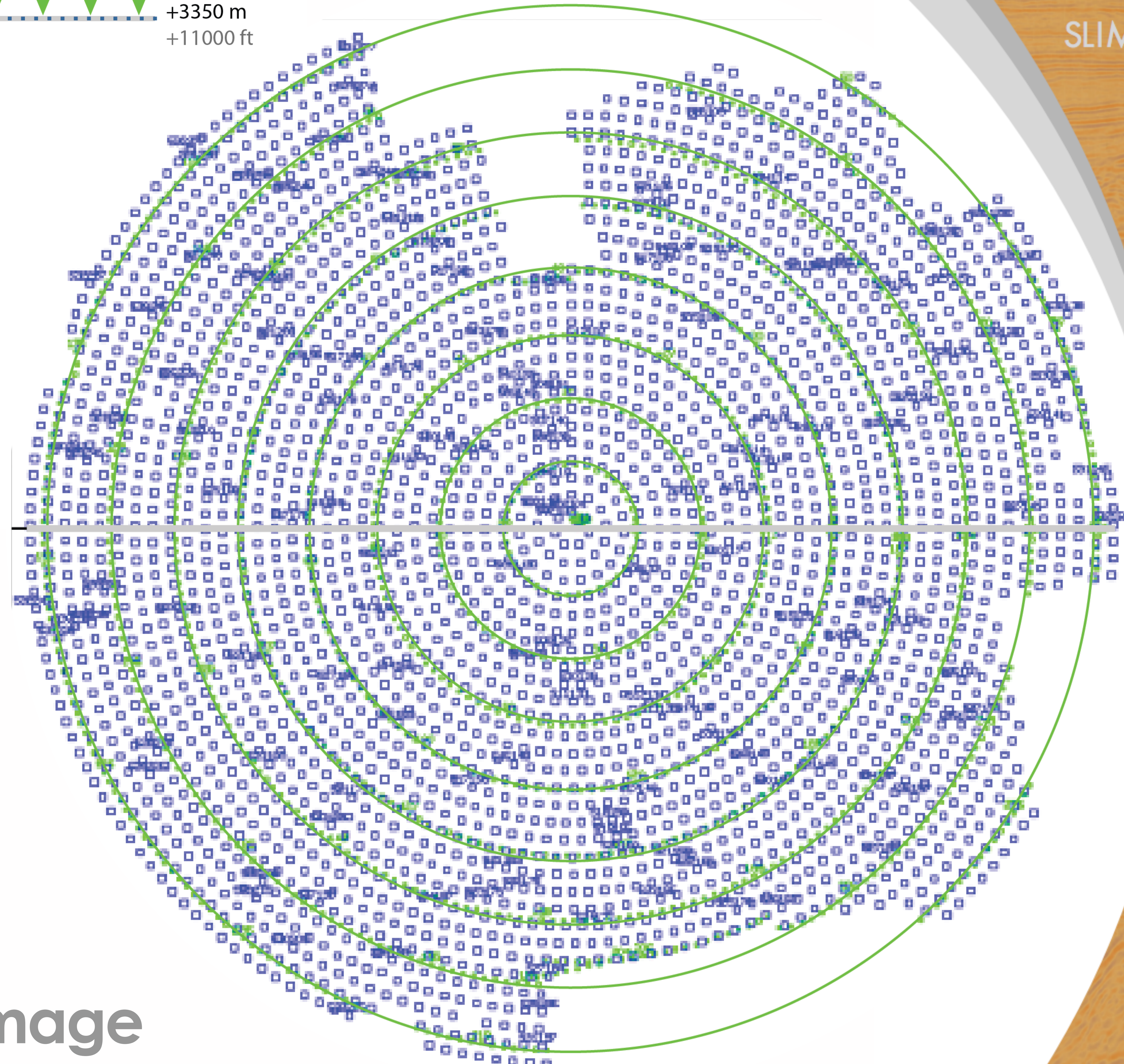
Flexible algorithm testing framework.

Geometry



Plan View
MCS Sources
VSP Main Sources
VSP Check Sources
Surface Receivers
Borehole Receivers
Local Grid Y (m)
Local Grid X (m)
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-4000
-2000
0
2000
4000





Geometry – Alternate Image

Problem info

- Permian basin
- lowest useful frequency: 8 Hertz
- initial model (velocity & anisotropy) provided
- result obtained by other means than FWI also provided
- well & check shots (no well measurements)

- vibrator source on land
- 1-component receivers on land
- 3-component receivers in well

Our initial approach

- work on 2D lines
- acoustic modeling
- work with 1 receiver component
- correction for 2D/3D geometric spreading error
- work with 8-16 Hertz data
- no denoising

use existing SLIM FWI software

SLIM FWI software

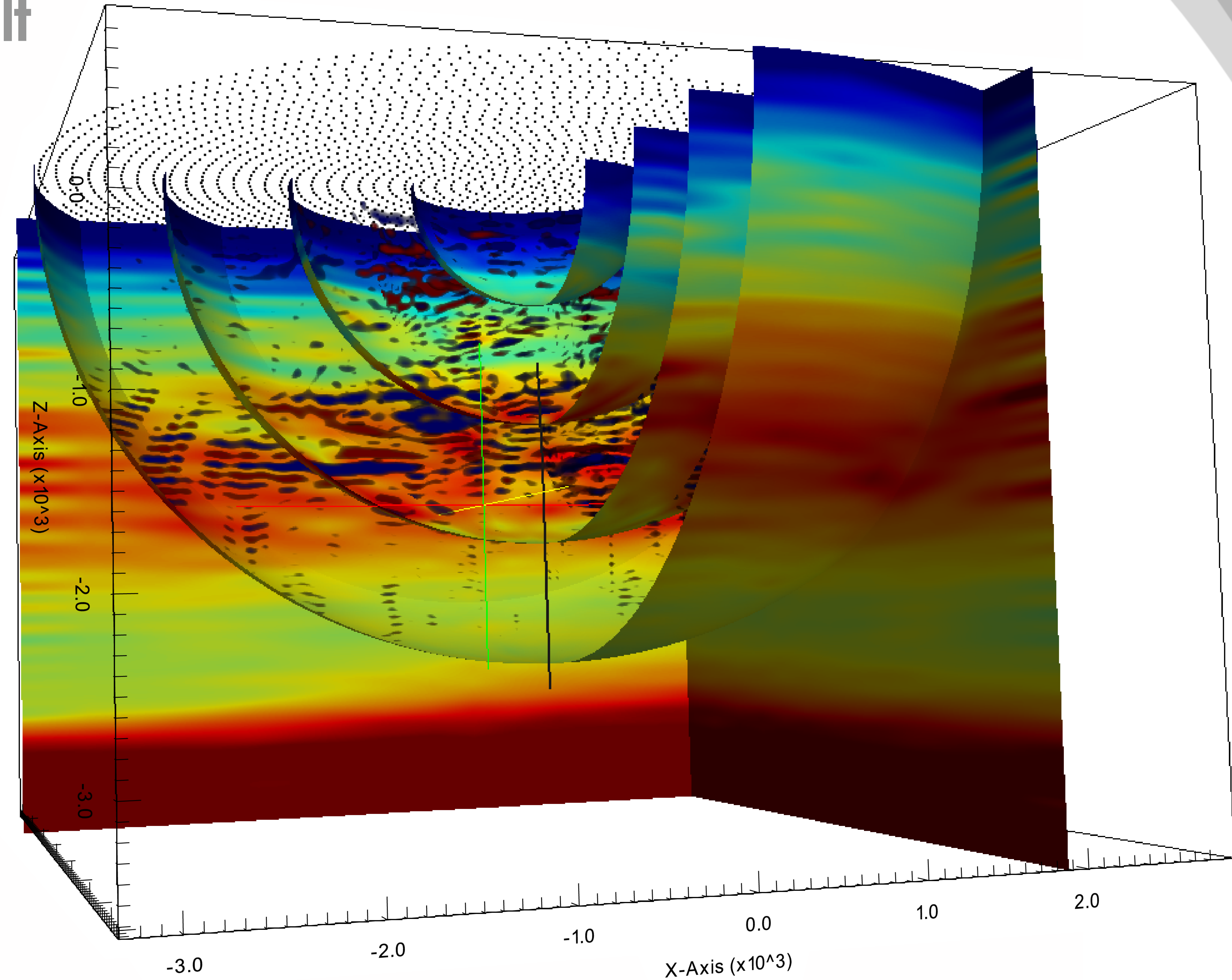
- frequency domain
- parallel Matlab
- discretize-then-optimize
- quasi-Newton / Gauss-Newton methods
- no data pre-processing

SLIM

SLIM FWI software; development

- added functionality to handle field data
- added options to handle too-big-for-memory files though Matlab
- created automatic algorithms to remove ‘bad’ sources/receivers

Pseudo-3D result



Regularization

Initial results without regularization were not good.

attempted to use Tikhonov-style regularization

minimize:

$$\phi(m) = f(m) + \frac{\alpha}{2}\|R_1 m\|^2 + \frac{\beta}{2}\|R_2 m\|^2$$

finding good weights was too time-consuming

Regularization

$$\phi(m) = f(m) + \frac{\alpha}{2}\|R_1 m\|^2 + \frac{\beta}{2}\|R_2 m\|^2$$

instead we work with a constrained problem:

$$\min_m f(m) \quad s.t. \quad m \in C_1 \cap C_2$$

Regularization

$$\min_{m} f(m) \quad s.t. \quad m \in C_1 \cap C_2$$

“find a model which satisfies all pieces of prior info simultaneously”

Can solve using projection methods:

- no weights to be determined
- model satisfies prior info at every iteration
- can work with more than 2 sets
- can work with gradient-descent, quasi-Newton, Newton-type

Regularization

$$\min_{m} f(m) \quad s.t. \quad m \in C_1 \cap C_2$$

The convex sets can be:

- bound constraints
- minimum smoothness constraints
- much more

Regularization

$$\min_{m} f(m) \quad s.t. \quad m \in C_1 \cap C_2$$

implementation:

Dykstra-splitting within spectral projected gradient with a quasi-Newton method.

spectral projected gradient with a quasi-Newton method: PQN

[Schmidt et. al, 2009]

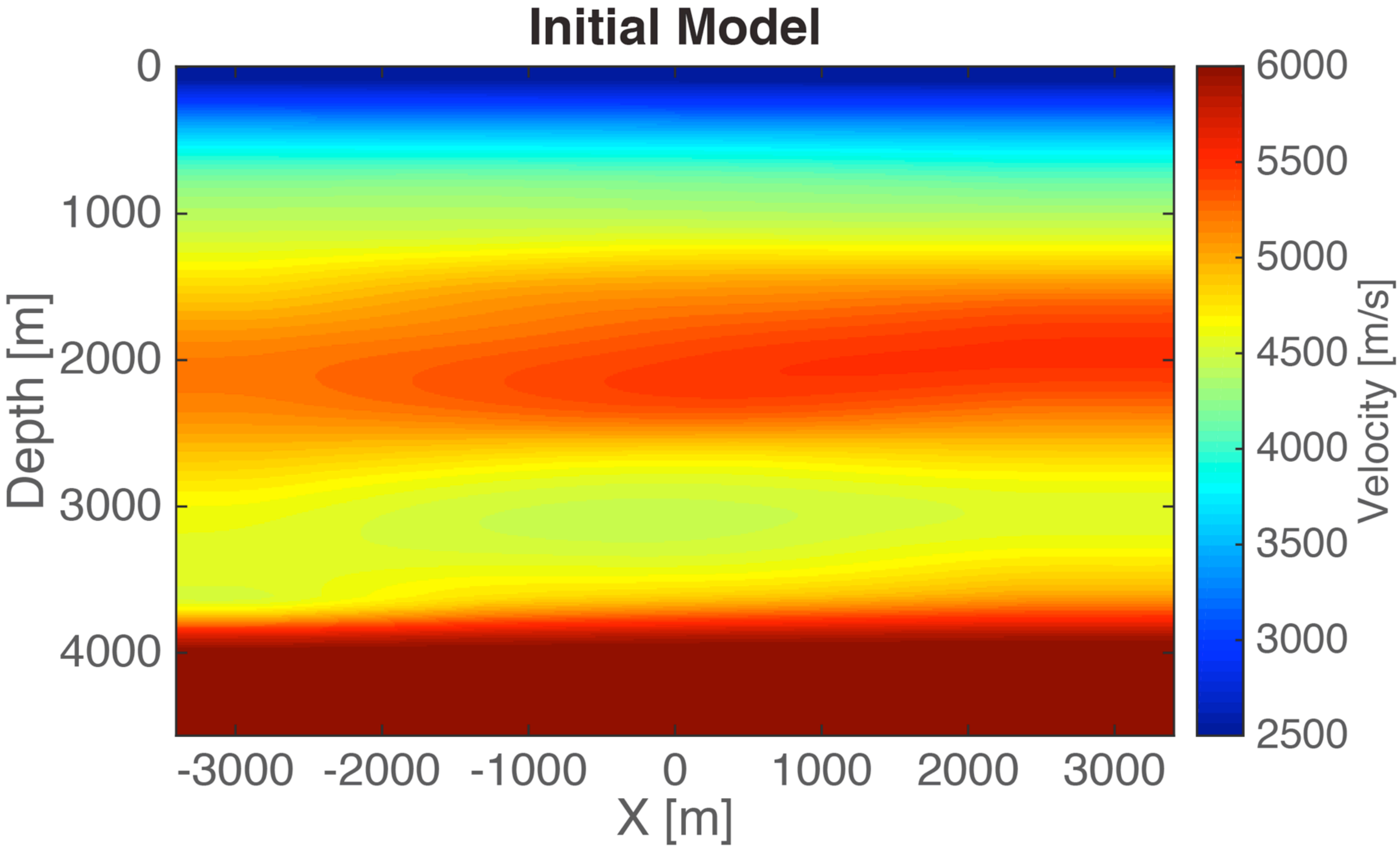
Regularization

$$\min_{m} f(m) \quad s.t. \quad m \in C_1 \cap C_2$$

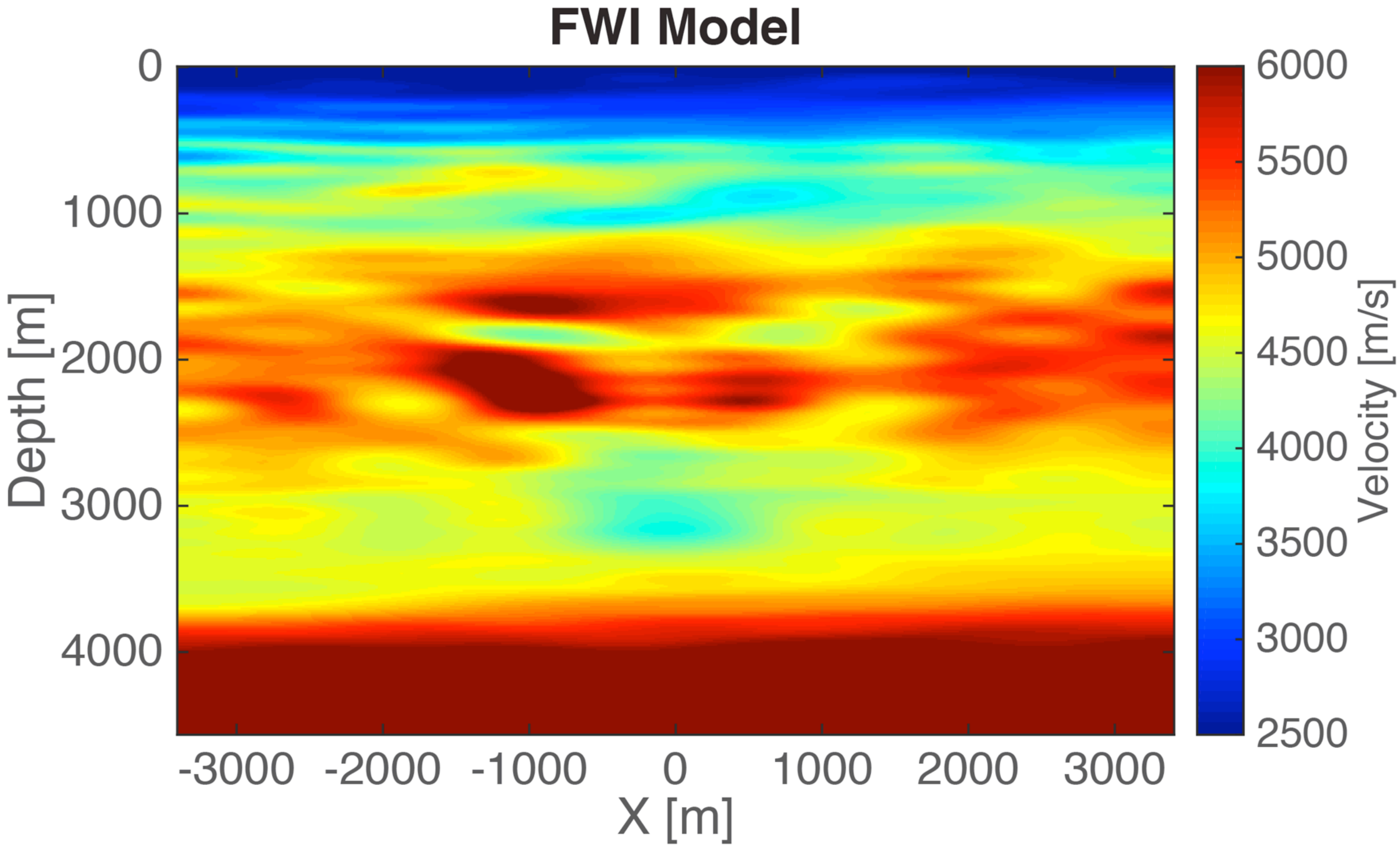
for multi-parameter anisotroptic Wavefield Reconstruction Inversion:

Dykstra-splitting within ADMM within Projected-Newton-type

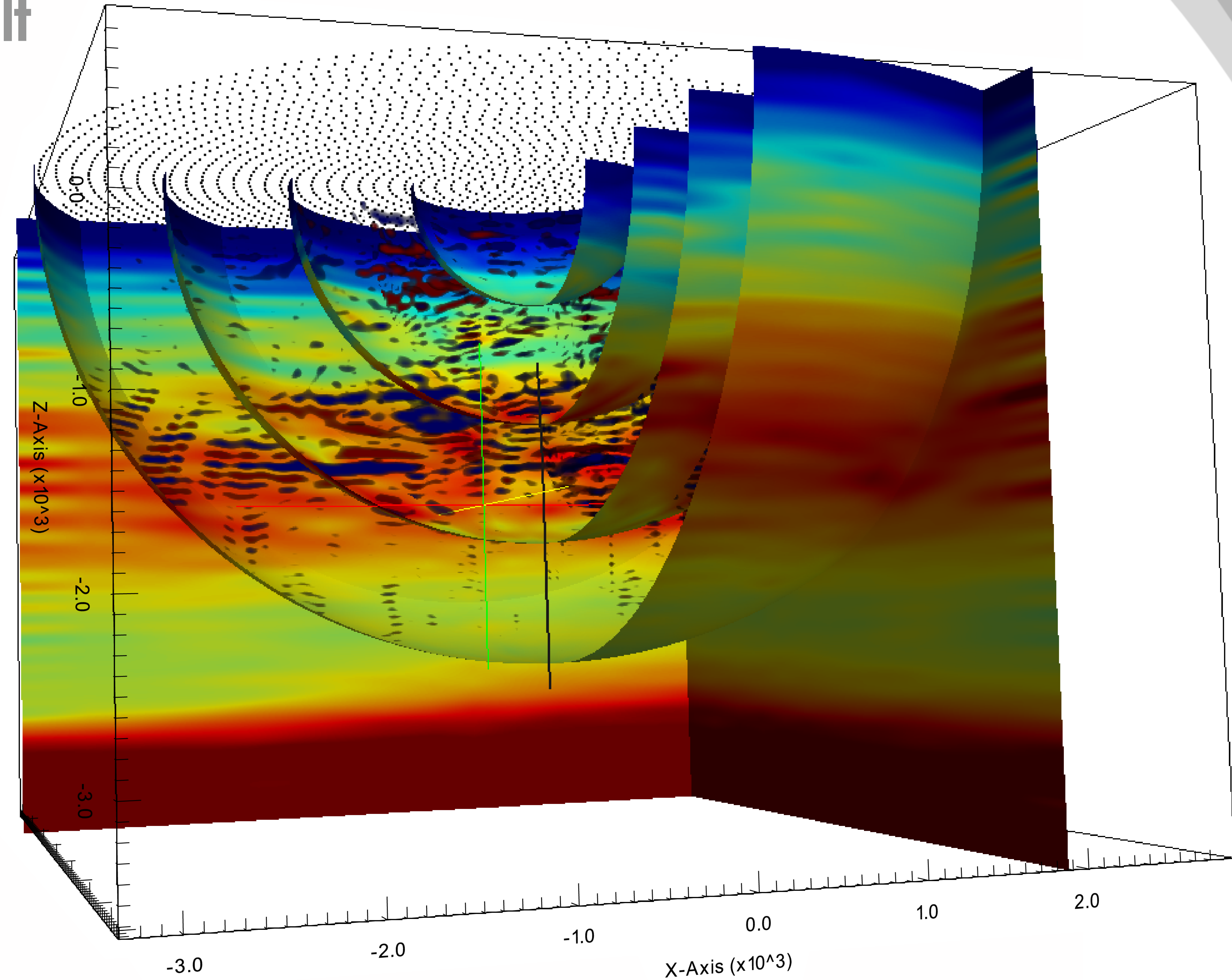
Initial model

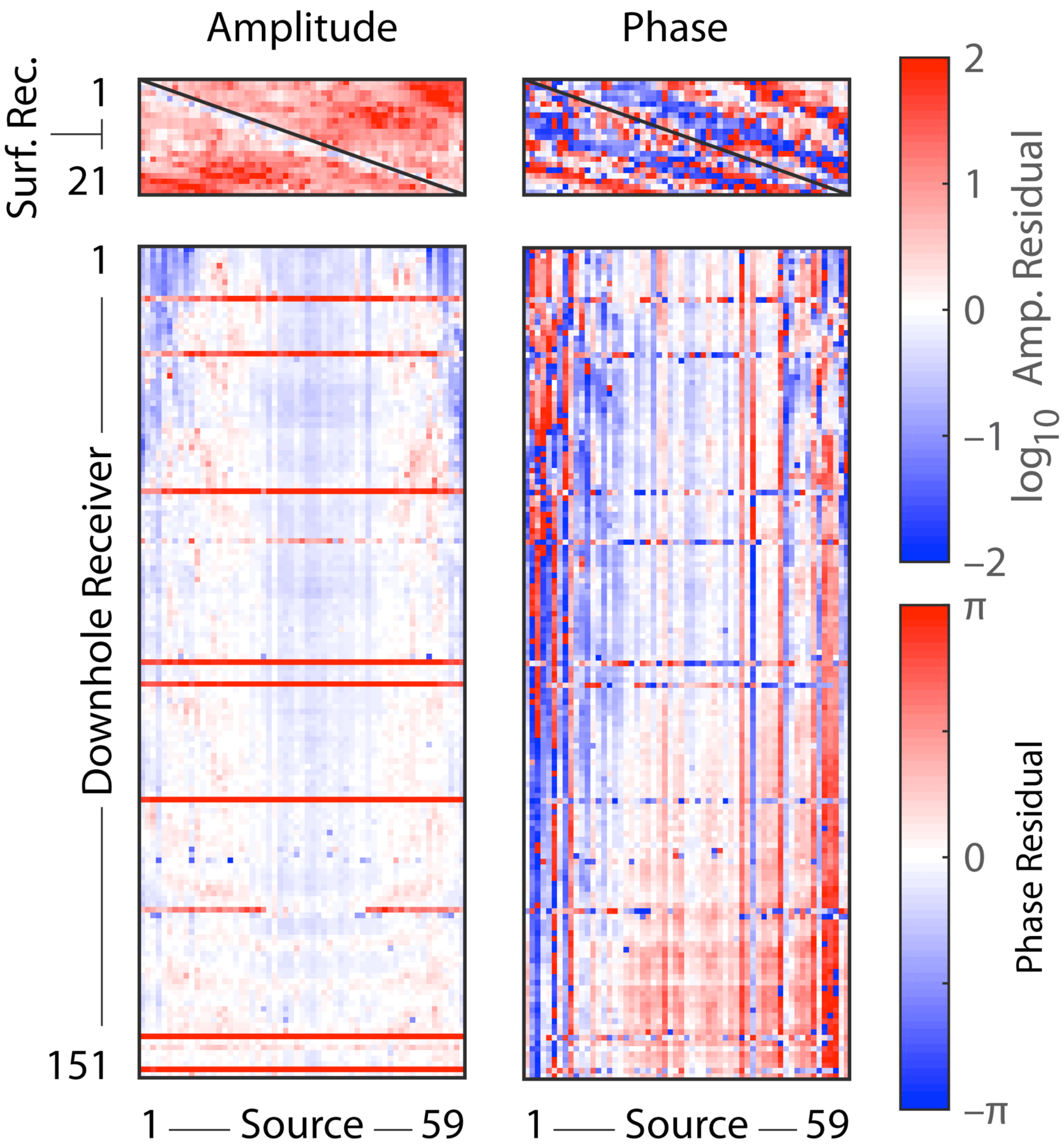


Final model, used PQN

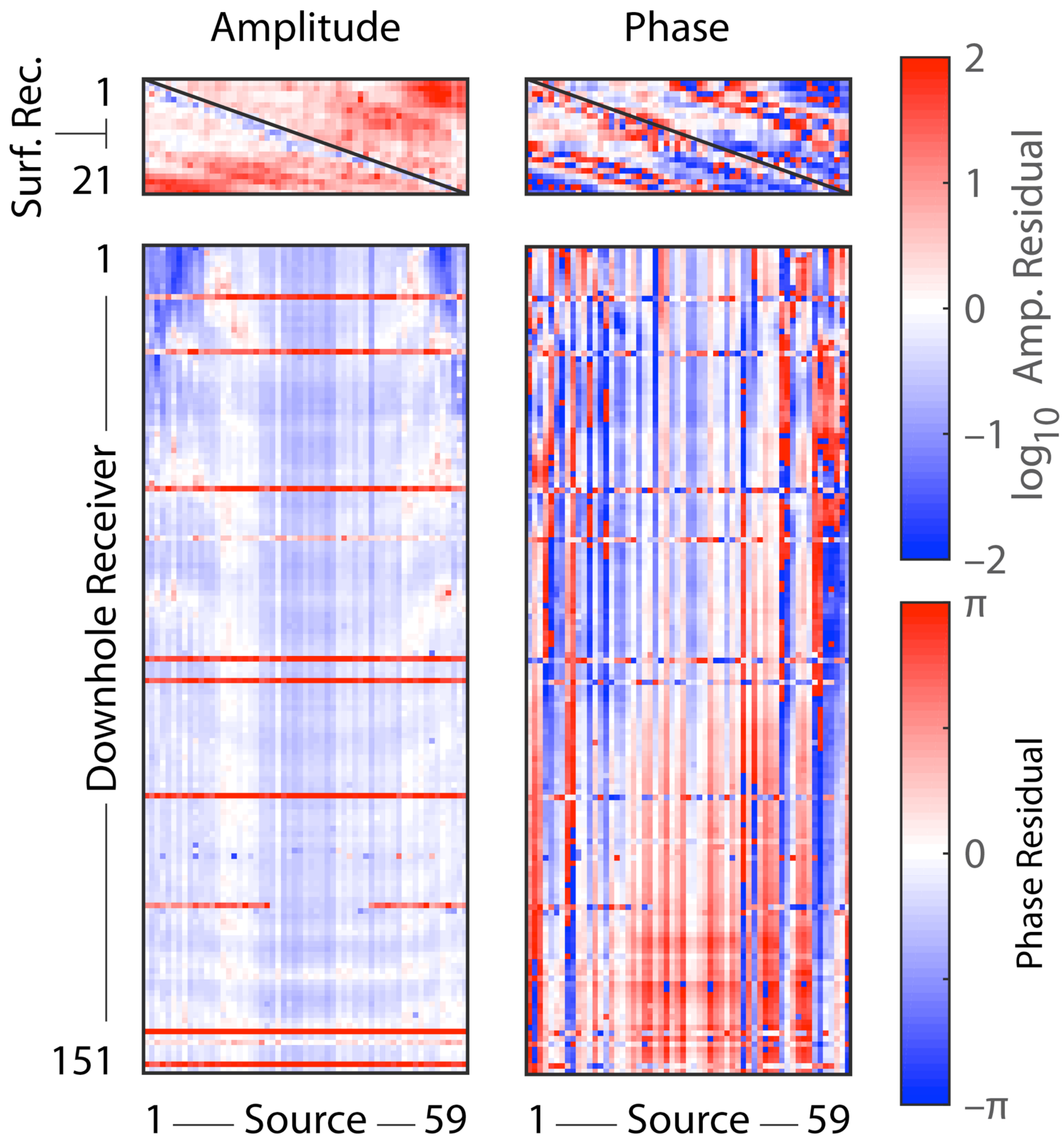


Pseudo-3D result

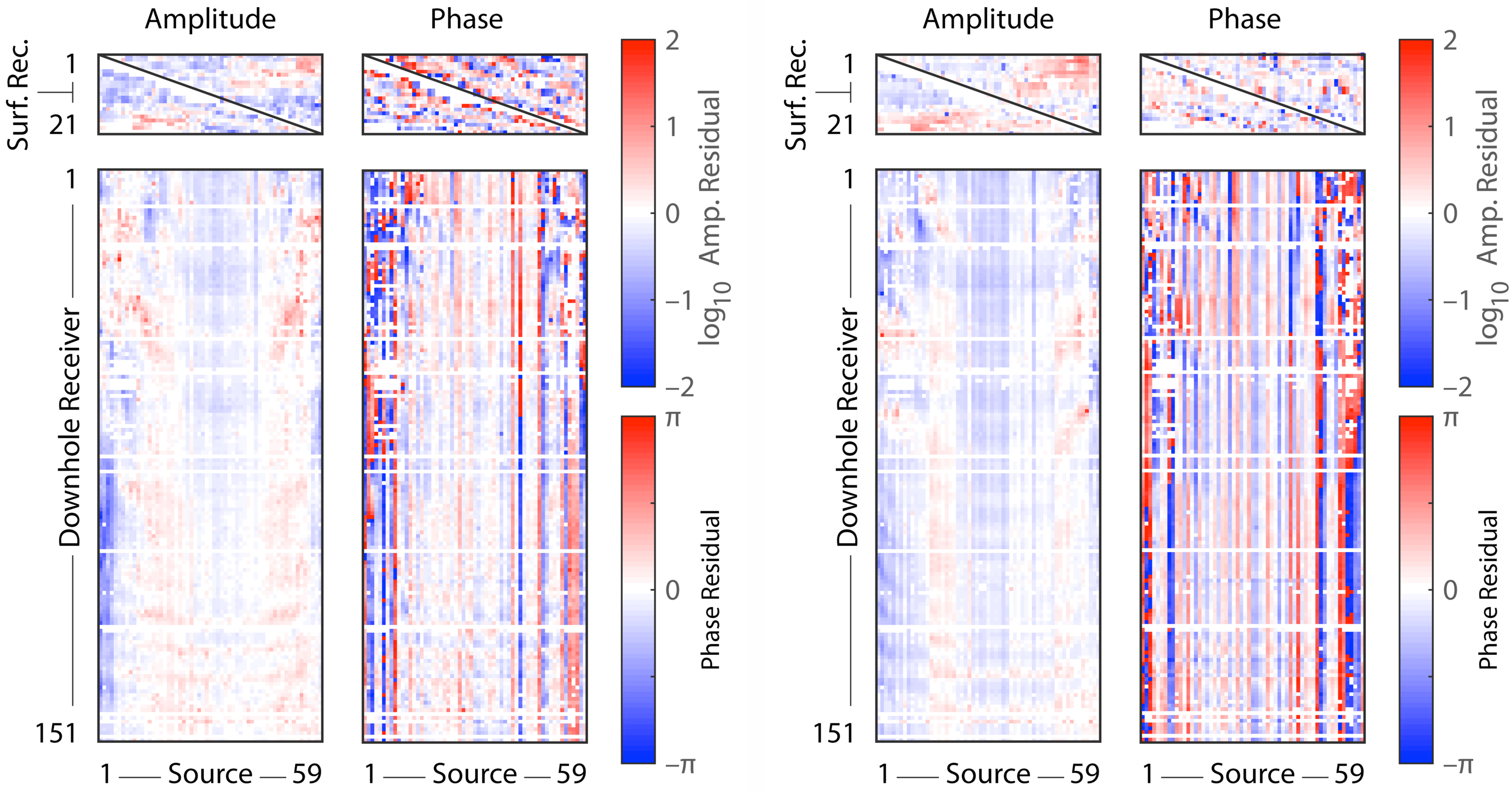




Initial Model — 8.75 Hz

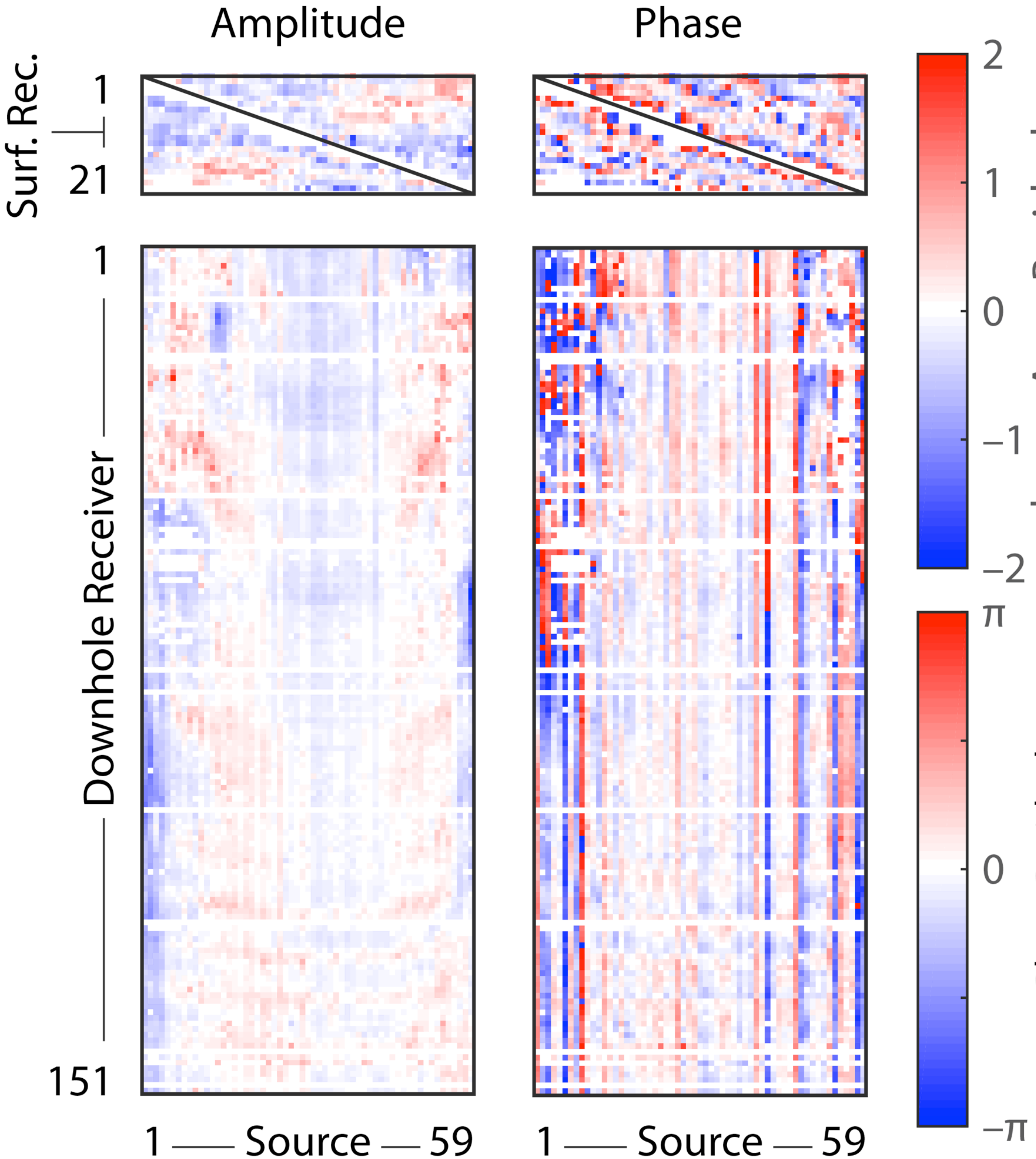


Initial Model — 15.75 Hz

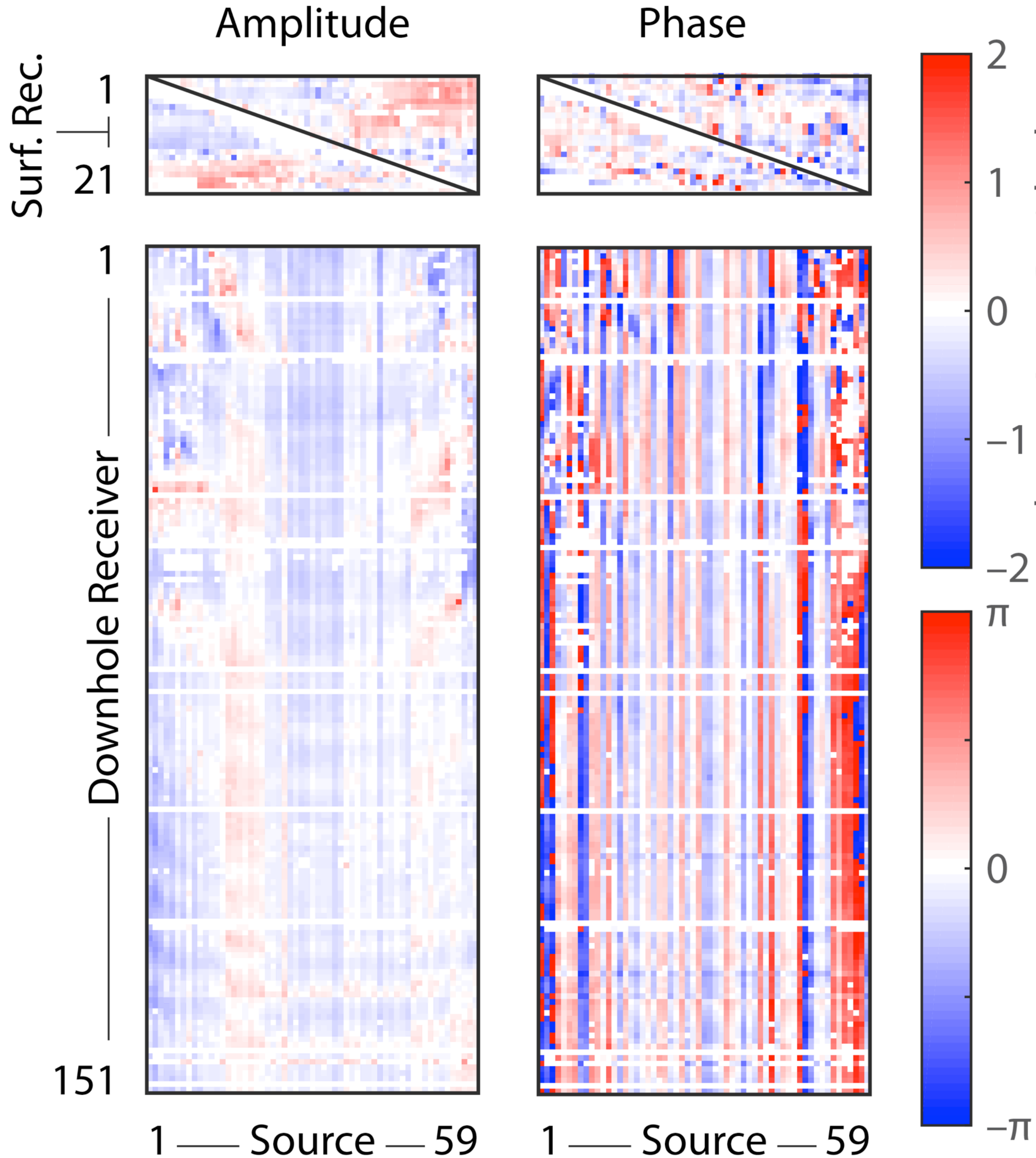


Stage 1 FWI Model — 8.75 Hz

Stage 1 FWI Model — 15.75 Hz



Stage 2 FWI Model — 8.75 Hz



Stage 2 FWI Model — 15.75 Hz

Quality control

decreased phase residuals

good agreement with check shot model near well

more quality control is work in progress

SLIM

Current work

Anisotropic modeling (done)

- use fixed and provided anisotropy model
- invert for anisotropy (1 parameter) and velocity

Wavefield Reconstruction Inversion (done)

Repeat in 3D

SLIM

Conclusions

SLIM FWI codes work on real data.

Discretize-then-optimize & quasi-Newton methods are successful.

Developed additional software for data handling in parallel Matlab.

Set up an easy-to-use regularization and optimization framework.