中国科学技术大学
University of Science and Technology of China
地球和空间科学学院
School of Earth and Space Sciences

Introduction to SWIT

Haipeng Li (李海鹏) (haipengl@mail.ustc.edu.cn)

Supervisor：Prof. Junlun Li (李俊伦) (lijunlun@ustc.edu.cn)

USTC

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Introduction to SWIT

1. Features of SWIT
2. Installation of SWIT
3. How to run SWIT
4. Cases of SWIT

Introduction to SWIT

1. **Features of SWIT**
2. Installation of SWIT
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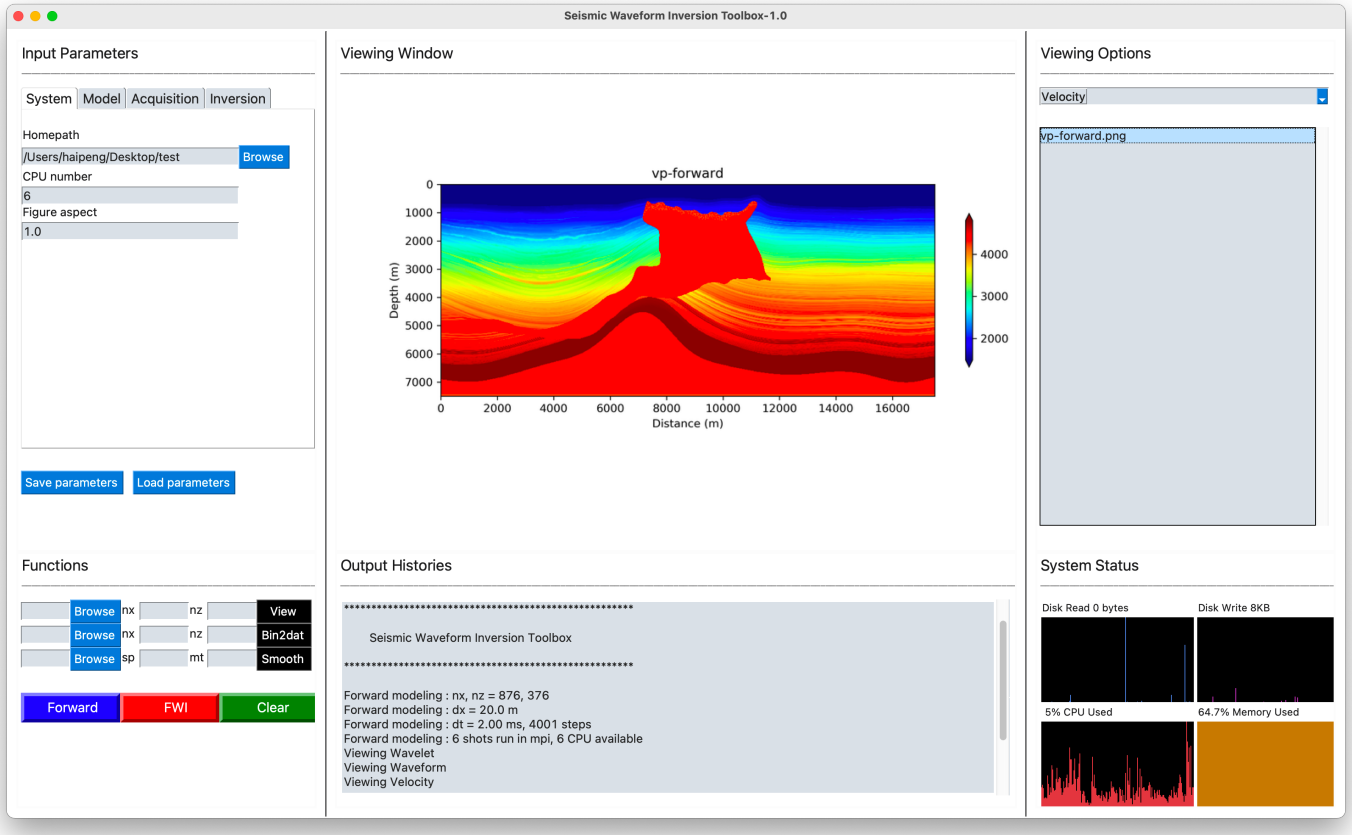
Features of SWIT

Homepage: https://github.com/Haipeng-ustc/SWIT-1.0

(Please star the project for latest updates)

- ✓ Forward wavefield modeling (FD)
- ✓ Adjoint wavefield modeling (FD)
- ✓ Calculation of gradient (on-the-fly)
- ✓ Preconditioning & Regularization
- ✓ L-BFGS & NLCG
- ✓ Effective Step Length Search
- ✓ Various misfit functions
- ✓ Multi-scale inversion

Seismic Waveform Inversion Toolbox



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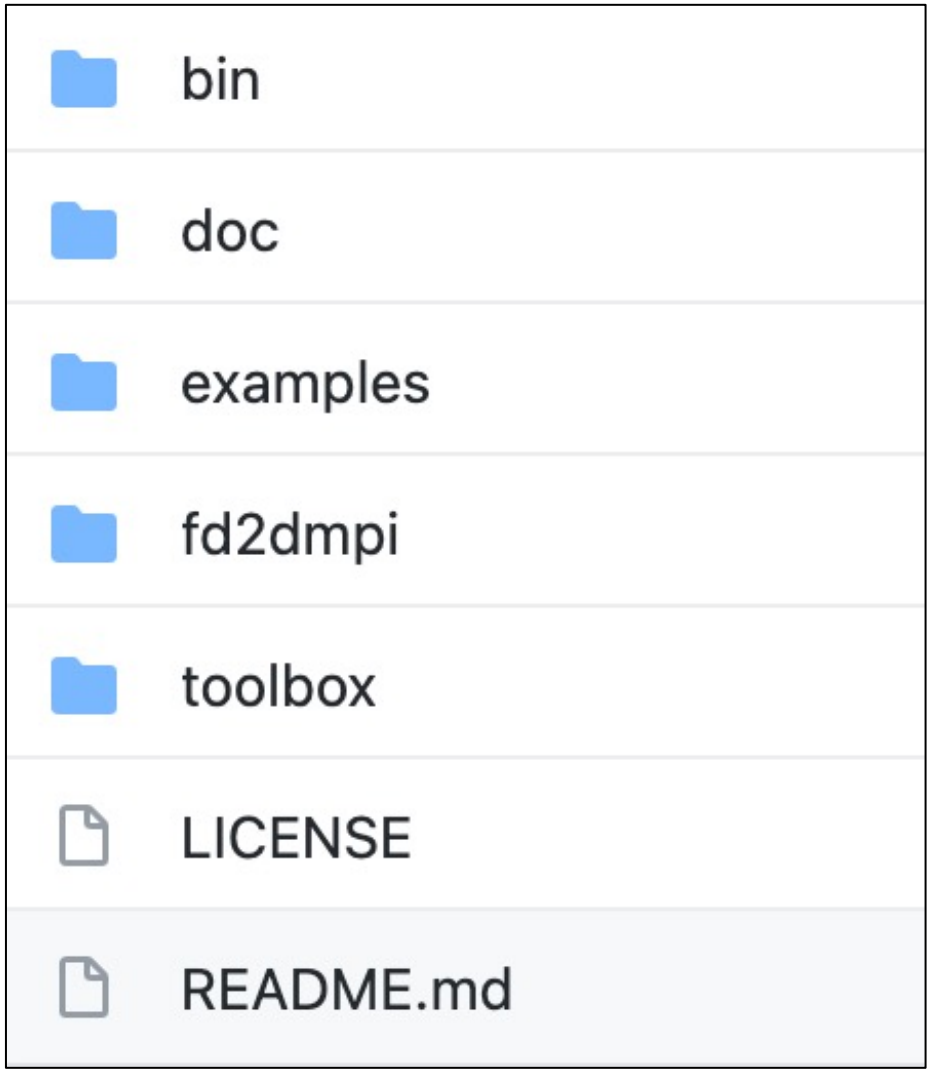
Features of SWIT

Homepage: https://github.com/Haipeng-ustc/SWIT-1.0

(Please star the project for latest updates)

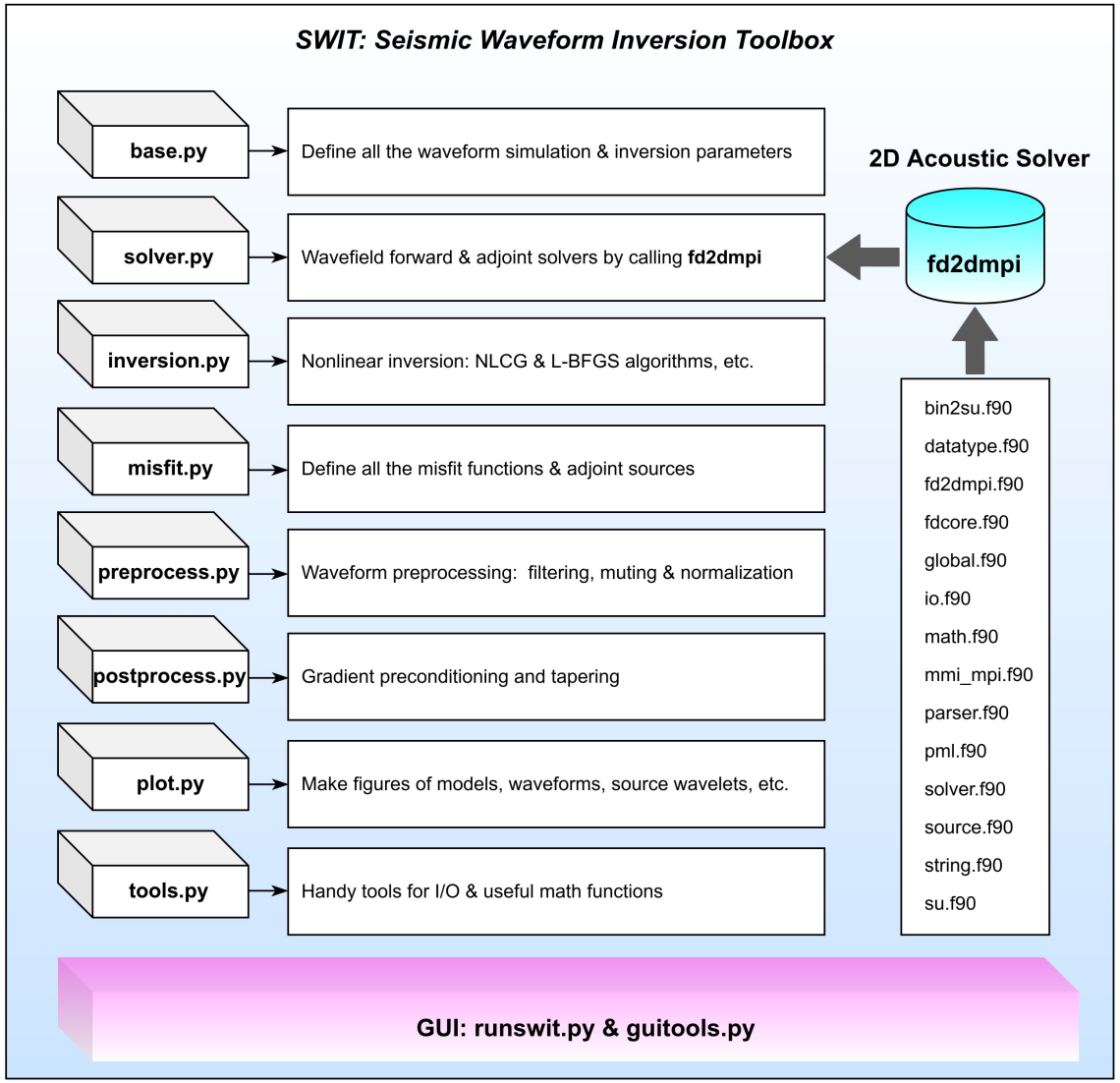
- ✓ Our in-house FWI platform (Keep updating)
- ✓ FD modeling engine (Efficient Fortran, MPI)
- ✓ State-of-the-art algorithms (Flexible Python)
- ✓ Easy definition of parameters (GUI)
- ✓ Industry-standard data format (SU data stream)
- ✓ Cross platform (Linux & MacOS)

Contents of SWIT



- The compiled wavefield solver (fd2dmpi)
- The Manual (keep updating)
- The provided examples (keep updating)
- Wavefield solver code in Fortran
- Full-waveform inversion code in Python
- License
- Readme

Structures of SWIT



- **Forward: Fortran, MPI**
- **Inversion: Python**
- **Usage:**
  - ✓ opt 1: GUI
  - ✓ opt 2: Python script
  - ✓ opt 3: Jupyter Notebook

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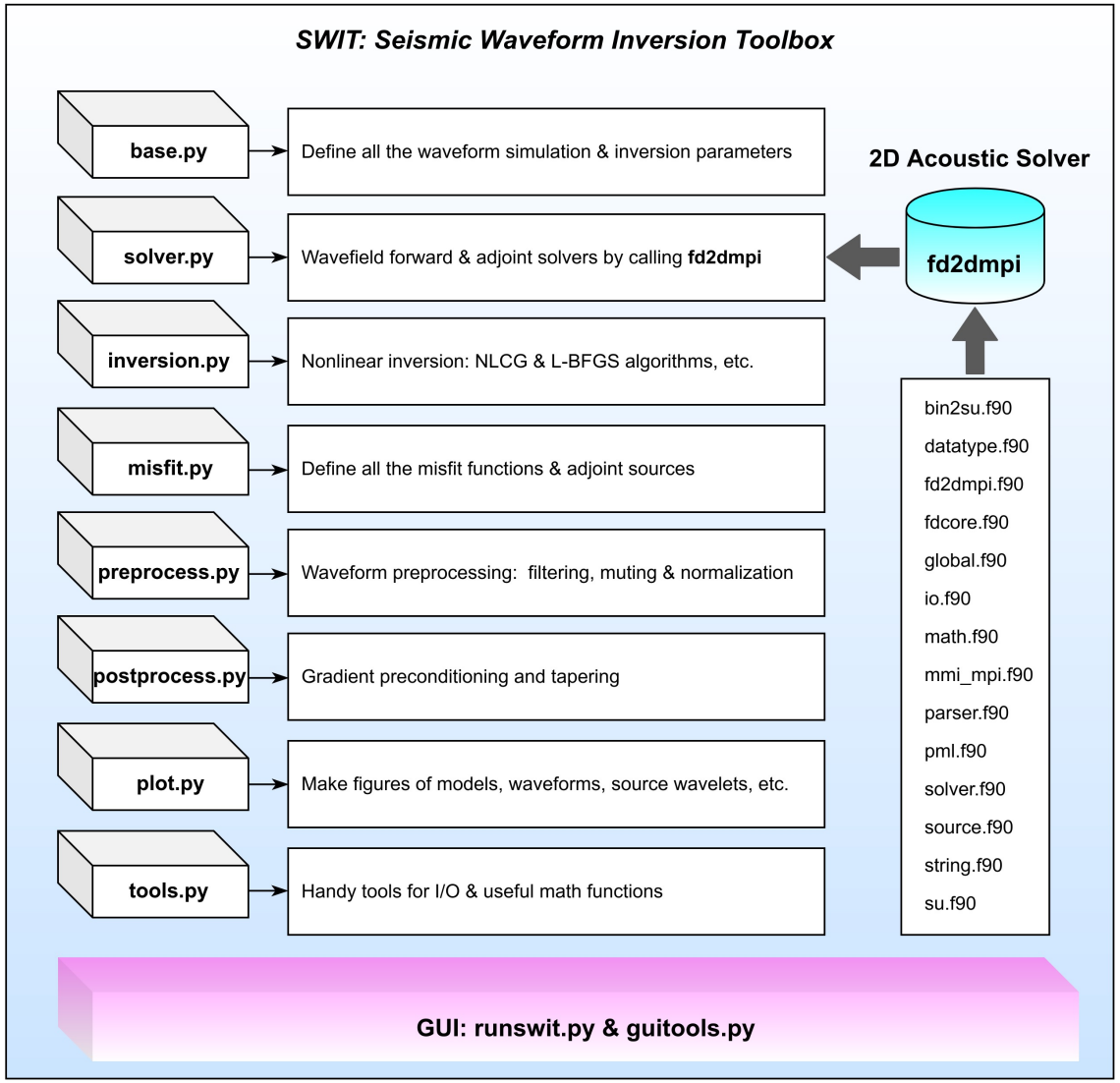
Structures of SWIT



➢ **Forward: Fortran, MPI**

➢ **Inversion & Usage: Python**

NumPy

ObsPy
A Python Framework for Seismology

SciPy

PySimpleGUI™

matplotlib . . .

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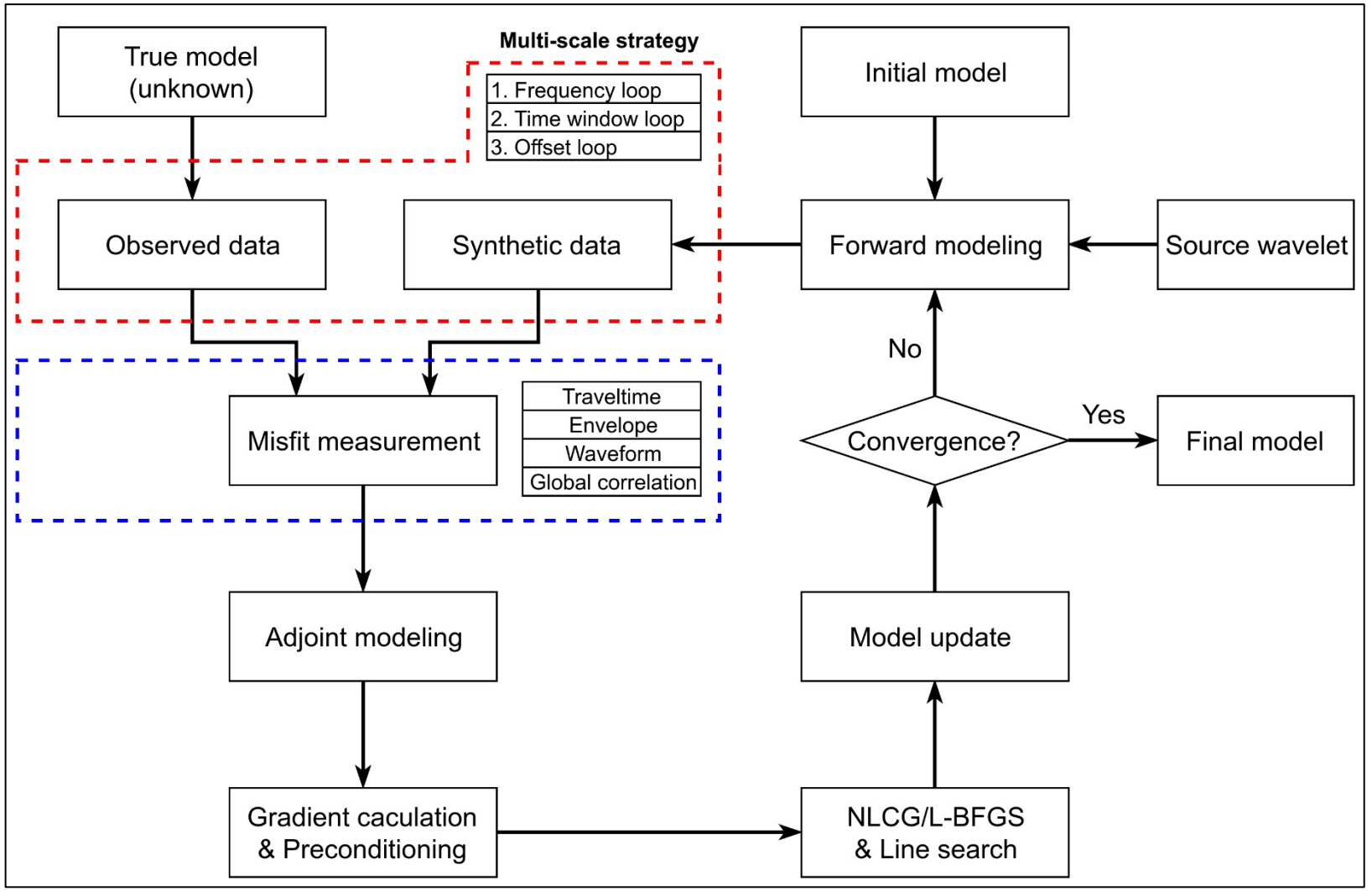
Workflow of SWIT

SWIT solves the **variable-density acoustic wave equation** in the stress-velocity form

SWIT uses a **4th-order Butterworth filter (zero-phase)**



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Installation of SWIT

(Tested on Ubuntu 16.04, 18.04, 20.04)

Homepage: https://github.com/Haipeng-ustc/SWIT-1.0

Step 1.

```
sudo apt-get install build-essential

sudo apt install gfortran
```

If you have already installed gfortran, gcc, MPI, Anaconda (recommended), go to"

- **Step3:** install Python dependencies, and then
- **Step4:** compile fd2dmpi

Installation of SWIT

(Tested on Ubuntu 16.04, 18.04, 20.04)

Step 2. Install OpenMPI

```
# Down load OpenMPI, and then install  (Home website: http://www.open-mpi.org/software/ompi)
wget https://download.open-mpi.org/release/open-mpi/v4.1/openmpi-4.1.1.tar.gz
tar xvfz openmpi-4.1.1.tar.gz
cd openmpi-4.1.1
# configure & make (takes some time)
./configure --prefix=/usr/local/openmpi CC=gcc FC=gfortran
make    # make -j8 (use 8 cores to accelerate the process)
sudo make install
# add environment path to  ~/.bashrc and check whether you successfully install OpenMPI or not
export PATH=/usr/local/openmpi/bin:$PATH
source ~/.bashrc
which mpirun
```

Installation of SWIT

(Tested on Ubuntu 16.04, 18.04, 20.04)

Step 3. Install Anaconda and Python Dependencies

```
# For install Anaconda, refer to: https://docs.anaconda.com/anaconda/install/linux/

# download package from: https://www.anaconda.com/products/individual/download-success

# bash ~/your_Anaconda_package

# Create new Anaconda env for SWIT

conda create --name SWIT python=3.7

conda activate SWIT

# Install python dependencies using pip with USTC resources

pip install numpy obspy scipy matplotlib -i https://pypi.mirrors.ustc.edu.cn/simple/

pip install multiprocess PySimpleGUI psutil Pillow -i https://pypi.mirrors.ustc.edu.cn/simple/
```

Installation of SWIT

(Tested on Ubuntu 16.04, 18.04, 20.04)

Step 4. Compile the wavefield solver fd2dmpi

```
# Compile the Fortran code

cd ~/SWIT-1.0/fd2dmpi/

rm *.mod; make clean; make

# add environment path to  ~/.bashrc

export PATH=~/SWIT-1.0/bin:$PATH

export PYTHONPATH=~/SWIT-1.0/toolbox

source ~/.bashrc

which fd2dmpi

python >>  import inversion      # test whether you can import this module from ~/SWIT-1.0/toolbox/
```

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How to run SWIT

(Tested on Ubuntu 16.04, 18.04, 20.04)

Opt 1: run SWIT via GUI

```
cd ~/SWIT-1.0/toolbox/

python runswit_Linux.py

# or python runswit_MacOS.py
```

Opt 2: run SWIT via Python script

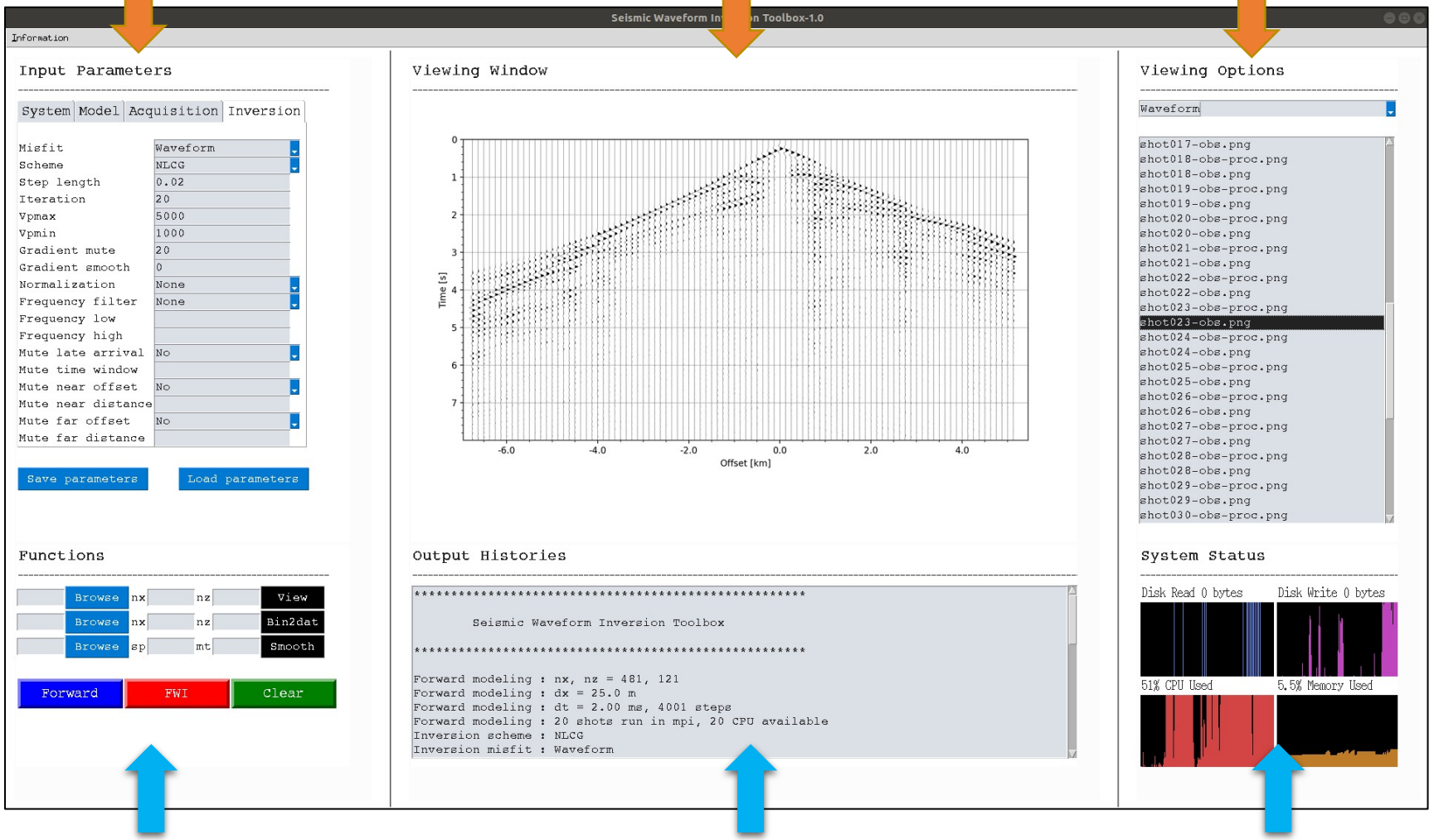
```
cd ~/example/some_case/

python -W ignore SWIT_workflow.py
```

Run SWIT via GUI

1. Input parameters

3. Viewing Window

5. Viewing Options

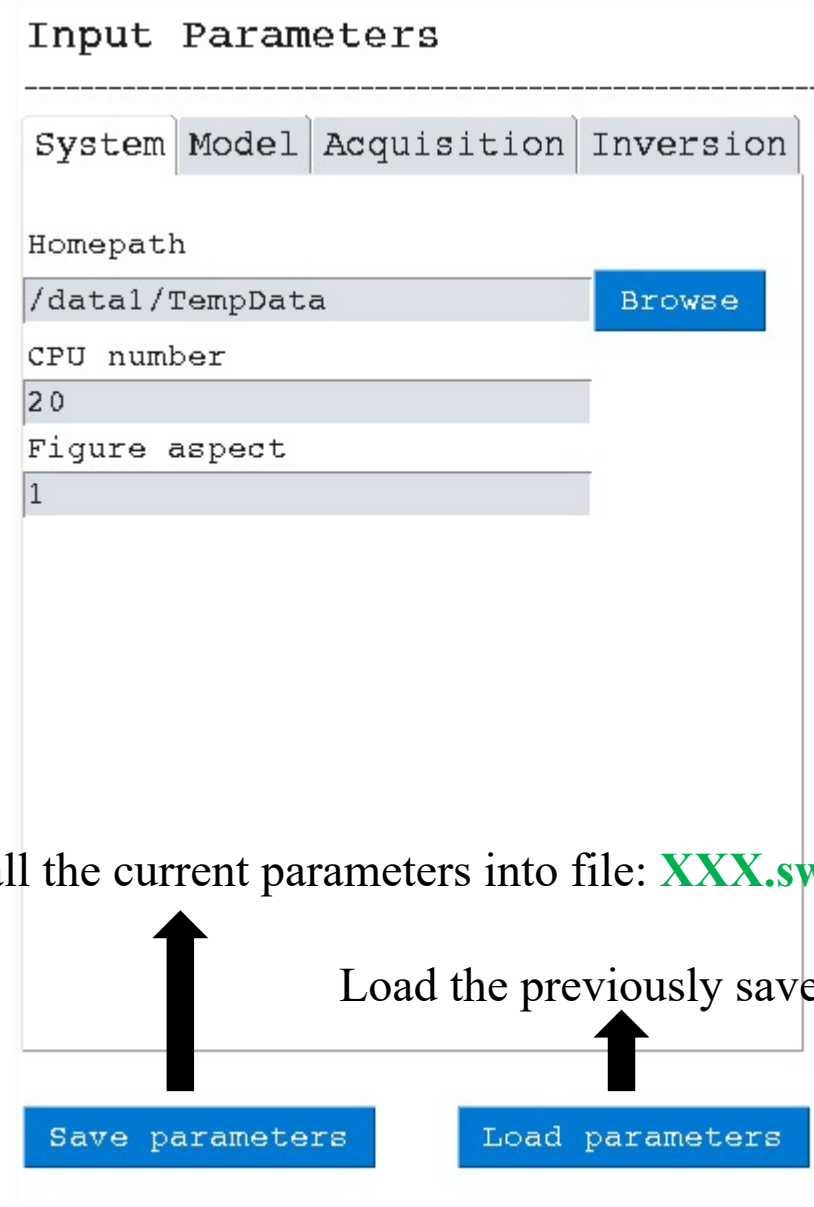


2. Functions

4. Output Histories

6. System Status

Input Parameters: System



Project working folder

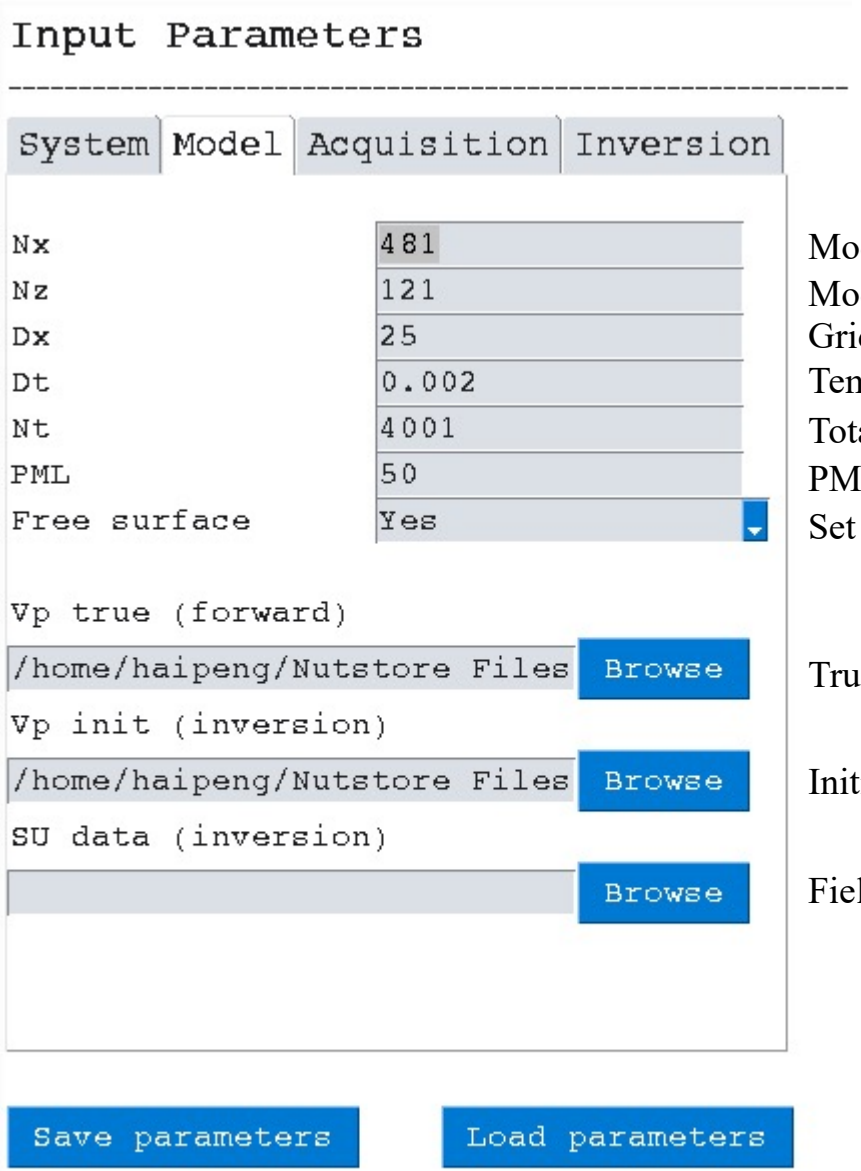
CPU number for MPI

Figure aspect for plotting

Save all the current parameters into file: **XXX.swit**

Load the previously saved parameter file: **XXX.swit**

Input Parameters: Model



Model size along x direction

Model size along z direction

Grid size (in m)

Temporal step (in s)

Total time steps

PML size, use a relatively large one, i.e., 50

Set free surface or not

True Vp model saved in the **txt file**

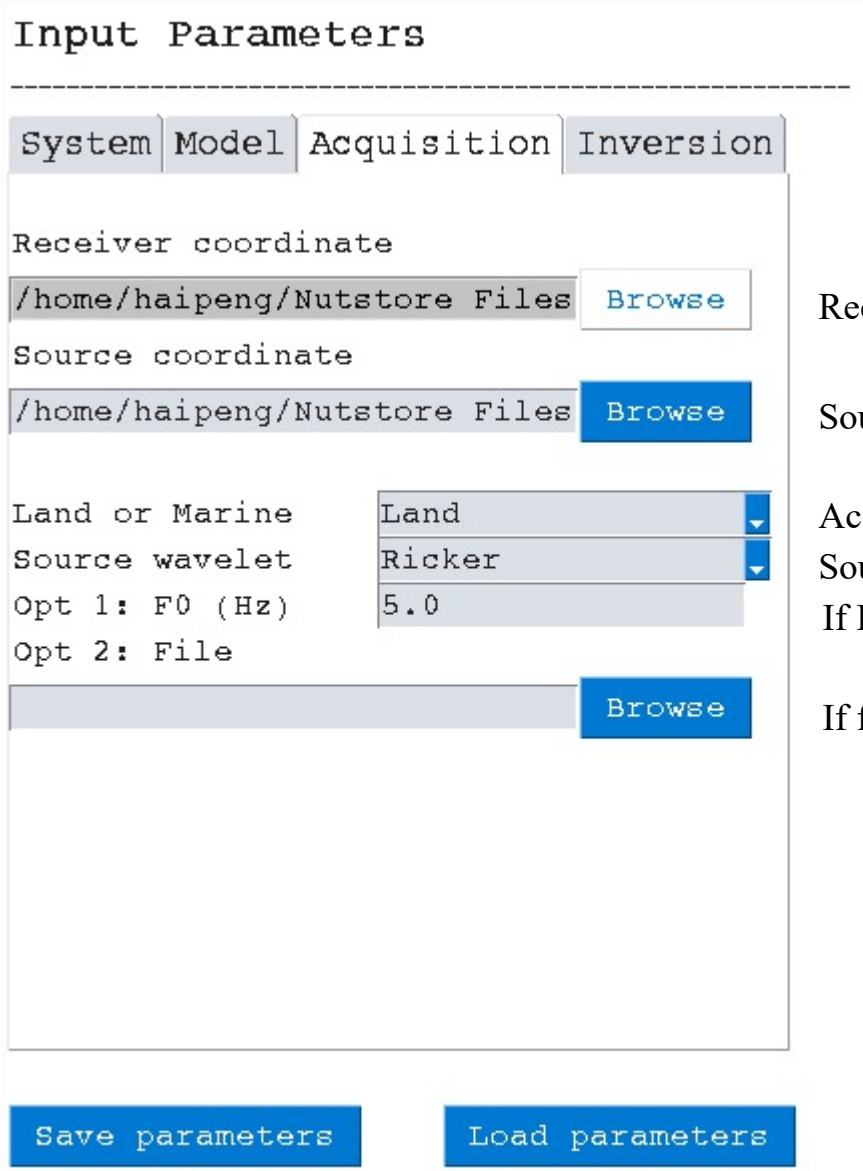
Initial Vp model saved in the **txt file**

Field-data path, data should be named as: **src1_sg.su, src2_sg.su, ..., src40_sg.su, ...**

For model study: Vp true & Vp init

For field-data: SU data & Vp init

Input Parameters: Acquisition



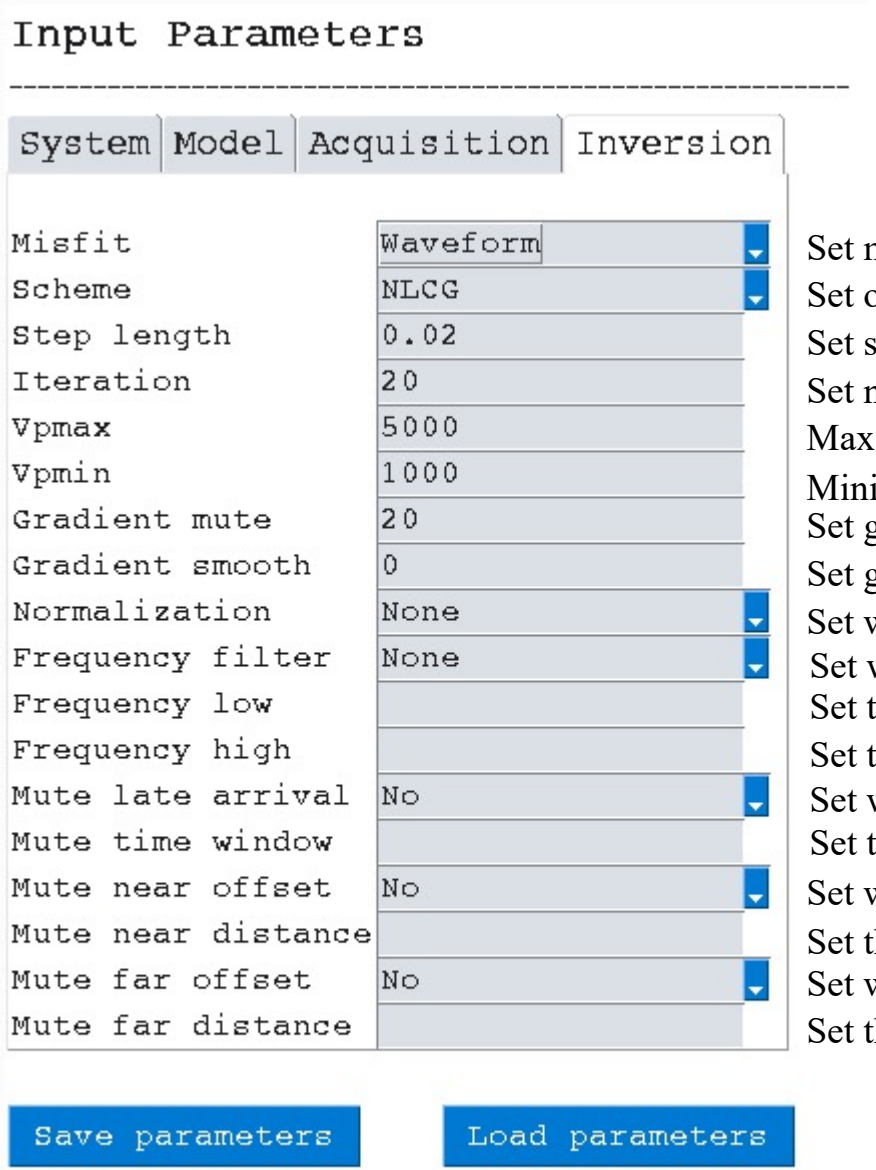
Receiver file, see examples for detailed format

Source file, see examples for detailed format

Acqusition type: land or marine
Source wavelet: Ricker or from file
If Ricker, set the dominant frequency

If from file, set the file path, txt files

Input Parameters: Inversion



Set misfit function: Waveform, Traveltime, etc.

Set optimization scheme: NLCG or L-BFGS **(NLCG is recommended)**

Set step length, i.e., 0.01 or 0.02 (with respect to Vp model), **small step length is recommended**

Set number of iteration

Maximum Vp (in m/s)

Minimum Vp (in m/s)

Set gradient mute. **In marine case, it's the water layer size; in land case, set as ~10 (in grid)**

Set gradient smoothing size, i.e., 10 (in grid)

Set whether to normalize the data. If so, set which type

Set whether to filter the data. If so, set which type

Set the low frequency bound (in Hz)

Set the high frequency bound (in Hz)

Set whether to mute late arrivals based on the automatically picked first break

Set the time window after the first break, i.e., 1.0 (in s)

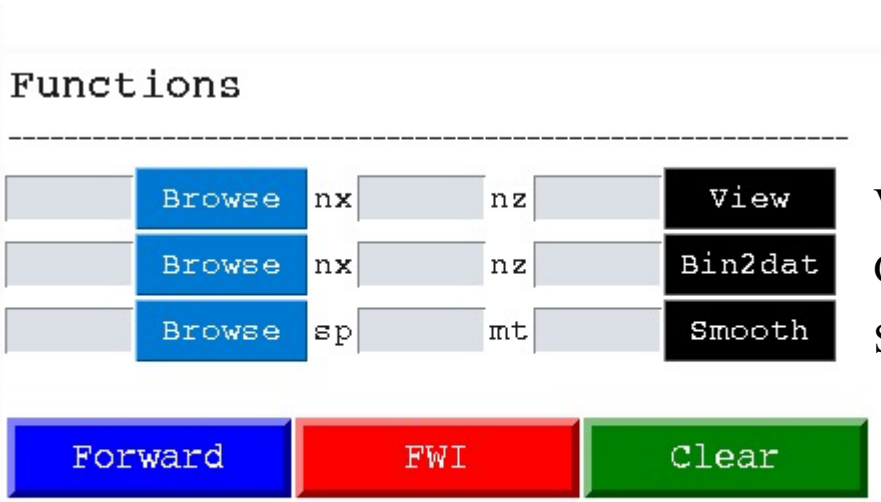
Set whether to mute traces of near offset

Set the distance to mute near offset distance (in m)

Set whether to mute far offset

Set the distance to mute traces of far offset distance (in m)

Functions



View a txt file (donot require nx & nz) or binary file (**require nx & nz**)

Convert a binary file to a txt file (**require nx & nz**)

Smooth a txt file. **sp:** the smoothing radius; **mt:** the top mute for any water layer

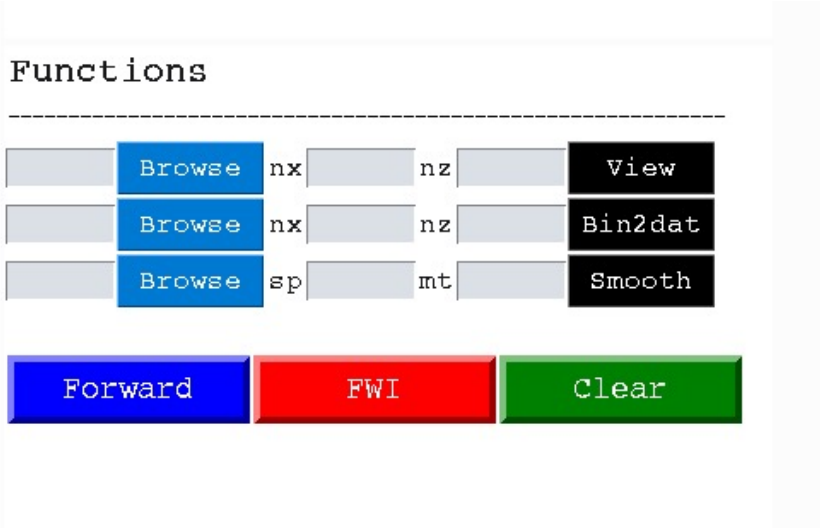
Forward Perform forward modeling based on the provided Vp true.

The generated shot gathers are saved in ~/data/obs/xxx.su

FWI Perform inversion based on the provided Vp initial and SU data

Clear **Clear output histories**

Few more words



- **Sythetic model FWI：**

  Step 1: set all the parameters **(must provide Vp true & Vp init)**;

  Step 2: run **Forward** to generate the ‘true’ data;

  Step 3: run **FWI** to perfrom the inversion.

- **Field-data FWI：**

  Step 1: set all the parameters **(must provide Vp init and SU data)**;

  Step 2: run **FWI** to perfrom the inversion.

Please keep in mind that the provided **SU data** should:

- Keep the same **source** and **receiver coordinates** with those set in the **Acquisition**
- Keep the same **Nt** and **Dt** with with those set in the **Model**
- For the varying locations of receivers with sources, use zero traces to keep all the receivers are the same for all sources
- Fill the bad traces with the zero traces, all the zero traces will be automatically skipped.

Run SWIT via Python script

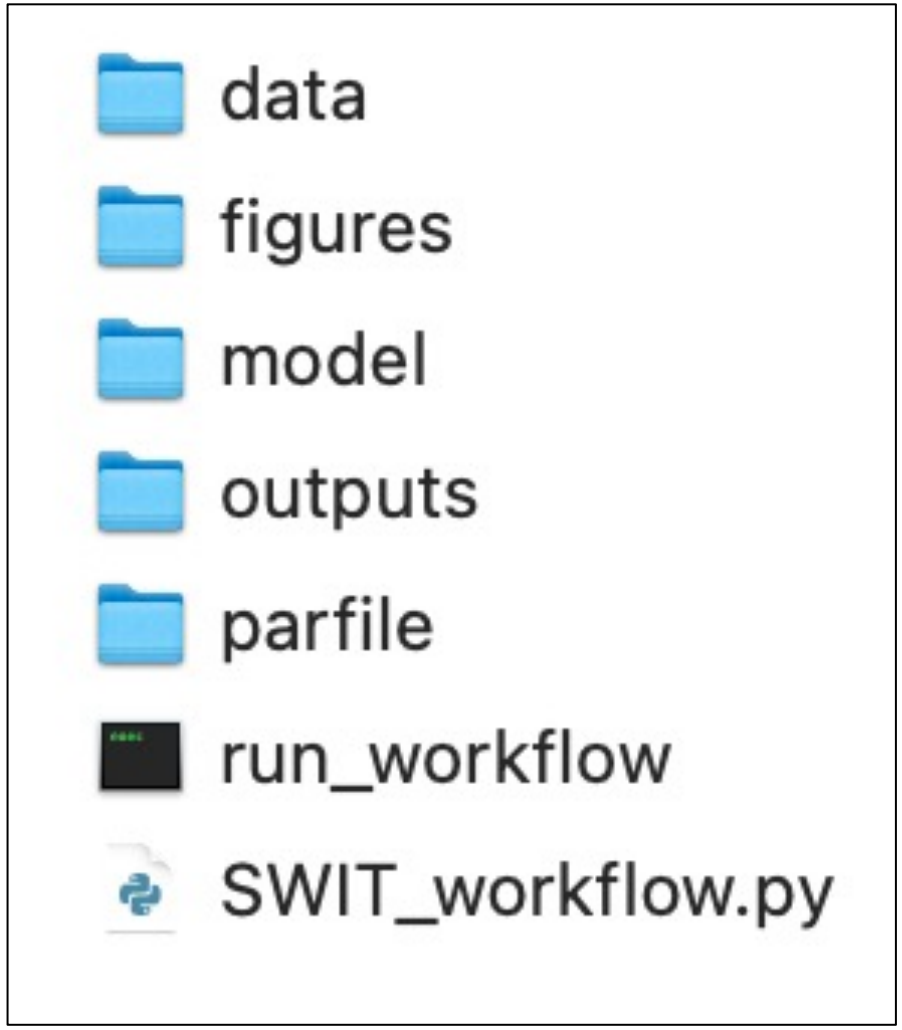
See the Python script under each example folder. All the parameters are well commented and thus should be axiomatic.

```python
# import modules
import numpy as np
import base
from inversion import inversion, source_inversion
from plot import plot_geometry, plot_model2D, plot_stf, plot_trace
from preprocess import process_workflow
from solver import forward, source_wavelet
from tools import saveparjson, smooth2d


### system setup
homepath   = '/data/haipeng/SWIT-1.0/examples/land-case1-marmousi/'   # working path
mpiproc    = 41                                    # mpi process for fd2dmpi
figaspect  = 1.0                                   # Figure aspect

### model setup
nx,  nz      = [481,  121]                         # Grid number along x and z directions
pml, fs      = [50,  True]                         # Grid number for PML layers (use a large one)
dx,  dt,  nt = [25, 0.002, 4001]                   # Grid size, time interval, and time step

# velocity and density
vp_true = np.zeros((nx, nz))
vp_init = np.zeros((nx, nz))
rho_true = np.zeros((nx, nz))
rho_init = np.zeros((nx, nz))

vp_true = np.loadtxt(homepath + 'model/Marmousi_481_121_25m_True.dat')
```

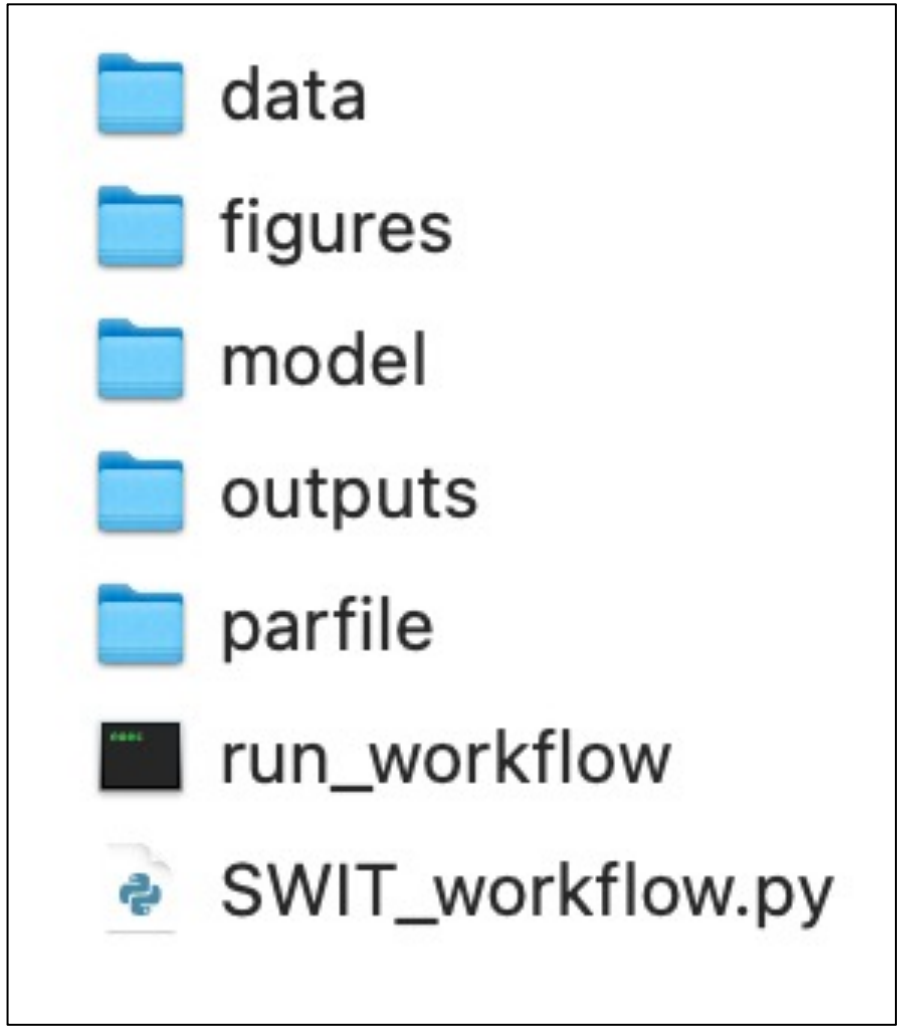
First activate SWIT Anaconda env, and then

python -W ignore SWIT_workflow.py

Outputs of SWIT



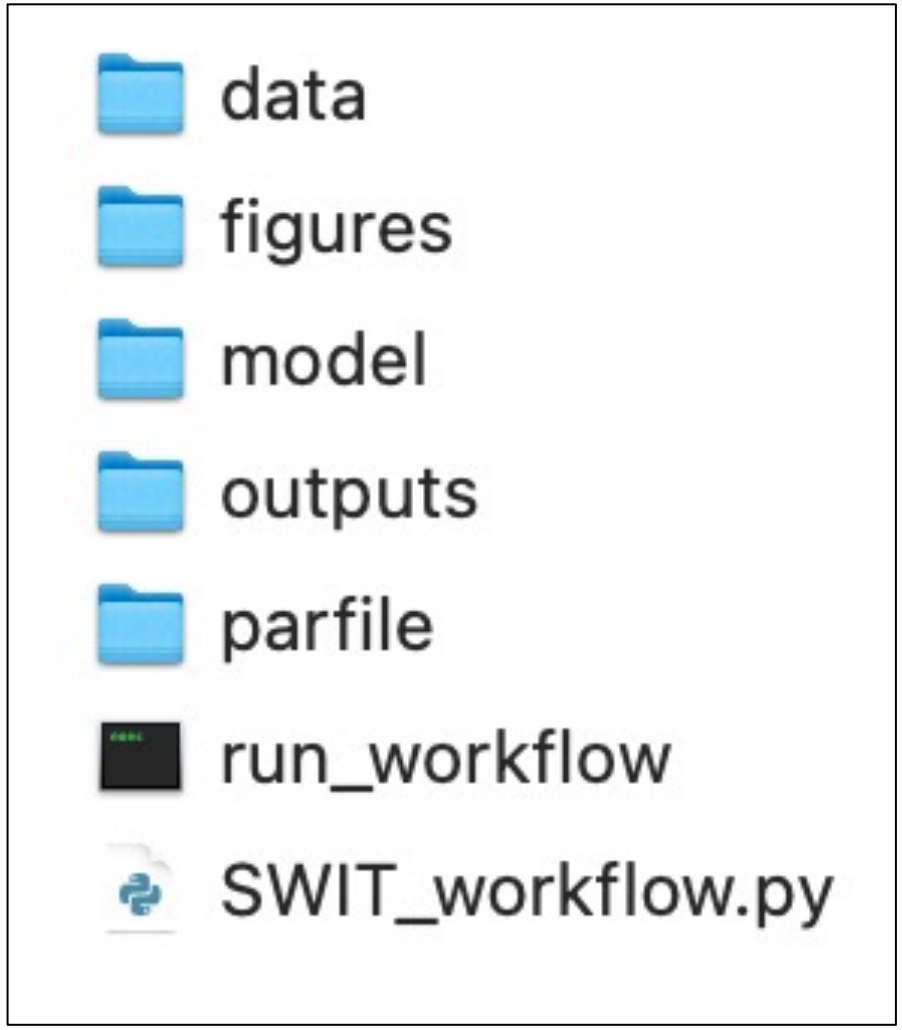
Outputs of SWIT

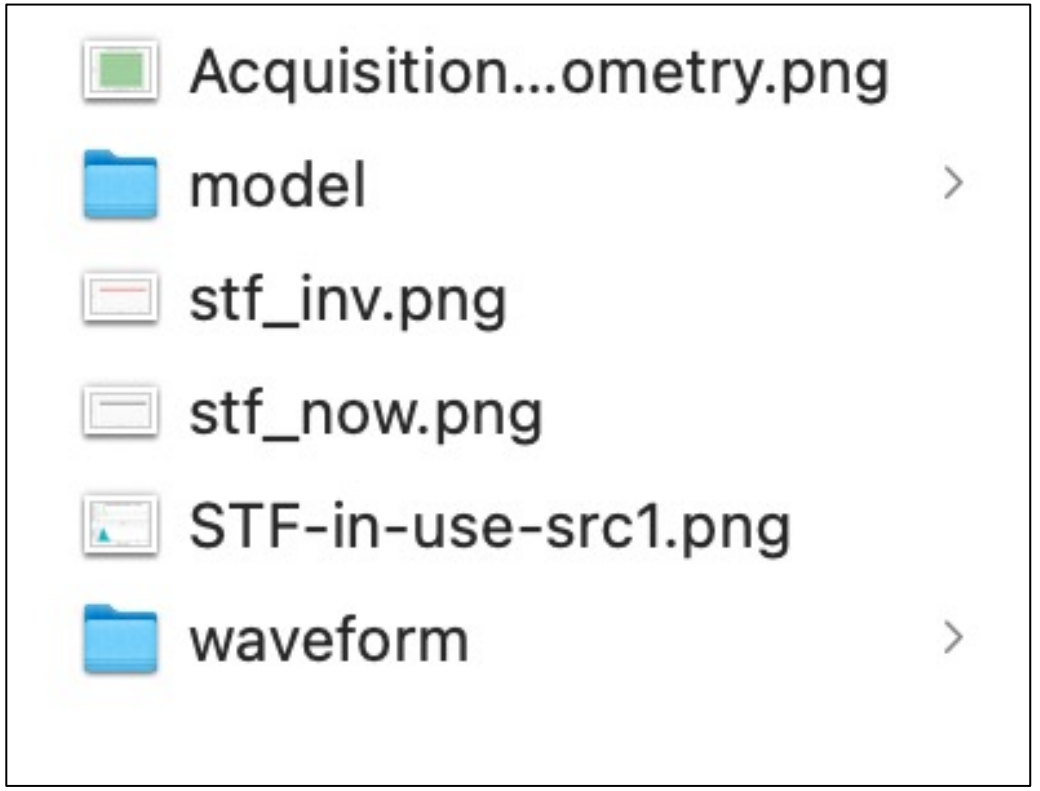


Waveform/wavefield data

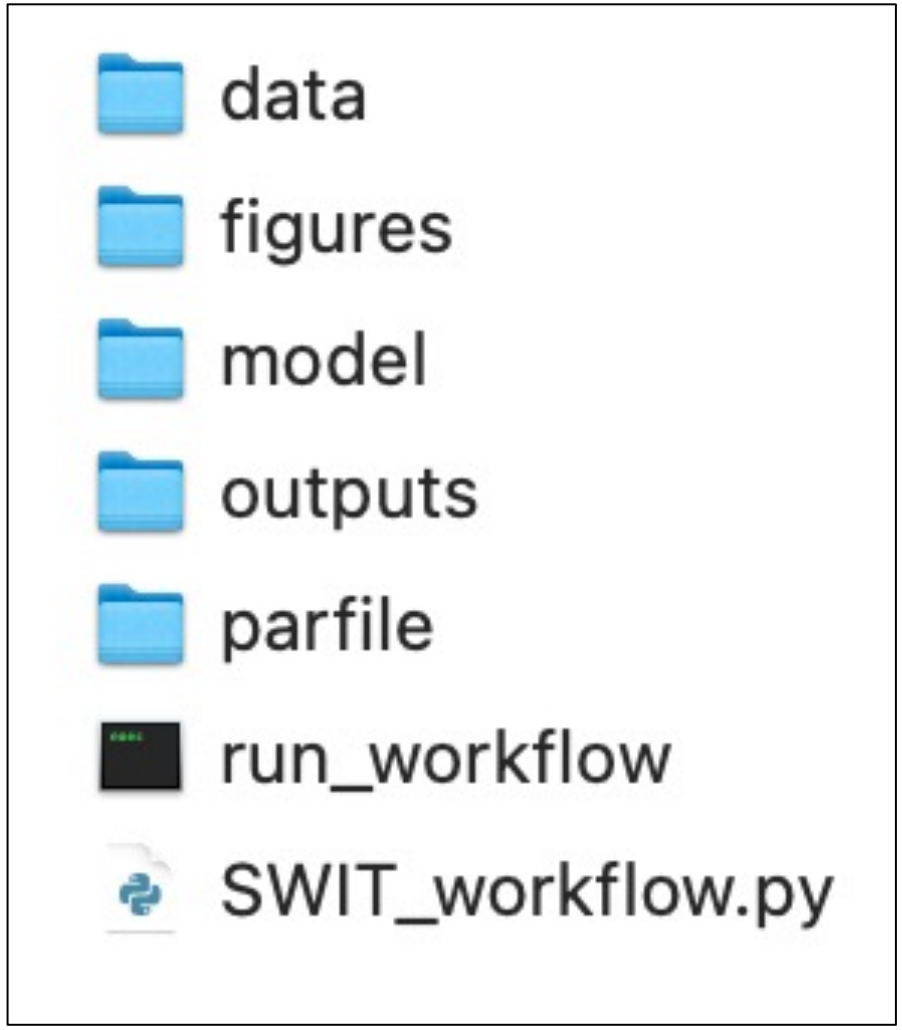
Outputs of SWIT

Visulization: acquisition, model (velocity, gradient, illumination), wavelet, waveform



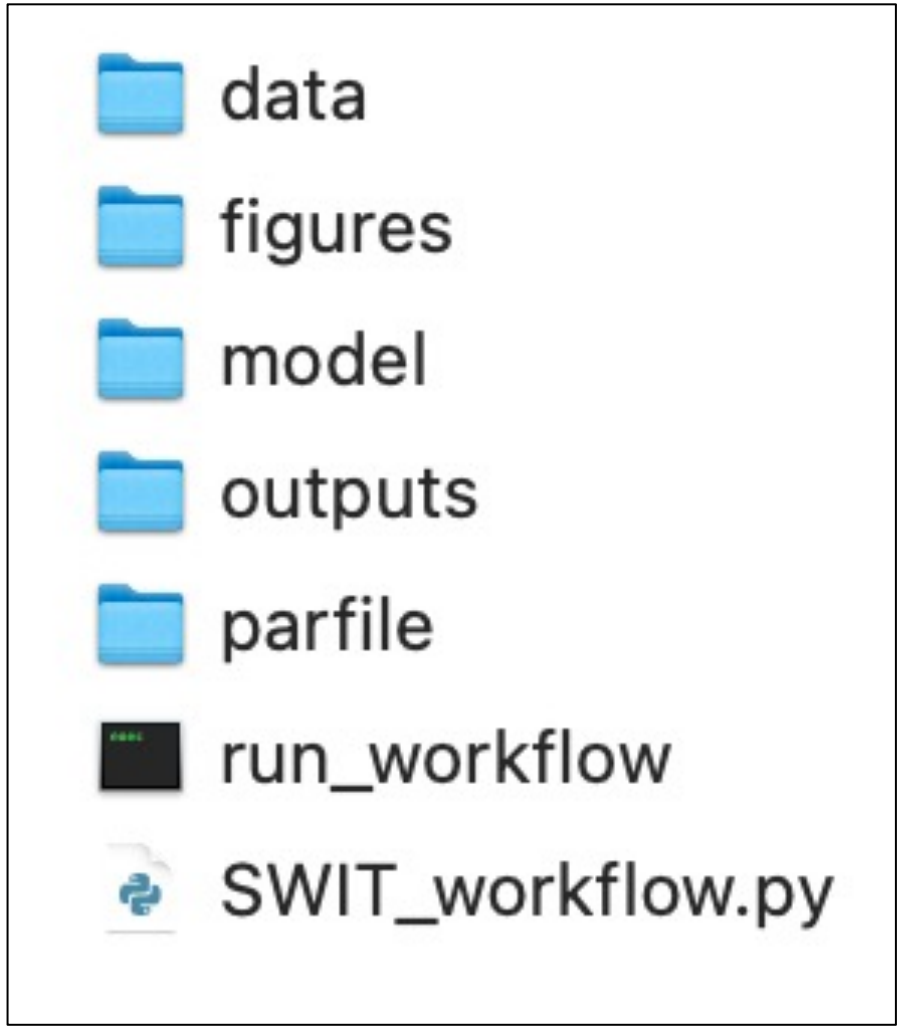


Outputs of SWIT

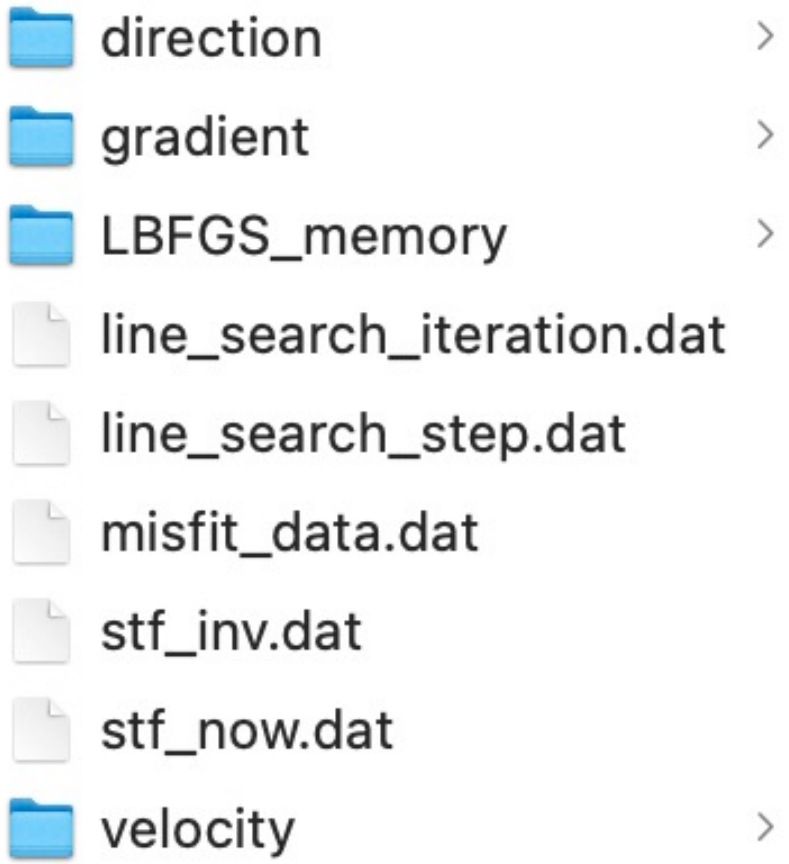


Where you put your true/initial velocity models

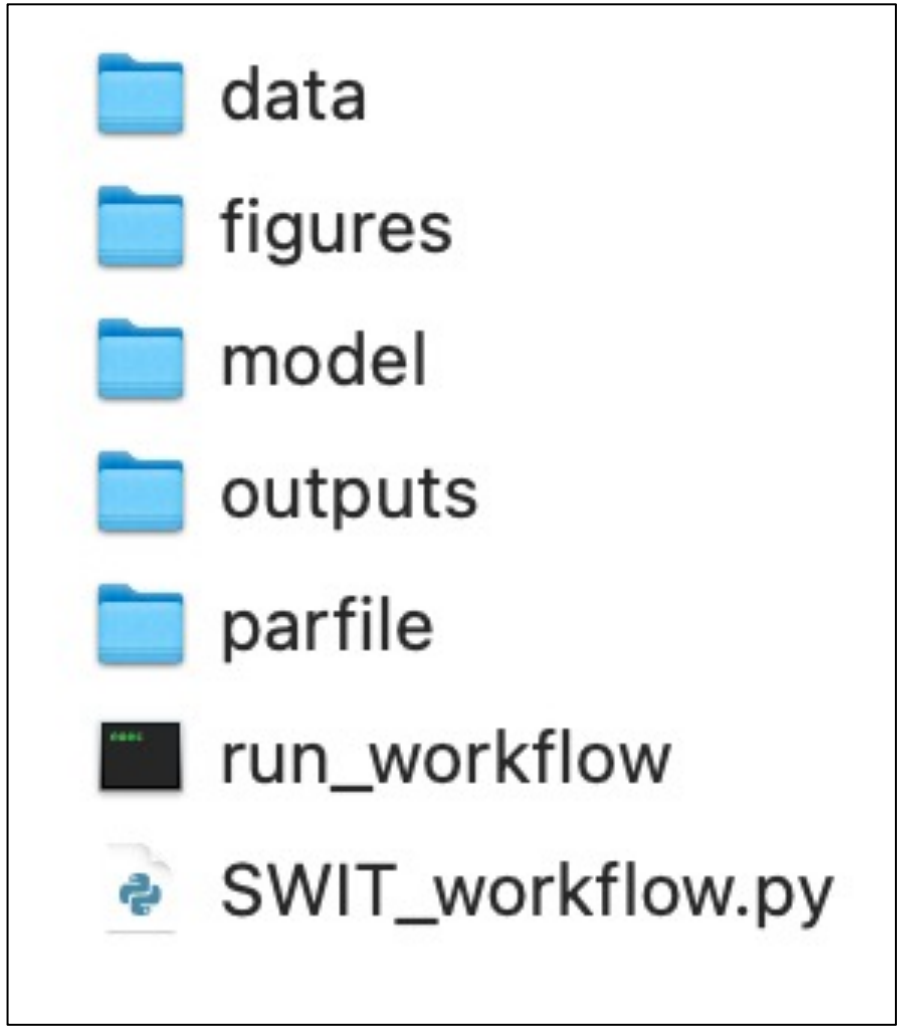
Outputs of SWIT



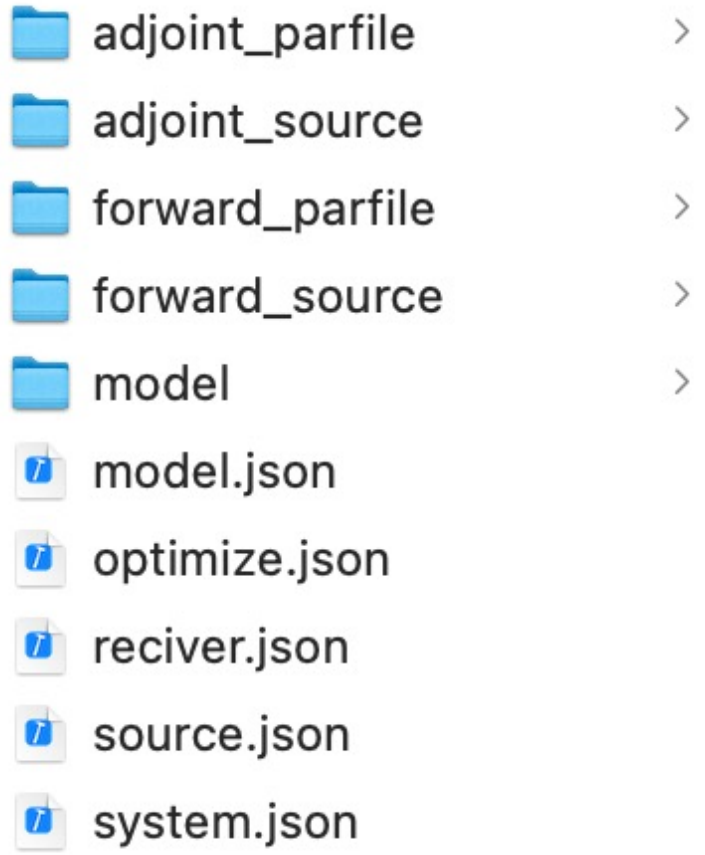
Inversion results: direction, gradient, line length, misfit, velocity, etc.



Outputs of SWIT



Parameters used during the running. All parameters are saved into json files in case for later use.



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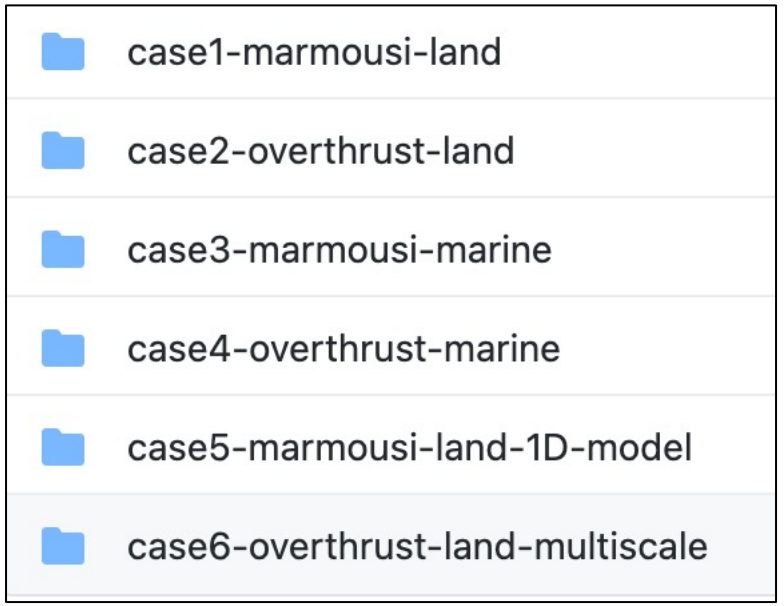
Cases of SWIT

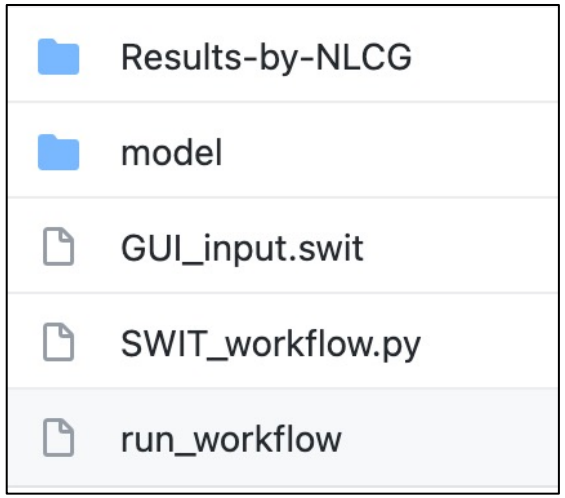
Homepage：https://github.com/Haipeng-ustc/SWIT-1.0

Provided examples

No.	Acquisition	Model	Misfit	Features	Optimization	Size
1	Land	Marmousi	Waveform	-	NLCG	481x121, 25 m
2	Land	Overthrust	Waveform	-	NLCG	401x101, 25 m
3	Marine	Marmousi	Waveform	-	NLCG	481x141, 25 m
4	Marine	Overthrust	Waveform	-	NLCG	401x121, 25 m
5	Land	Marmousi	Traveltime & Waveform	1D initial model	NLCG	401x121, 25 m
6	Land	Overthrust	Waveform	Multi-scale Inversion	NLCG	401x101, 25 m



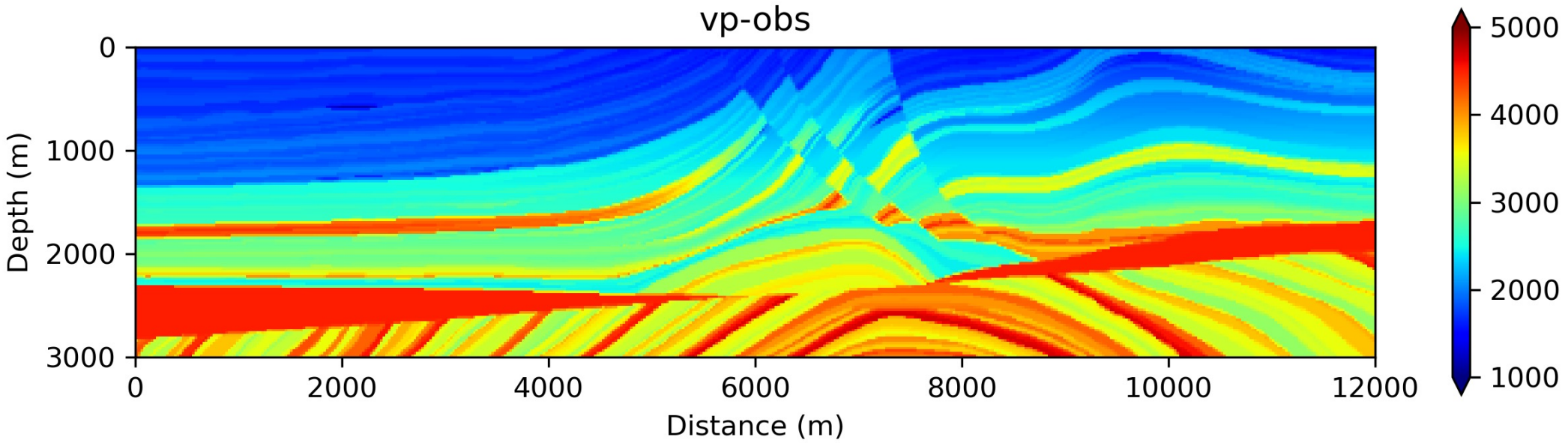
Content of each example



- Result for reference
- model
- Input parameters into GUI (you may change all the PATHs)
- Python script (you may change all the PATHs)
- Bash script

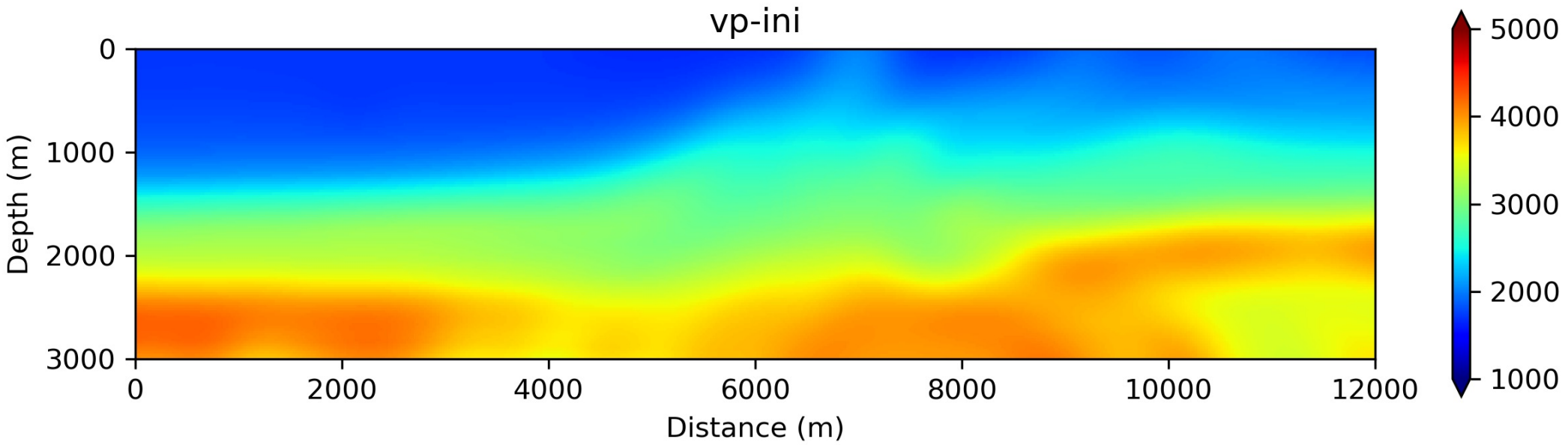
SWIT-Marmousi

True model



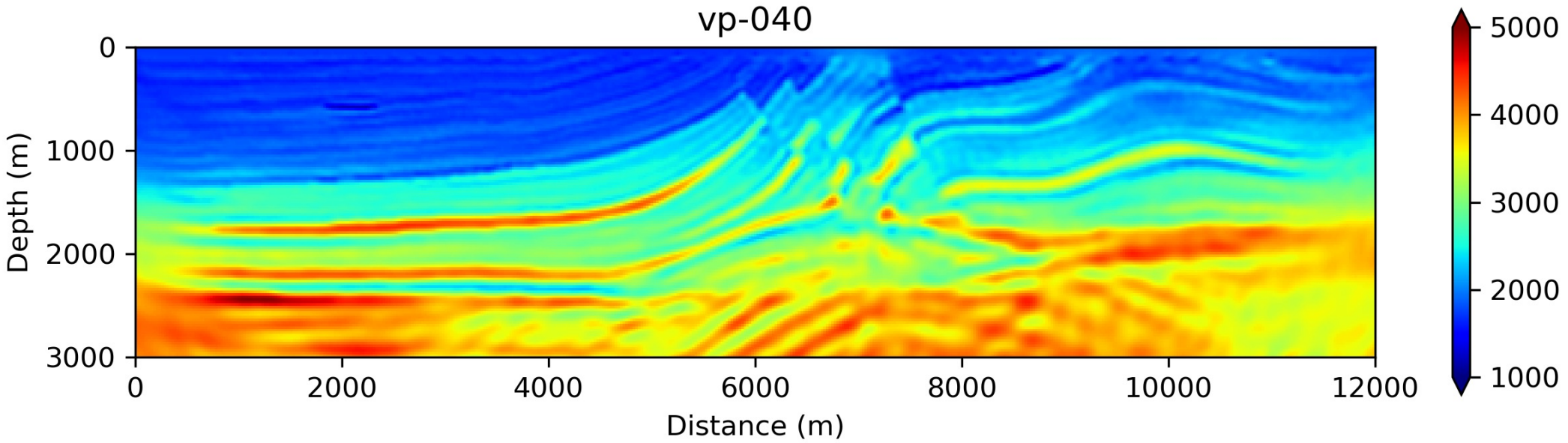
SWIT-Marmousi

Initial model



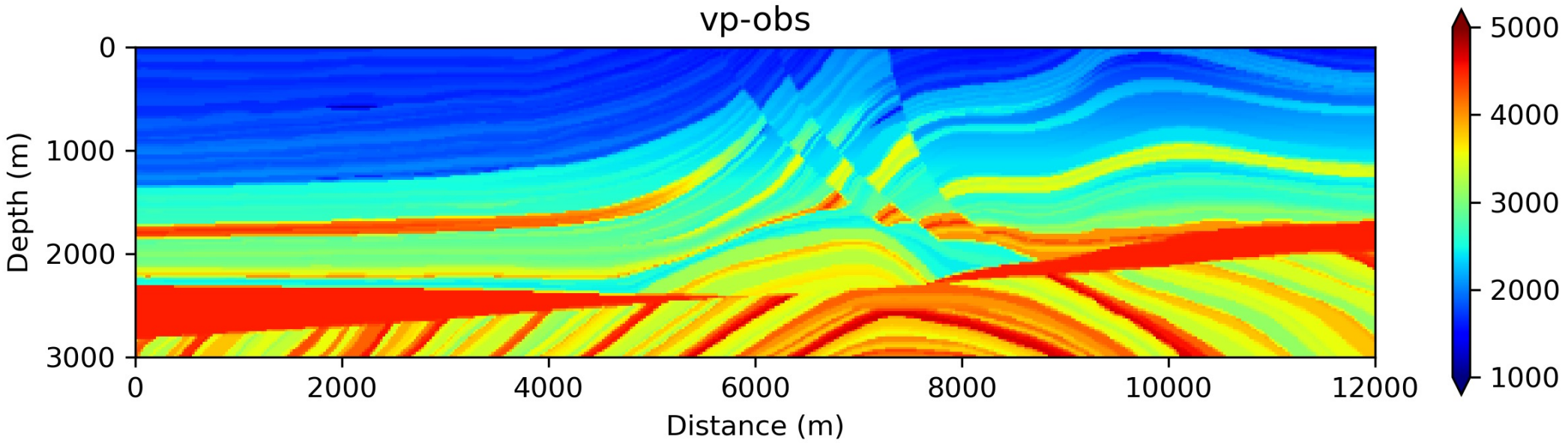
SWIT-Marmousi

Inversion result (40 iter.)



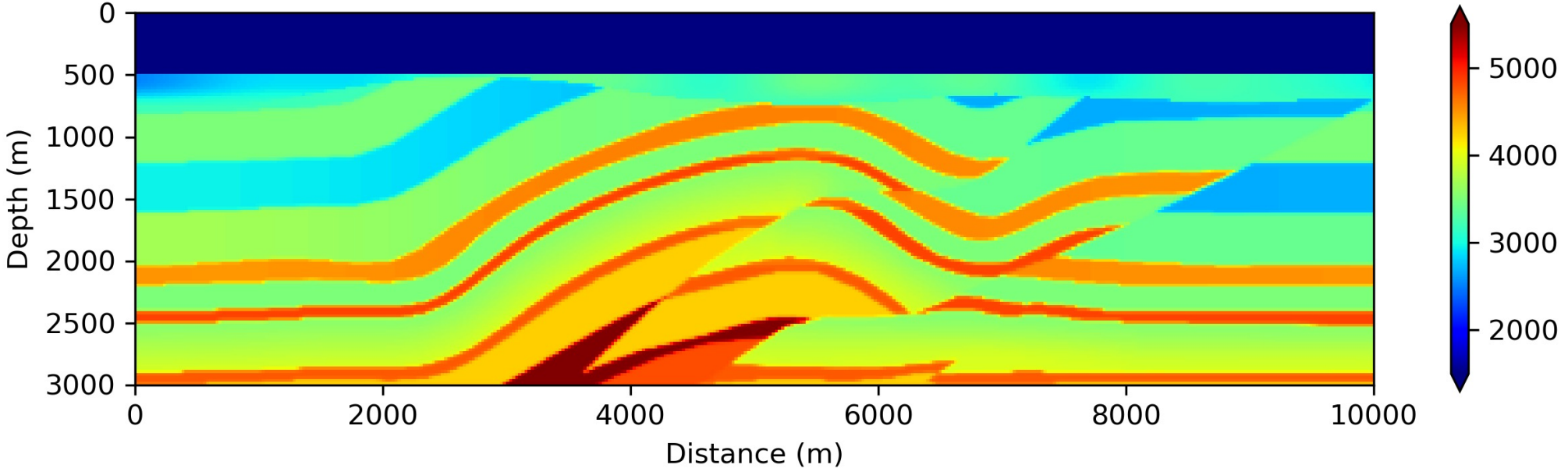
SWIT-Marmousi

True model



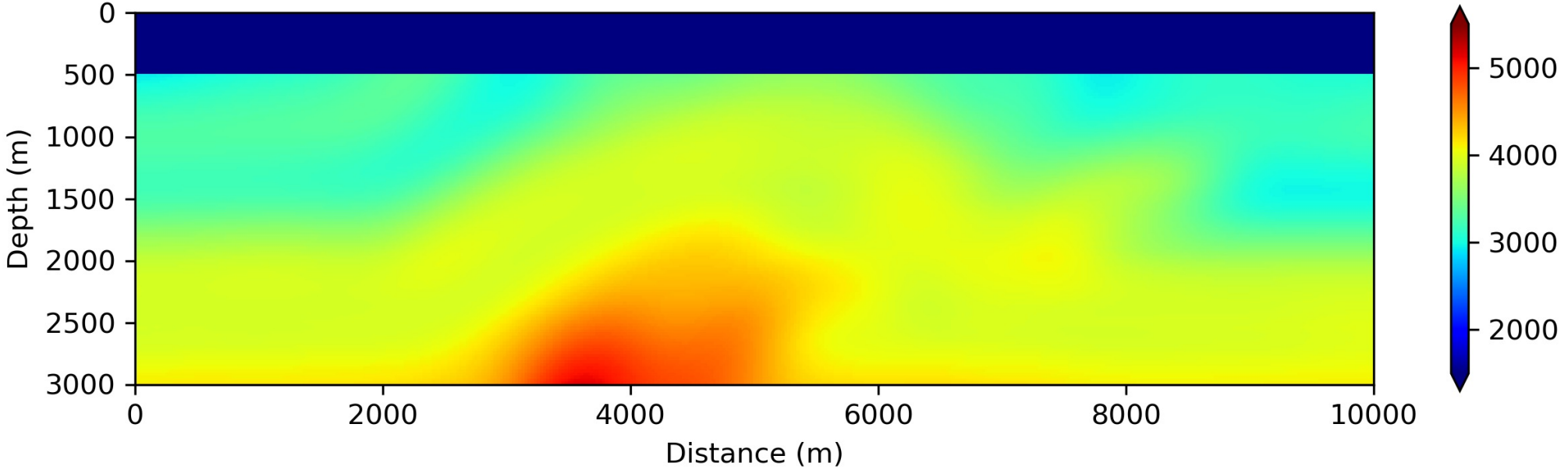
SWIT- SEG/EAGE Overthrust

True model



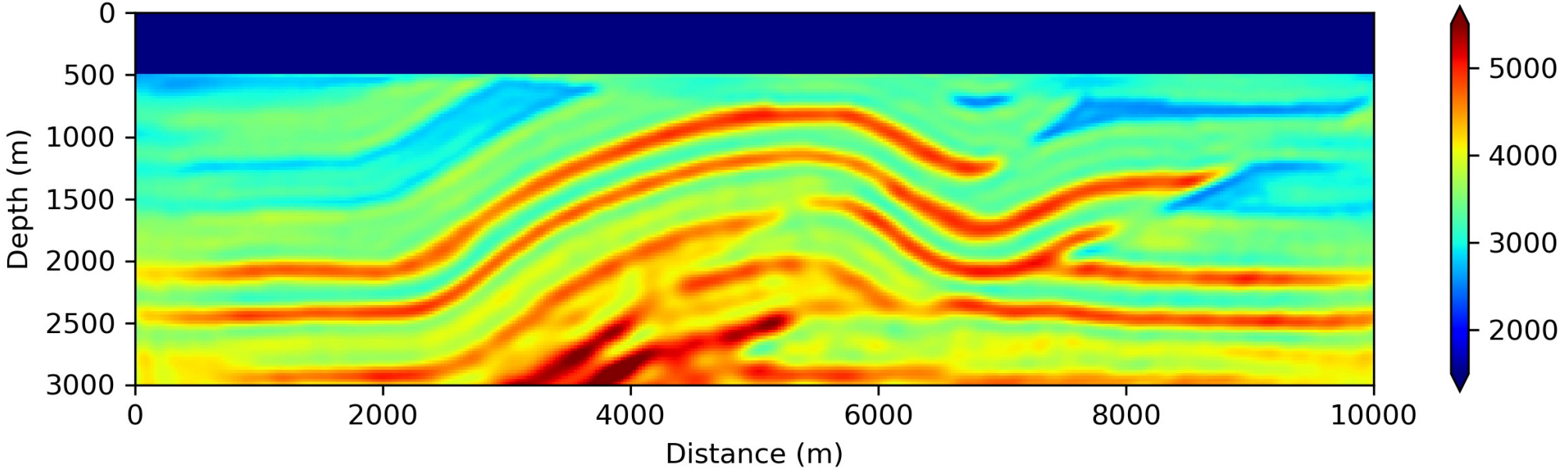
SWIT- SEG/EAGE Overthrust

Initial model



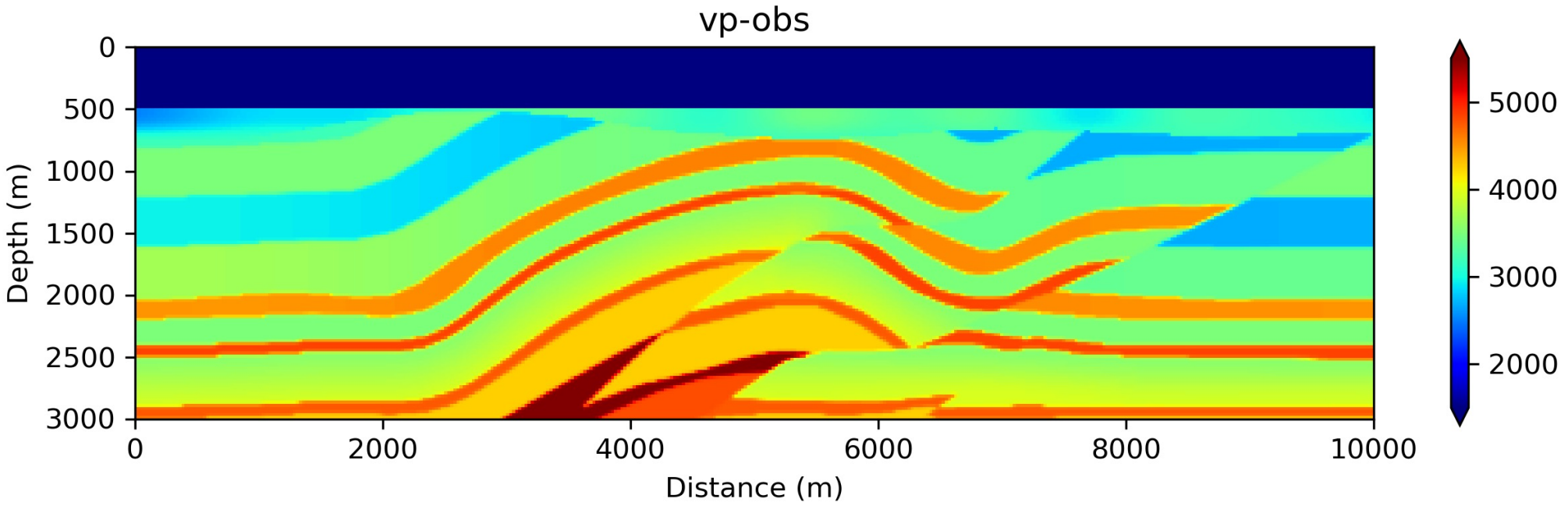
SWIT- SEG/EAGE Overthrust

Inversion result (40 iter.)



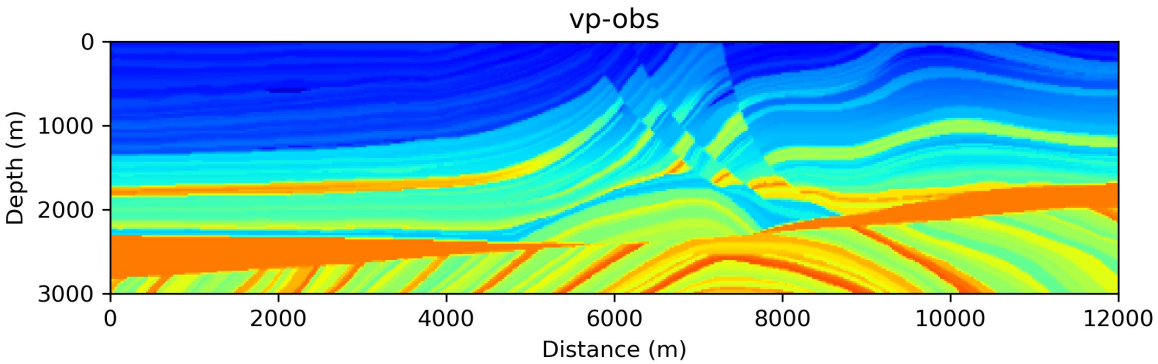
SWIT- SEG/EAGE Overthrust

True model

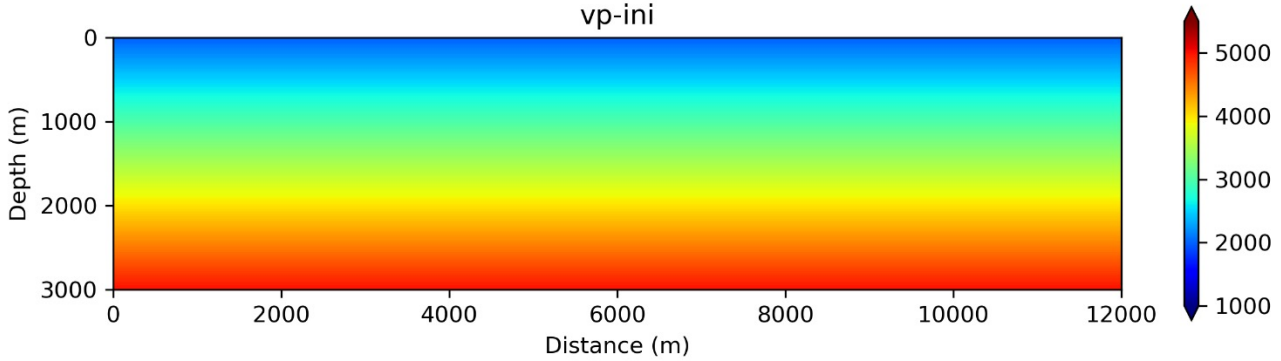


SWIT-From 1D 'blind' initial model

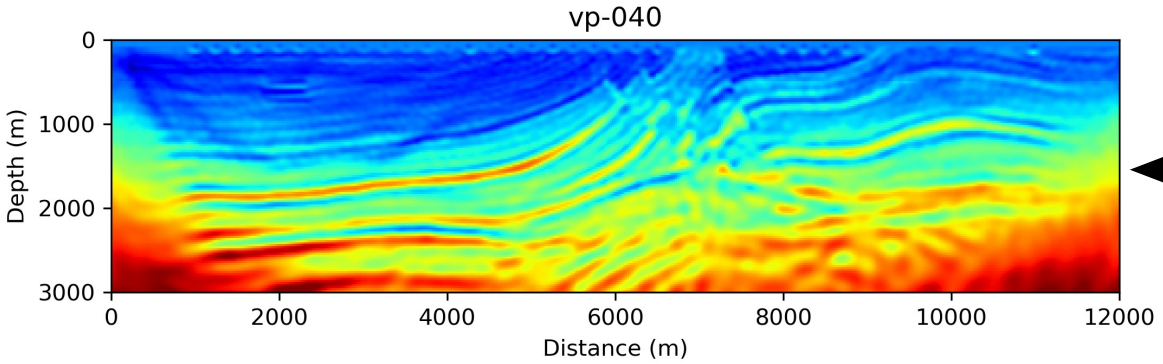
True model



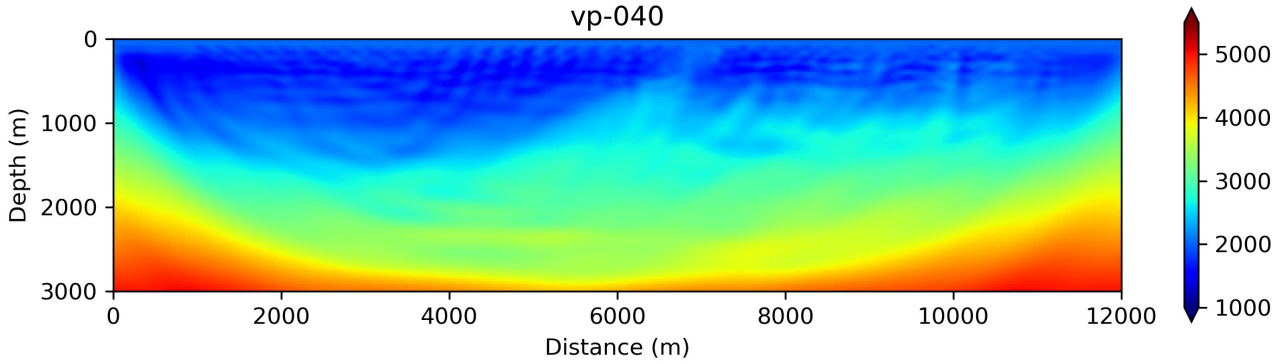
1D model



Waveform-FWI

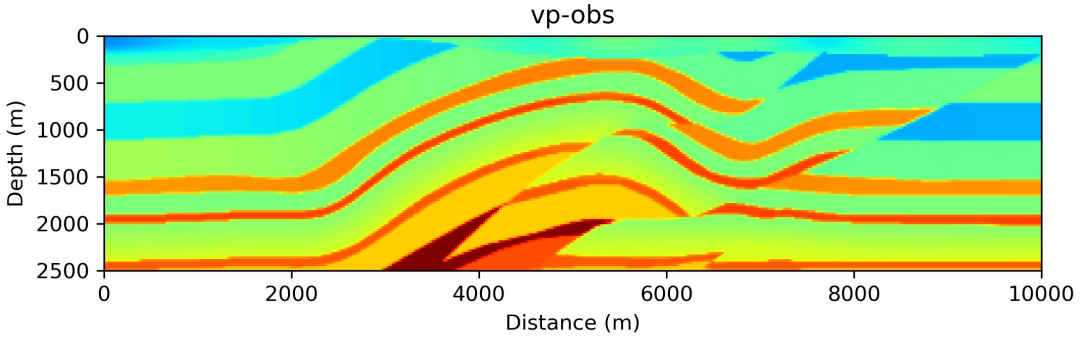


Traveltime-FWI

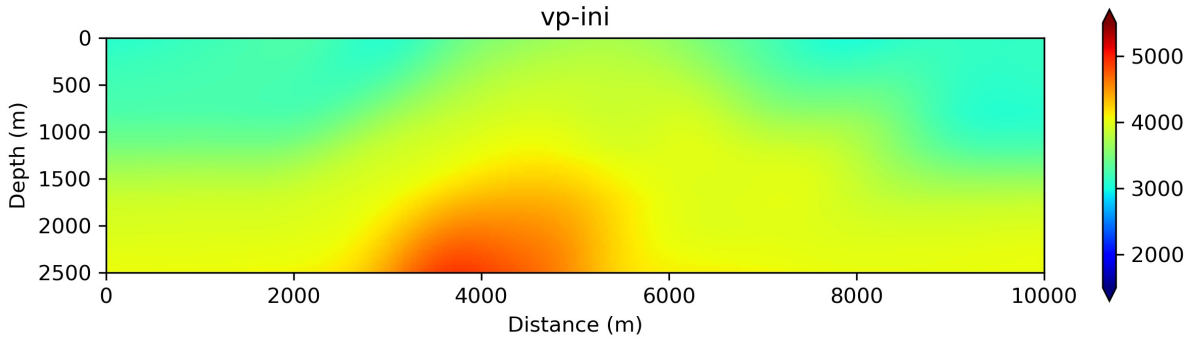


SWIT-Multiscale Inversion

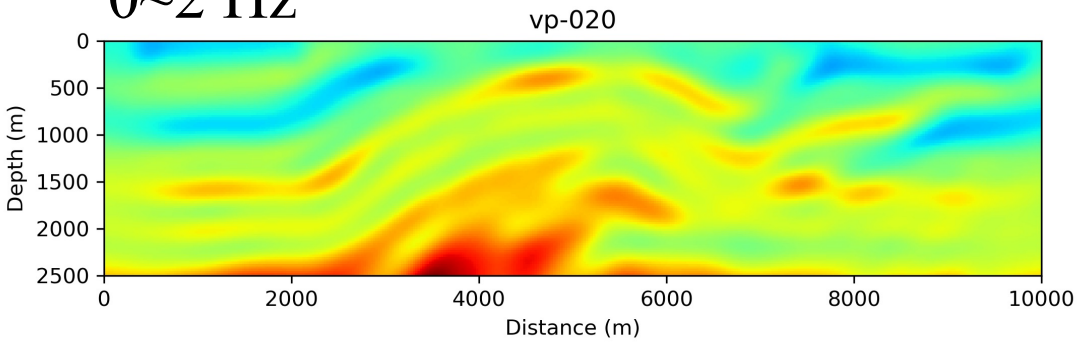
True model



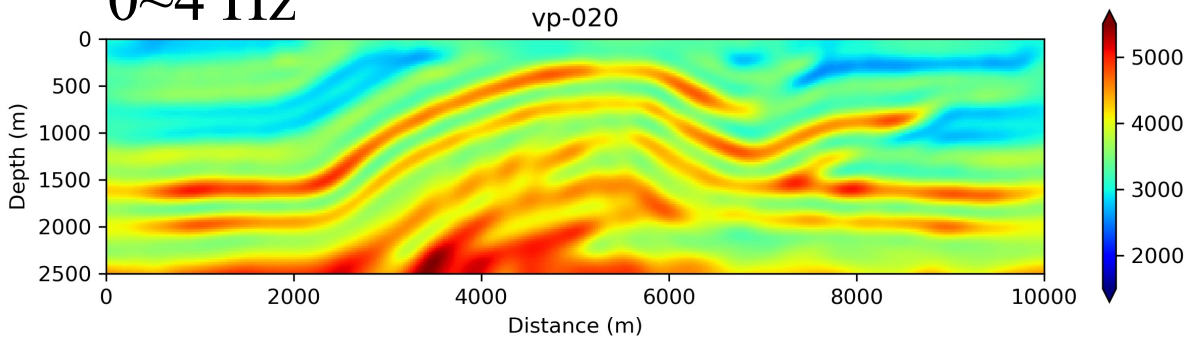
Initial model



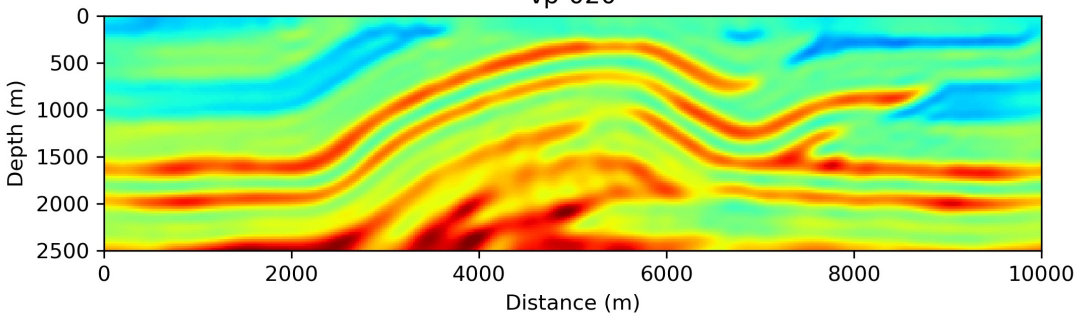
0~2 Hz



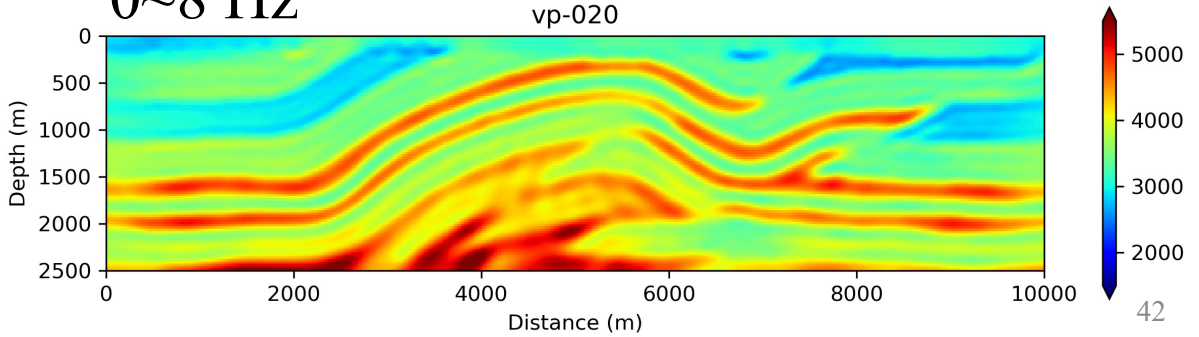
0~4 Hz



0~6 Hz



0~8 Hz



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References:

1. Li, H., Li, J., Liu, B., Huang, X. (2021). Application of full-waveform tomography on deep seismic profiling dataset for tectonic fault characterization. *International Meeting for Applied Geoscience & Energy*.

2. Schuster, G. T. (2017). Seismic inversion. *Society of Exploration Geophysicists*.

中国科学技术大学
University of Science and Technology of China
地球和空间科学学院
School of Earth and Space Sciences

Thanks

Haipeng Li (李海鹏) (haipengl@mail.ustc.edu.cn)

Supervisor：Prof. Junlun Li (李俊伦) (lijunlun@ustc.edu.cn)

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