Practice:

dynamic rupture in 2D and 2.5D

Huihui Weng

Jean-Paul Ampuero

ICTP, Trieste, Italy, 2-14 Sep.

Goals

- Learn to simulate dynamic rupture model
- Explore the effects of fault heterogeneities on dynamic ruptures
- Discussion: seismology problems

2D and 2.5D numerical codes

Download from GitHub

Jean Paul Ampuero
jpampuero

California Institute of Technology
Pasadena, CA, USA
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http://www.seismolab.caltech.edu/a...

Overview | Repositories 4 | Projects 0 | Stars 1 | Followers 15 | Following 0

Popular repositories

sem2dpack
SEM2DPACK - A spectral element method for 2D wave propagation and fracture dynamics, with emphasis on computational seismology and earthquake source dynamics.
Fortran ★ 4 3

semlab
Spectral Element Method for wave propagation and rupture dynamics in Matlab.
MATLAB ★ 3 1

specfem3d
Forked from geodynamics/specfem3d
SPECFEM3D_Cartesian simulates acoustic (fluid), elastic (solid), coupled acoustic/elastic, poroelastic or seismic wave propagation in any type of conforming mesh of hexahedra (structured or not). I...
Fortran 1

jpampuero.github.io
J. P. Ampuero - Seismology and Earthquake Dynamics
HTML

2D and 2.5D numerical codes

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Fortran 1

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HTML

The tutorial script will be uploaded to GitHub soon.

MATLAB code semlab

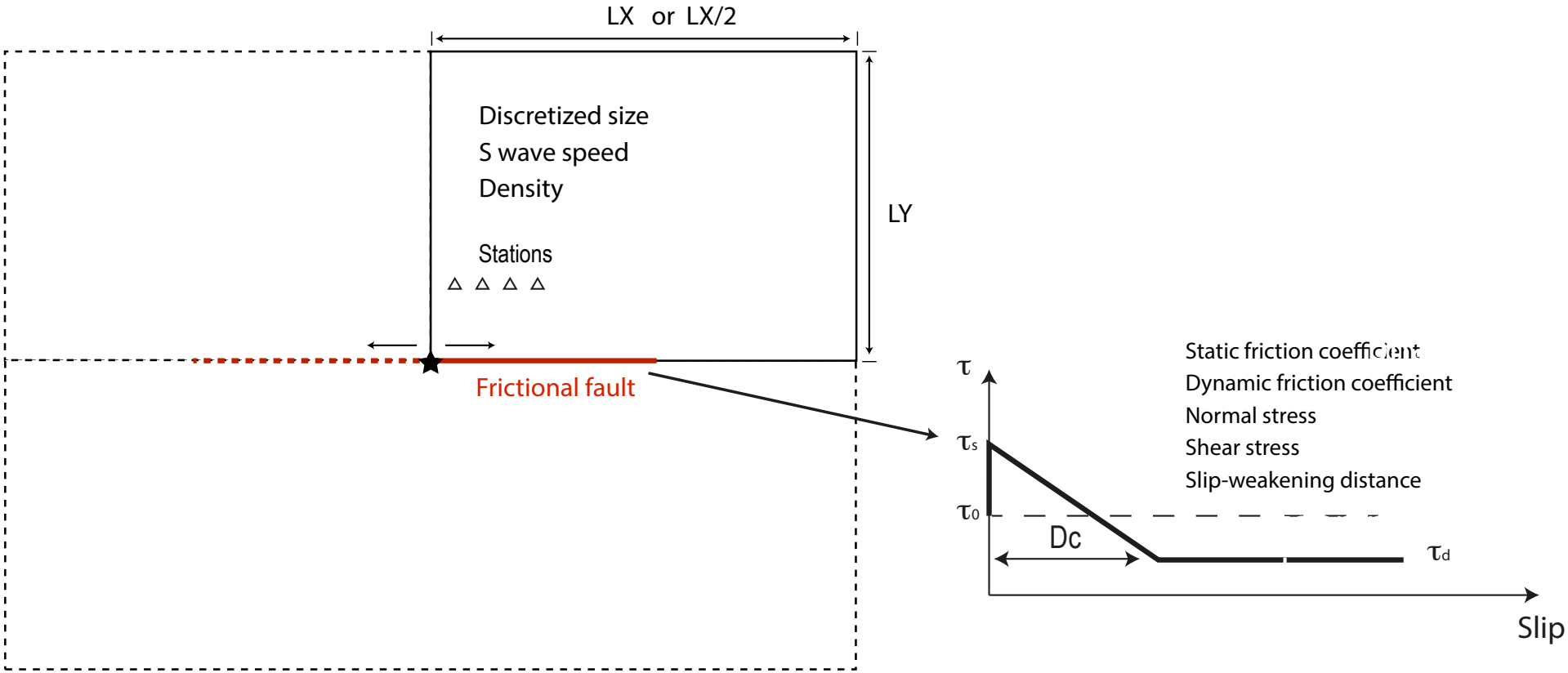
----- run it directly

Fortran code sem2dpack

----- installation is simple

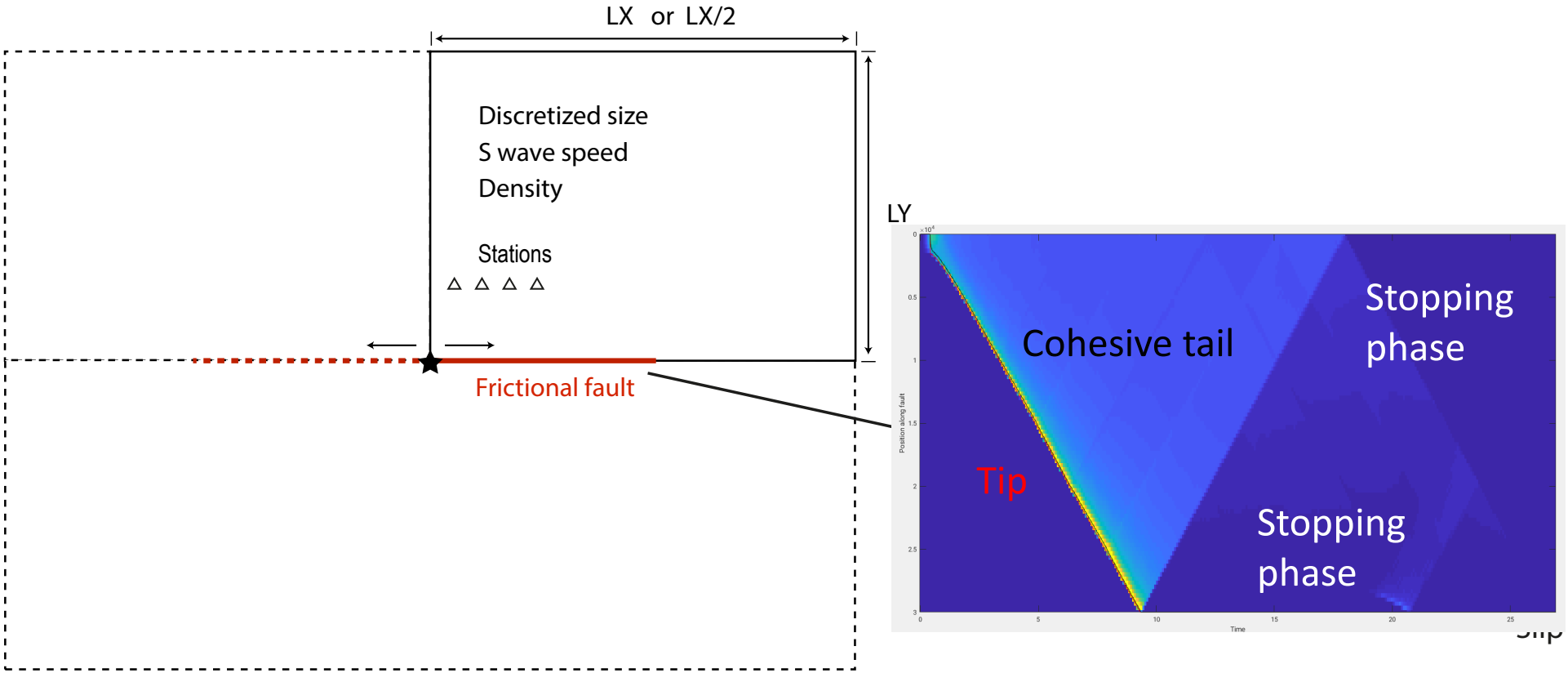
----- simulation is fast

Model parameters



Second stopping phase

Model parameters



Second stopping phase

Model parameters

$$\sigma_{ij,j} = \rho\ddot{u}_i \quad \text{(3 equations)}$$

↓ Reduce to 1 equation

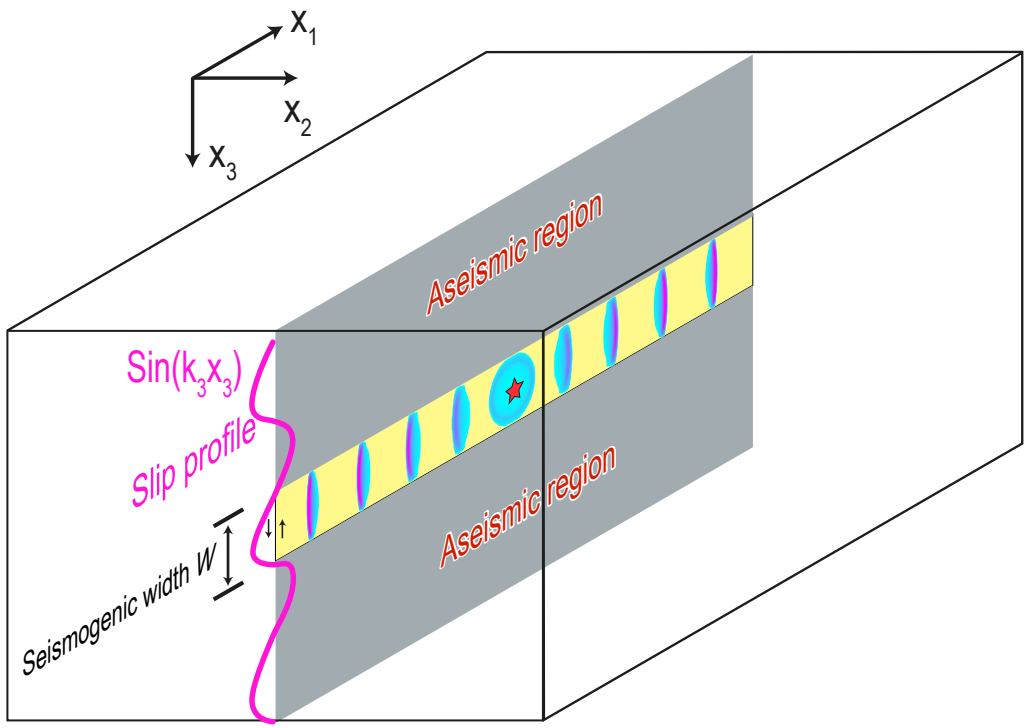
$$\frac{\partial^2 u}{\partial x_1^2} + \frac{\partial^2 u}{\partial x_2^2} + \frac{\partial^2 u}{\partial x_3^2} = \frac{1}{v_s^2}\frac{\partial^2 u}{\partial t^2}$$

Slip approximation

$$u(x_1, x_2, x_3) = u(x_1, x_2, t)e^{ik_3 x_3}$$

$$k_3 = \pi/W$$

$$\frac{\partial^2 u}{\partial x_1^2} + \frac{\partial^2 u}{\partial x_2^2} - {k_3}^2 u = \frac{1}{v_s^2}\frac{\partial^2 u}{\partial t^2}$$



Tutorial of semlab

Tutorial of sem2dpack

How to run semlab?

cp –r /home/nfs3/seismology_lectures/hweng .

ls ./hweng

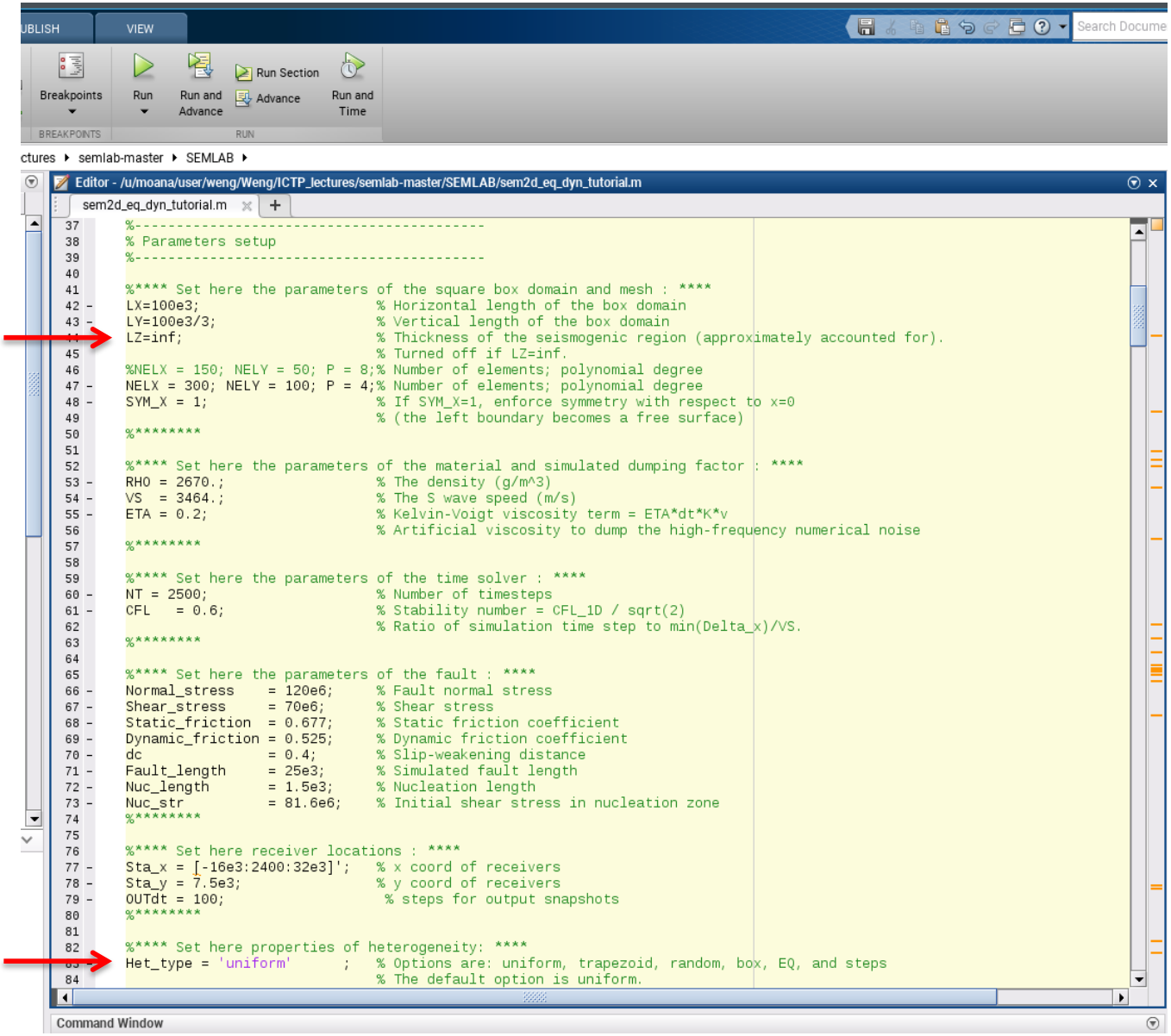
cd ./hweng/semlab-master/SEMLAB

matlab &

open this file from matlab:

sem2d_eq_dyn_tutorial.m

Parameter setup in semlab



Add a heterogeneity

```
%**** Set here properties of heterogeneity: ****
Het_type = 'uniform'       ; % options are: uniform, box, trapezoid, random, EQ, and steps
                           % The default option is uniform.
Het_para = 'stress'        ; % The options are: stress and dc. If Het_type='EQ',
                           % this option shall be stress.
Het_loc  = 20e3          ; % The beginning location of heterogeneity (m)
Het_len  = 10e3           ; % The length of heterogeneity (m)
Het_val  = 50e6           ;
                           % The value of heterogeneity. The unit is Pa for stress and m for dc.
%Het_val  = [70e6, 50e6]         ;
                           % For trapezoid, the format is [val1,val2]
                           % For random,    this value indicates pertubation range
                           % For EQ, this value indicates the stress drop of the previous event.
%Het_val  = [60e6,75e6,53e6]       ;
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%********
```

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%Het_val  = [60e6,75e6,53e6]       ;
                           % For steps, the format is [val1, val2, ...]
%********
```

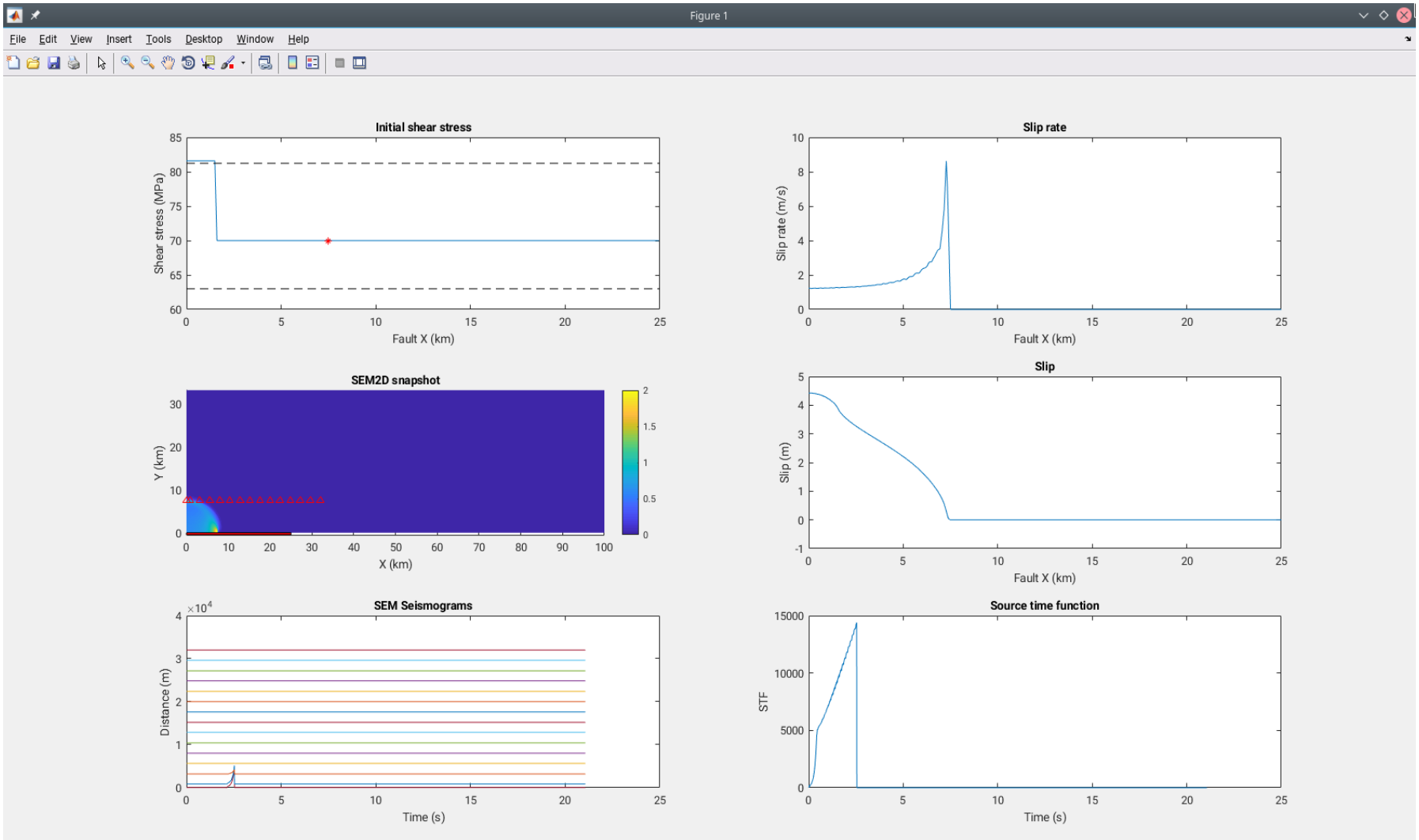
Model name meaning

2D or 2.5D stress or dc length

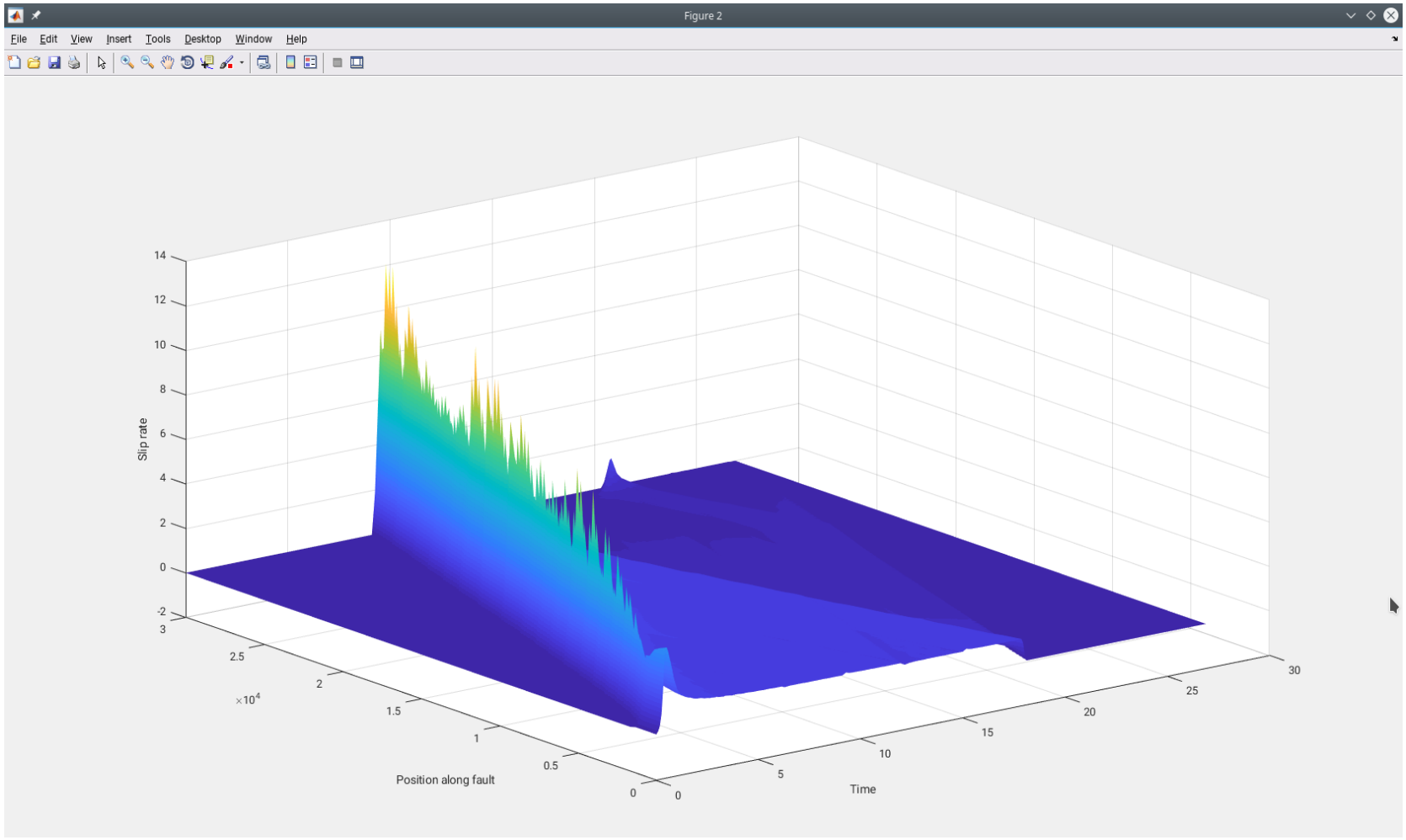
2.5D-8-box-stress-20-30-50

uniform, box, random … location value

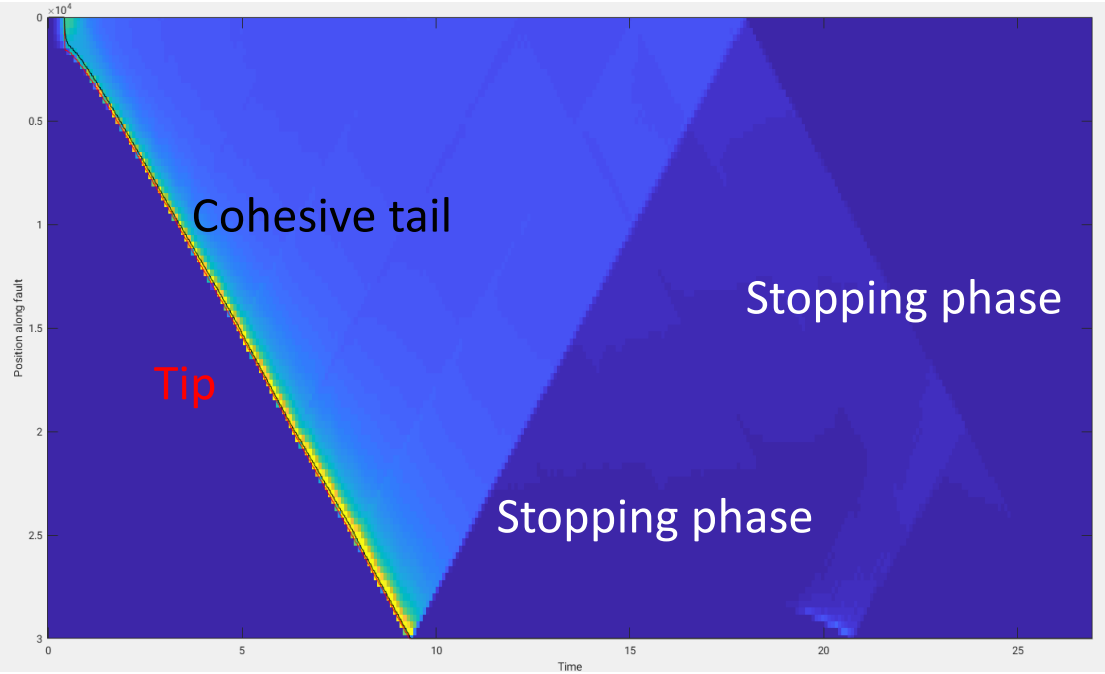
Result presentation (figure1)



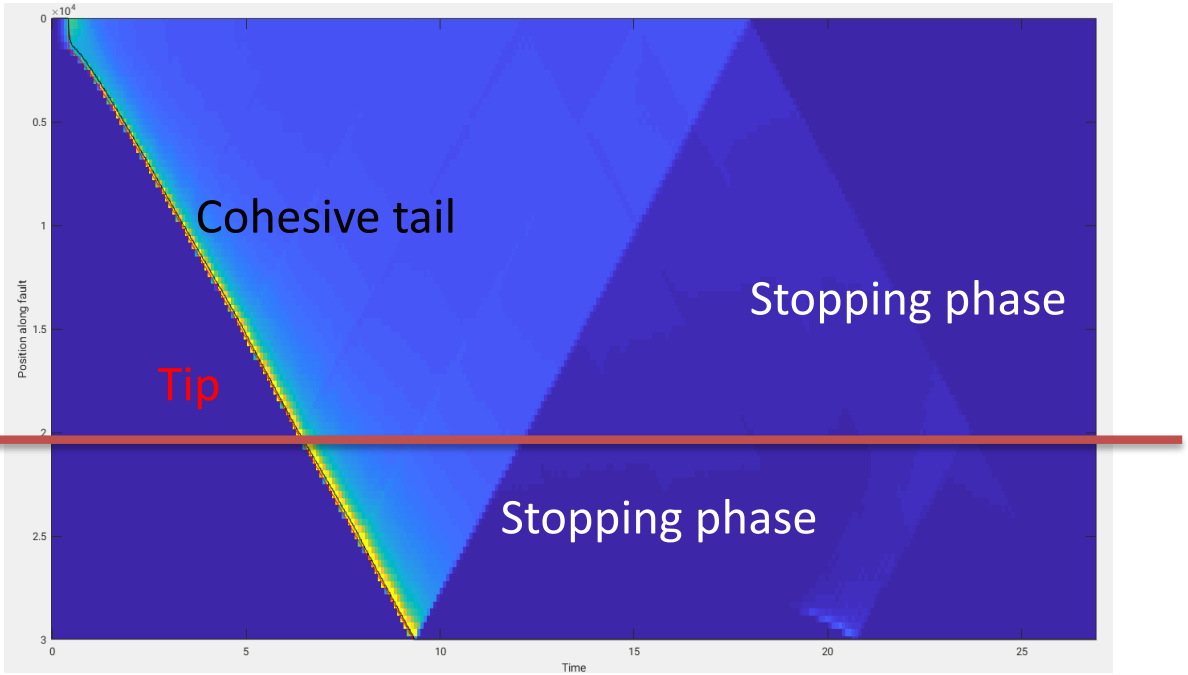
Result presentation (figure2)

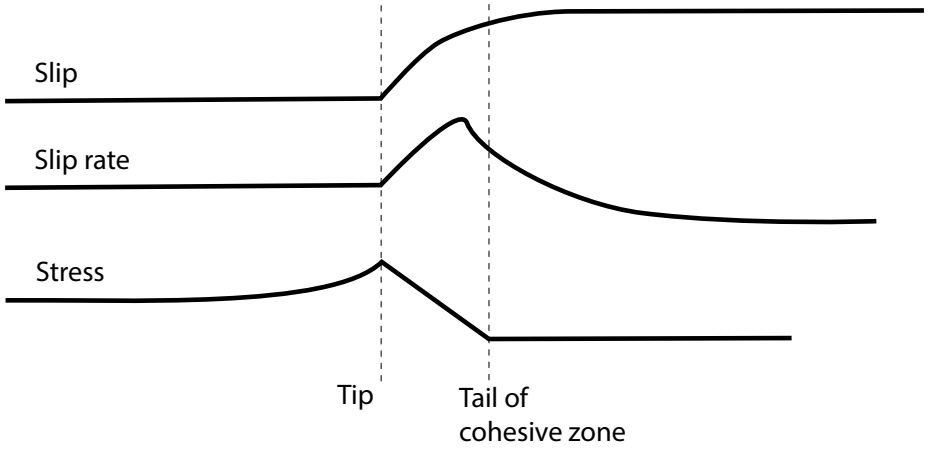


Result presentation (figure3)



Result presentation (figure3)

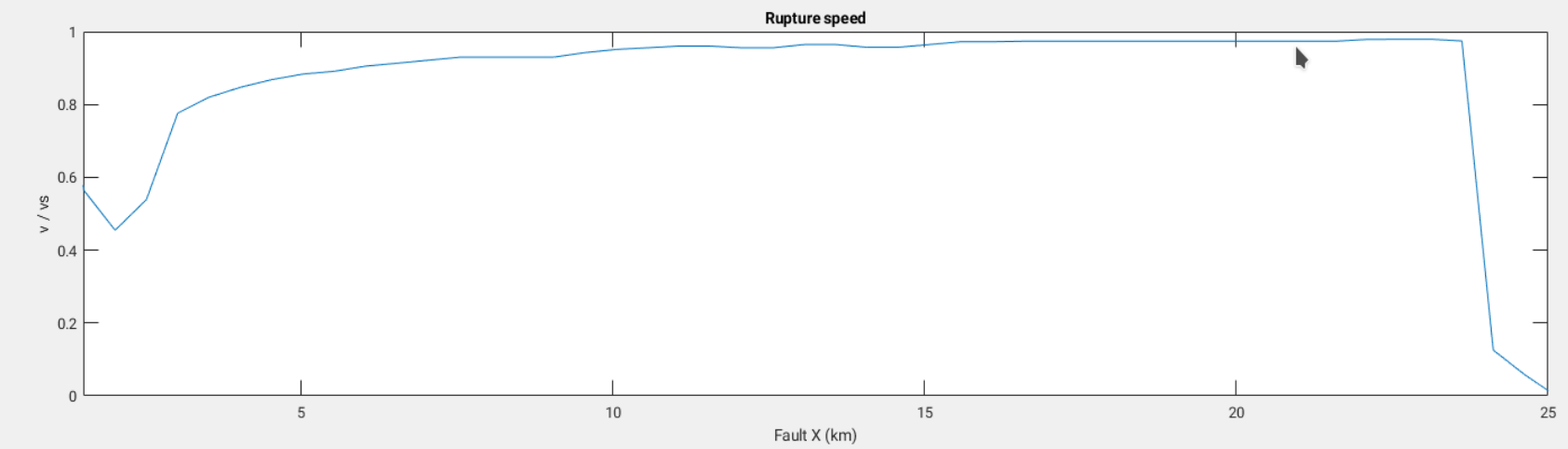


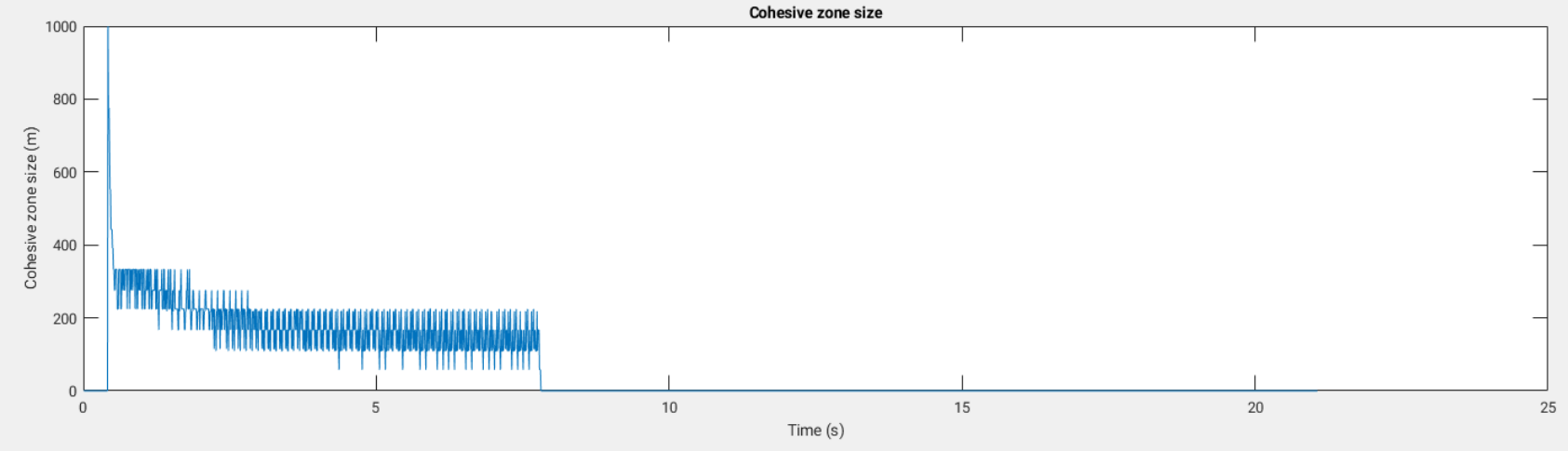


Definition of tip:
Slip rate > threshold

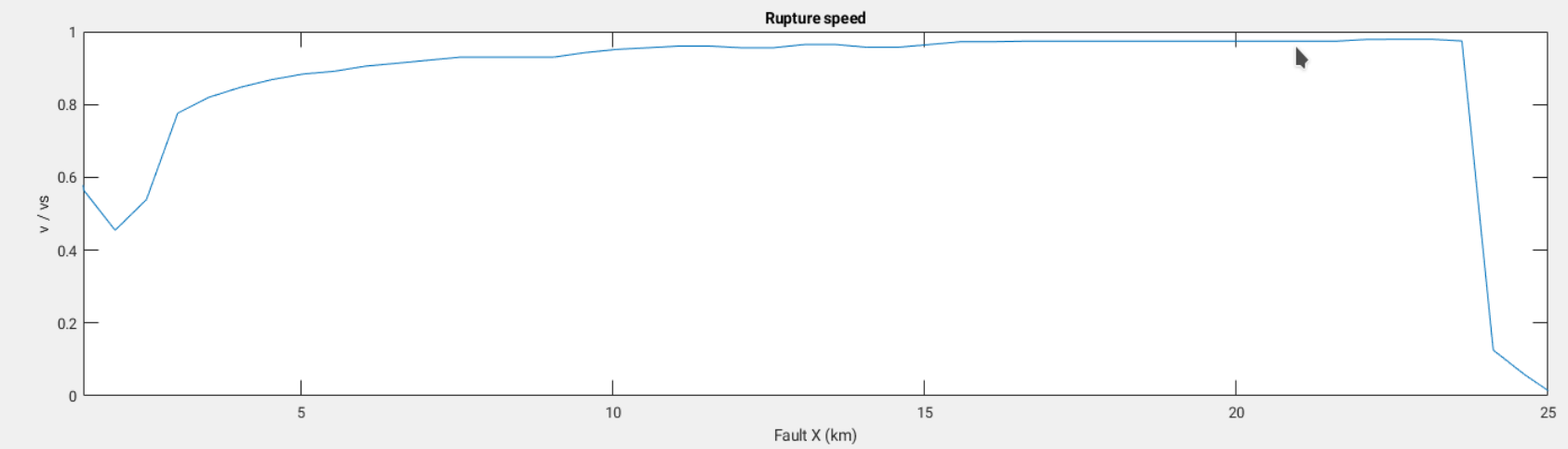
Definition of cohesive tail:
Slip = Dc

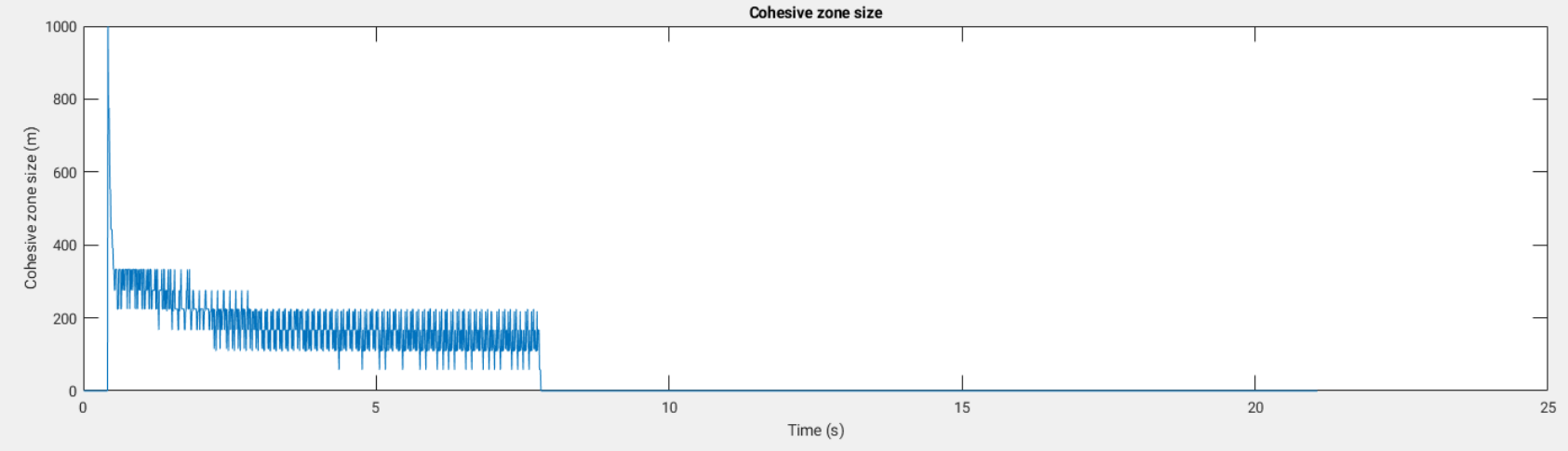
Result presentation (figure4)



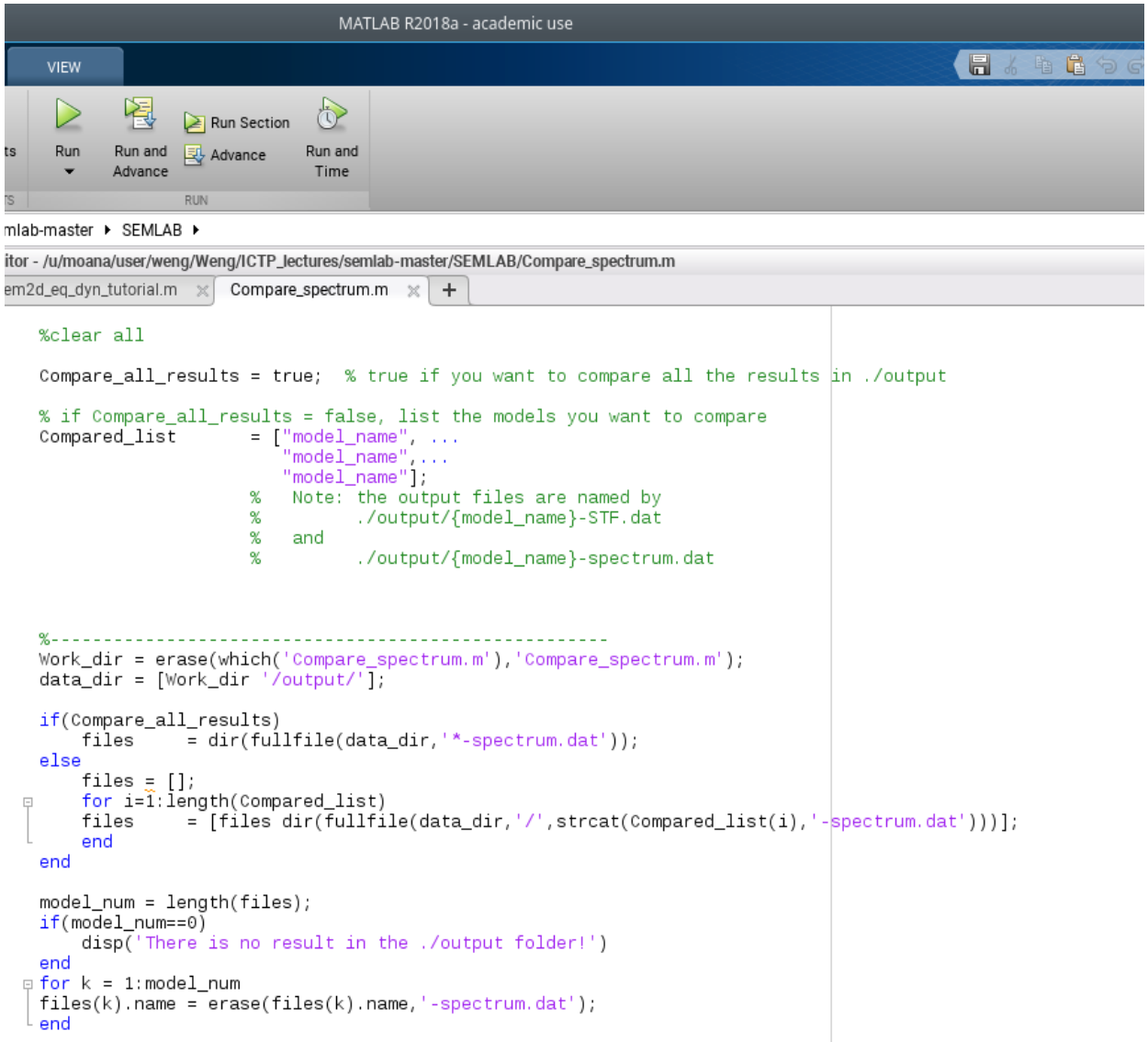


Result presentation (figure4)

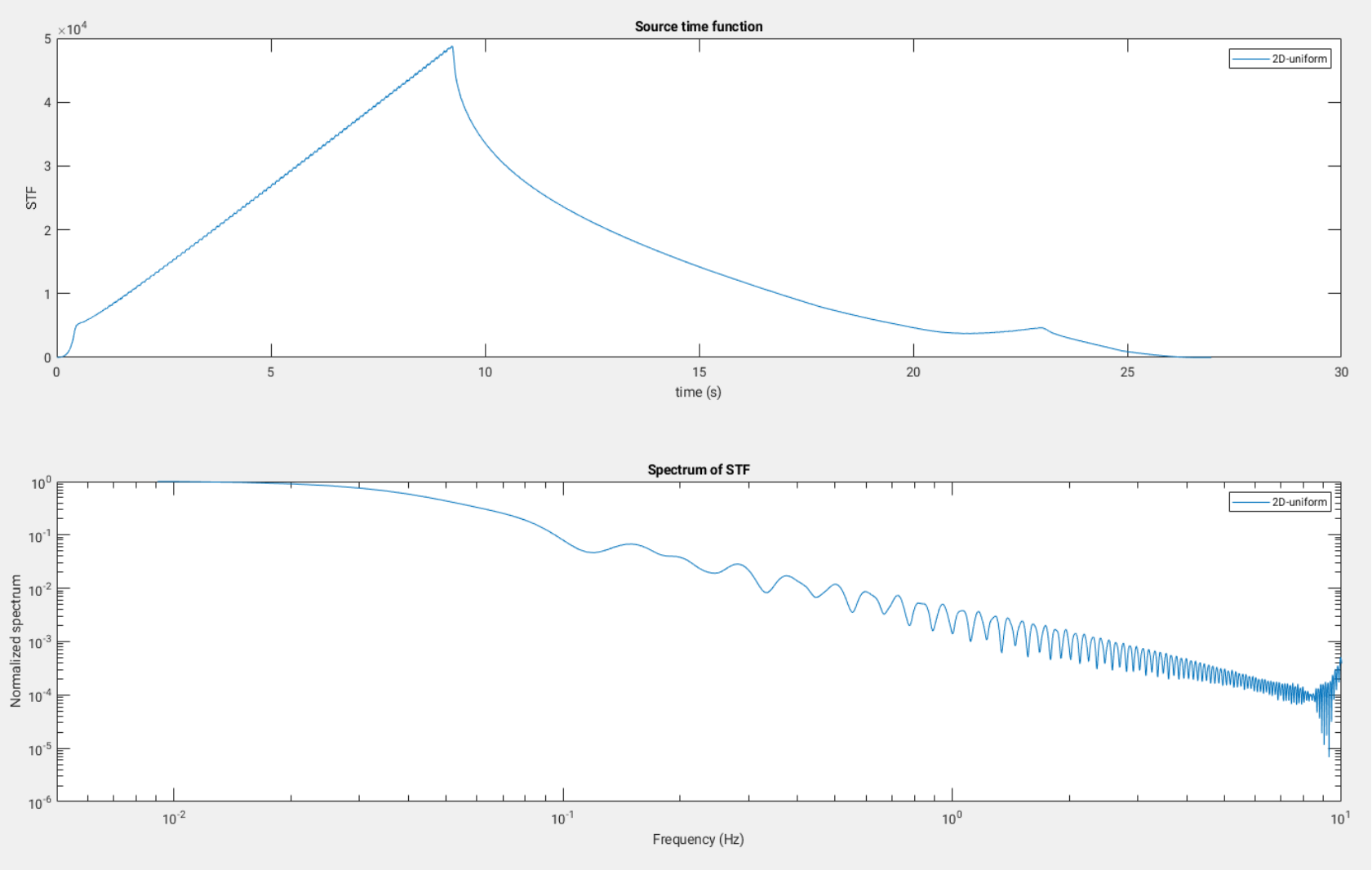




STF and its spectrum (final)



STF and spectra



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                           % For steps, the format is [val1, val2, ...]
%********
```
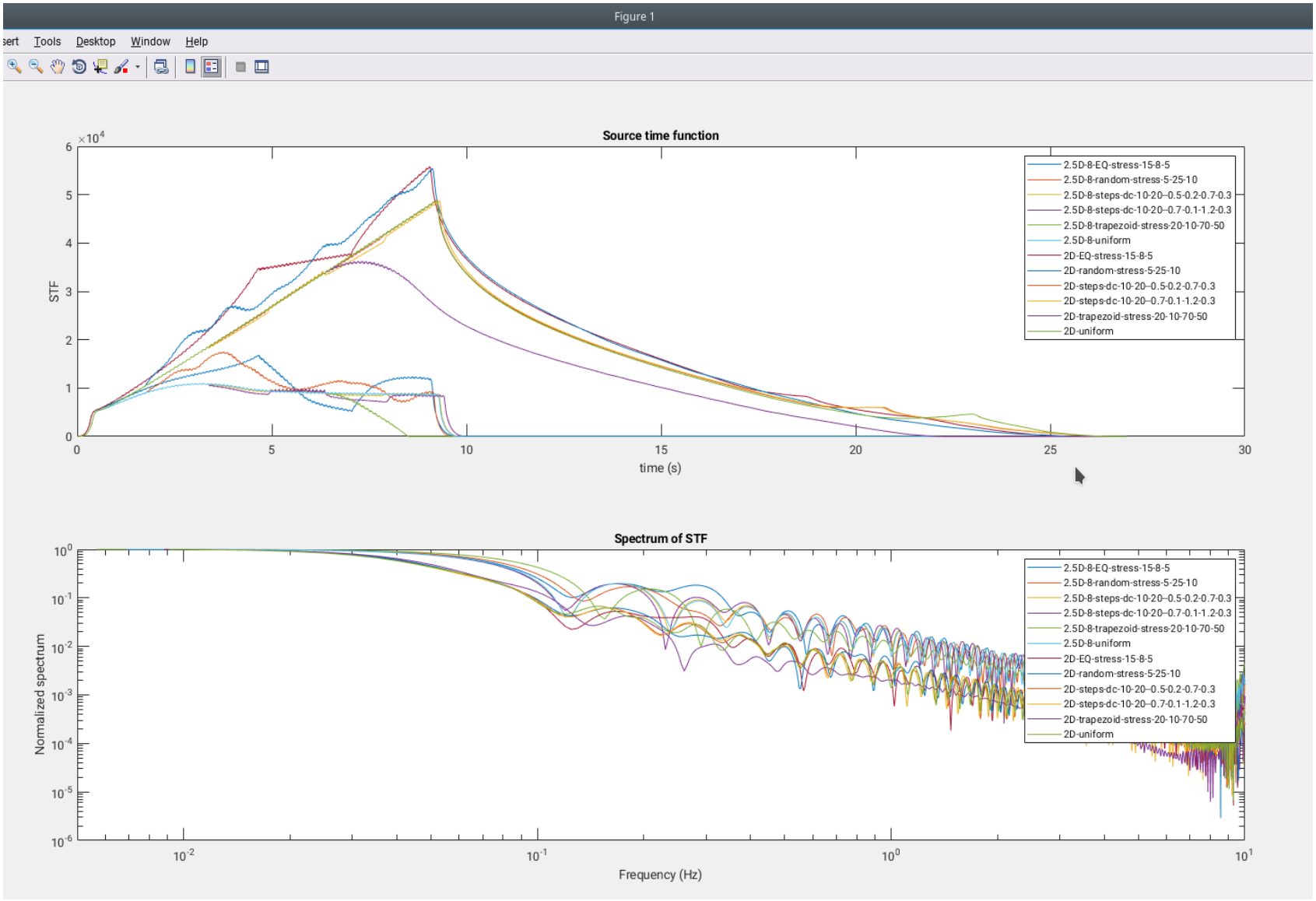
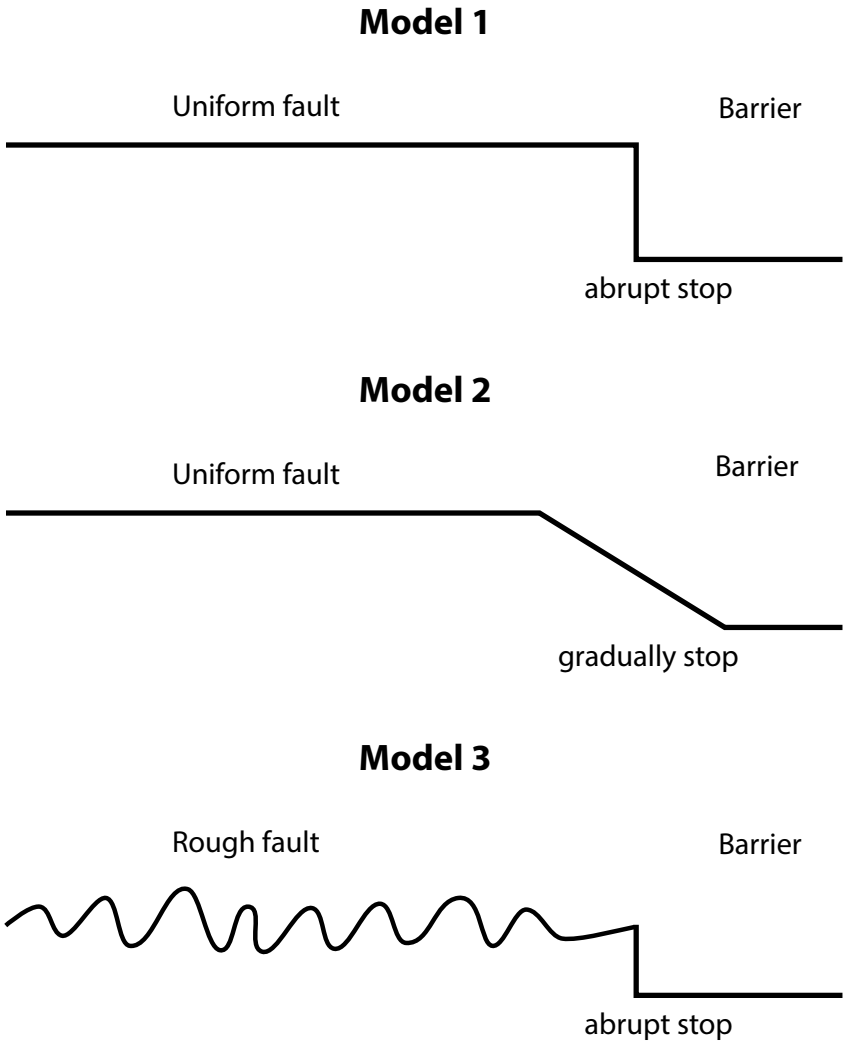

STF comparison



Models to test

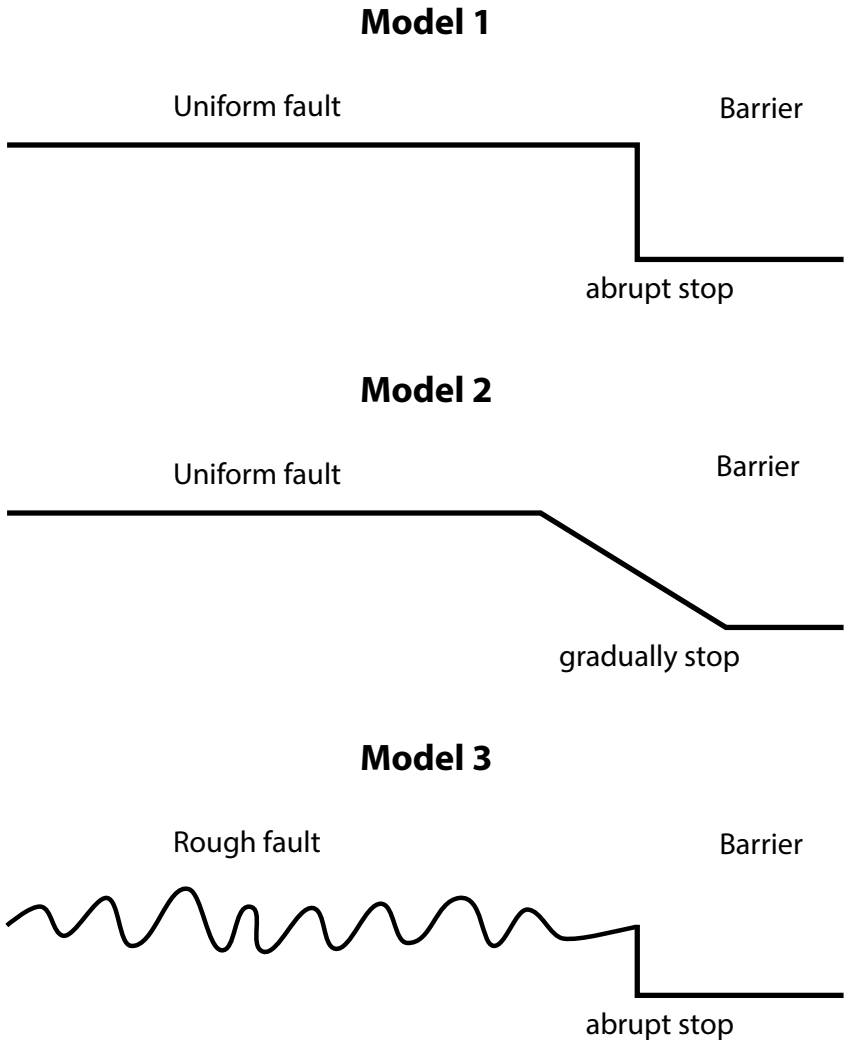
- Heterogeneity can be initial stress or Dc
- Question: what are the differences of STF and spectrum?
- Discussion: what are the differences between 2D and 2.5D models?



Discussion

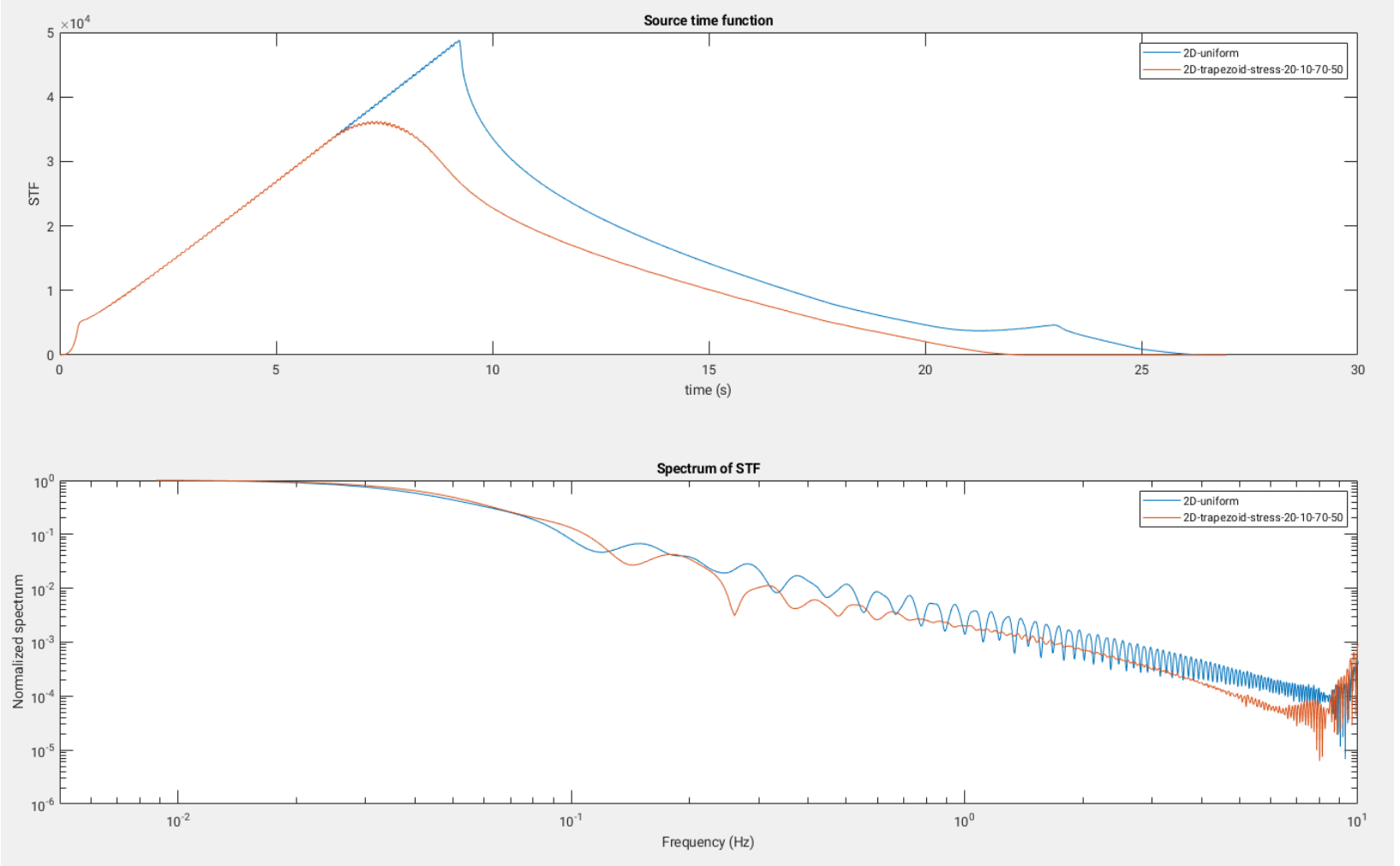
Apple to apple

- model 1 vs. model 2
- model 1 vs. model 3
- 2D vs. 2.5D



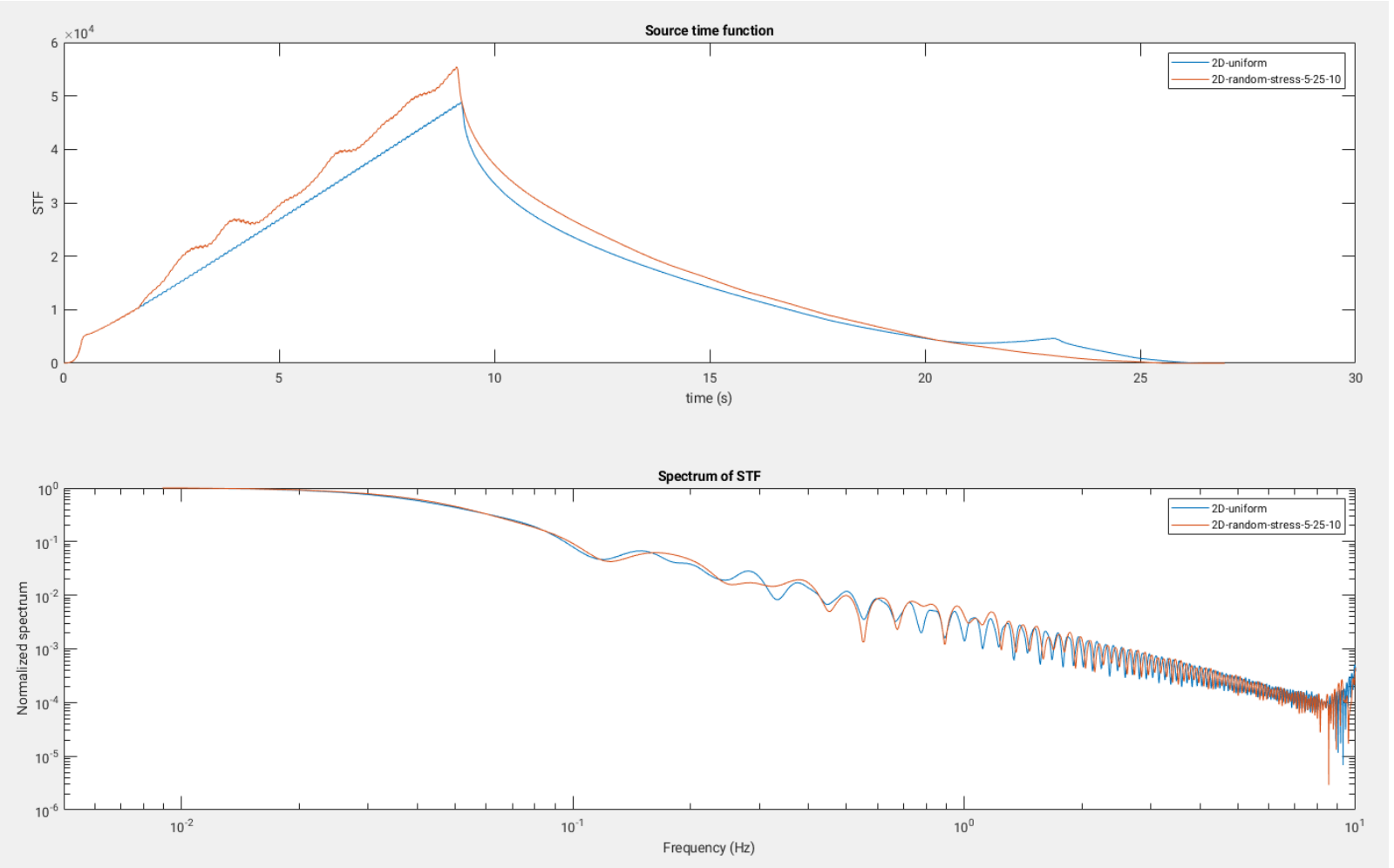
Discussion

- model 1 vs. model 2



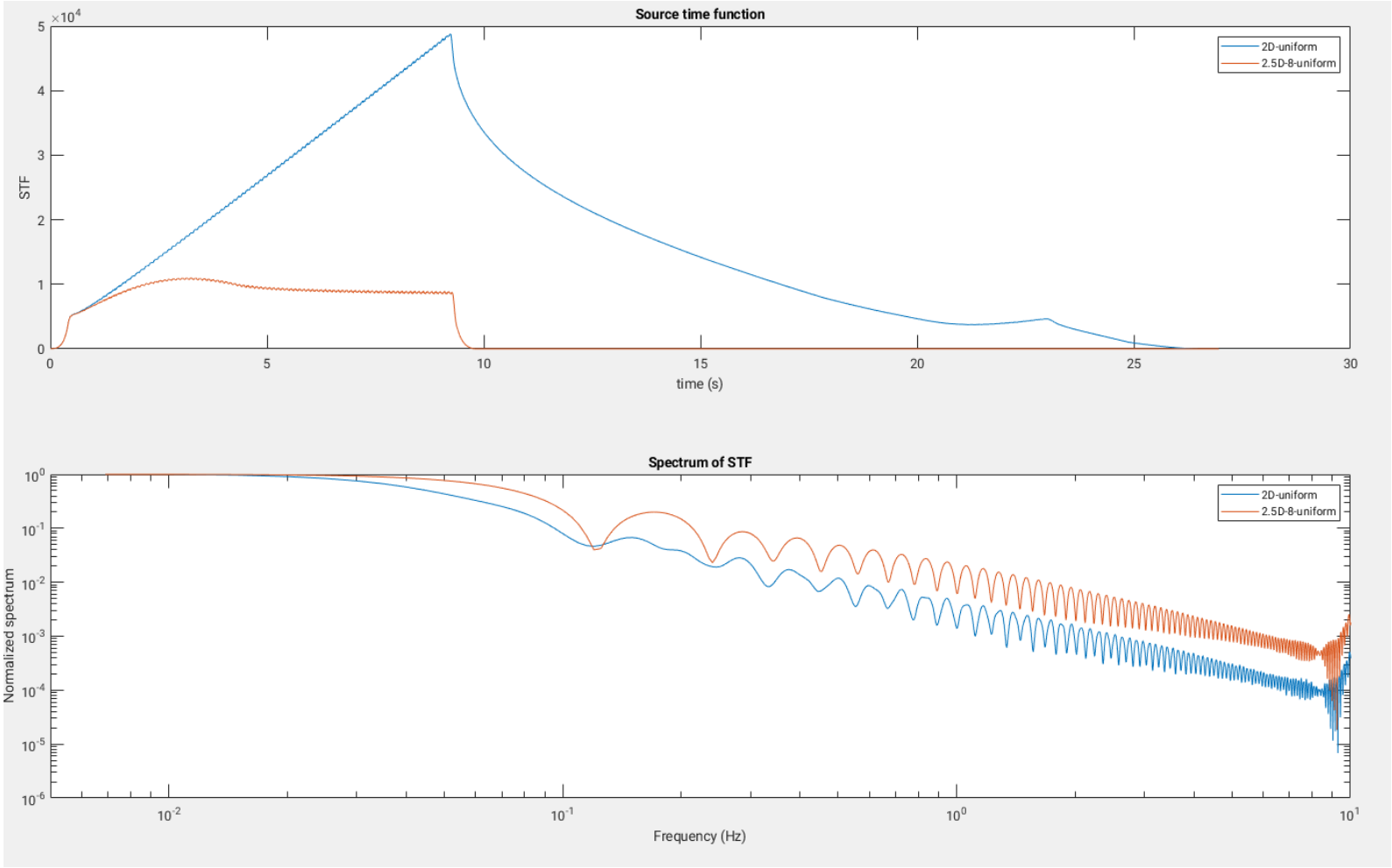
Discussion

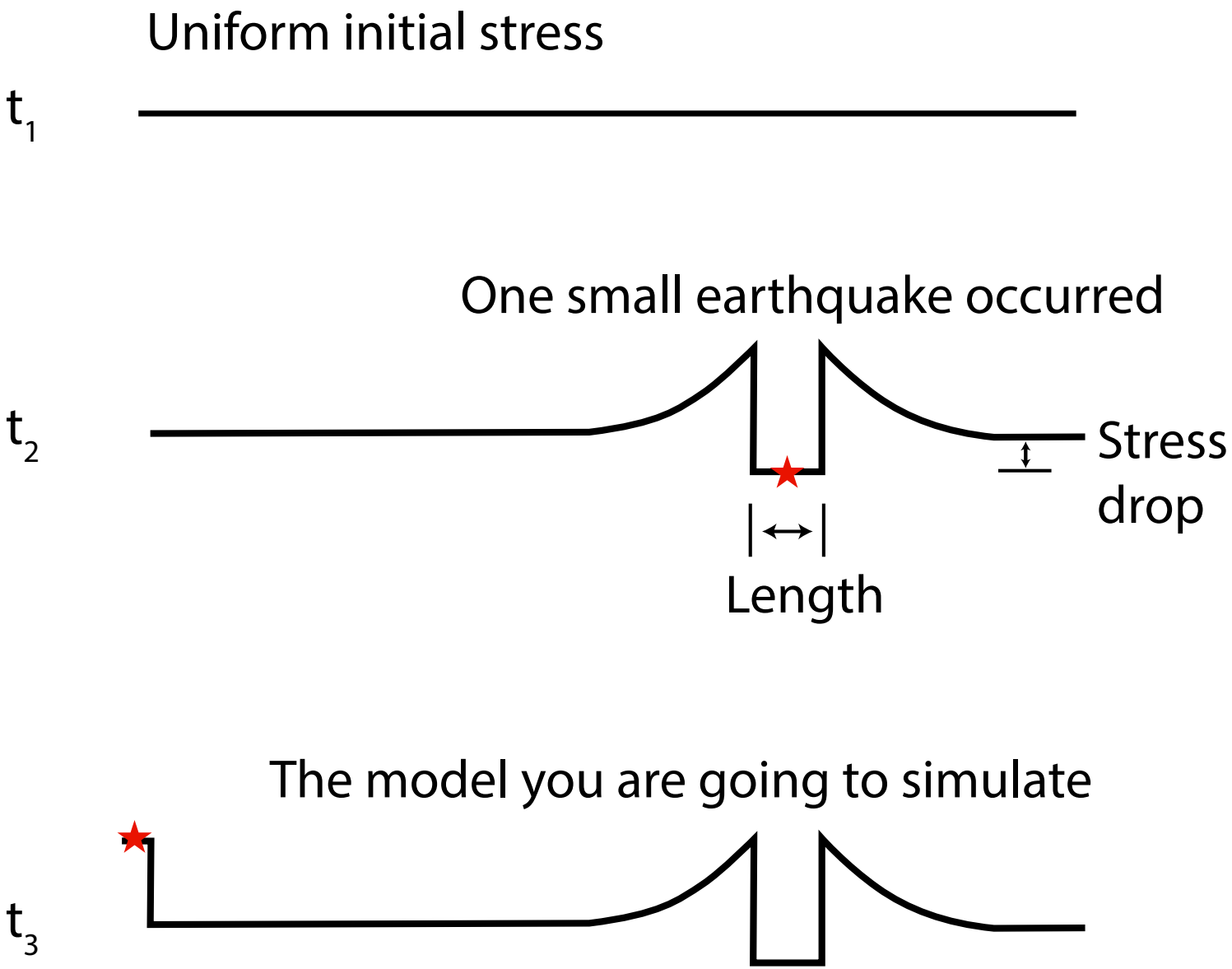
- model 1 vs. model 3



Discussion

- 2D vs. 2.5D

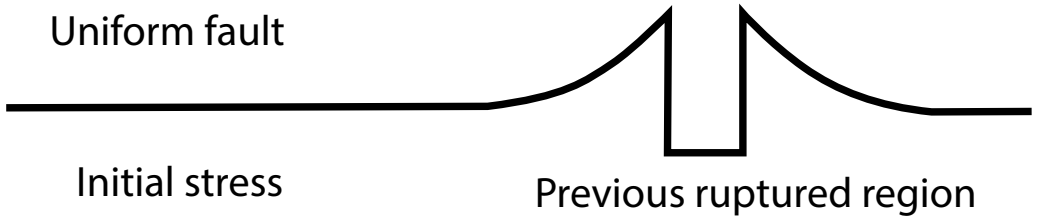



Uniform initial stress
t1
One small earthquake occurred
t2
Stress
drop
Length
The model you are going to simulate
t3

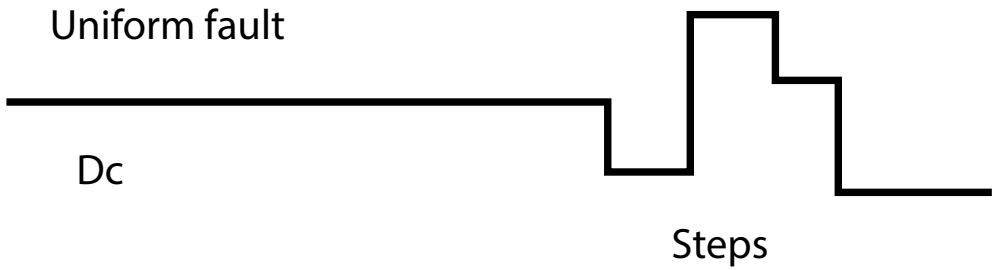
Models to test

- Heterogeneity is initial stress
- Question: do these heterogeneities increase high-frequency radiation?
- Discussion: what parameters may control the high-frequency radiation?

Model 4



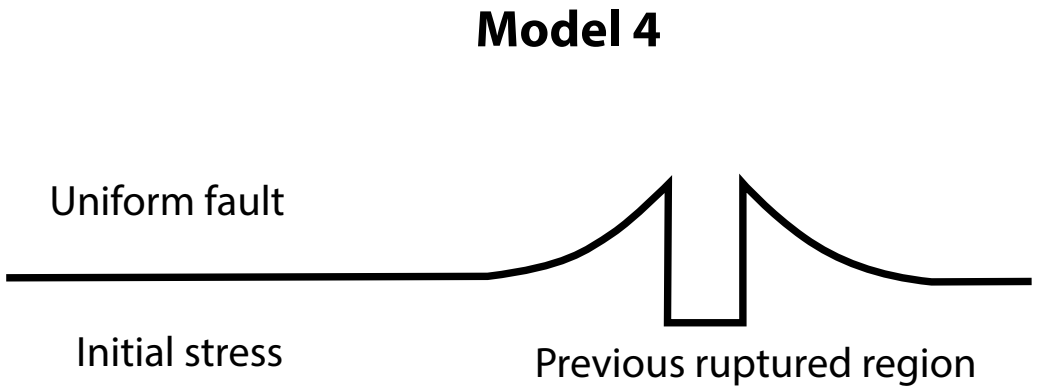
Model 5

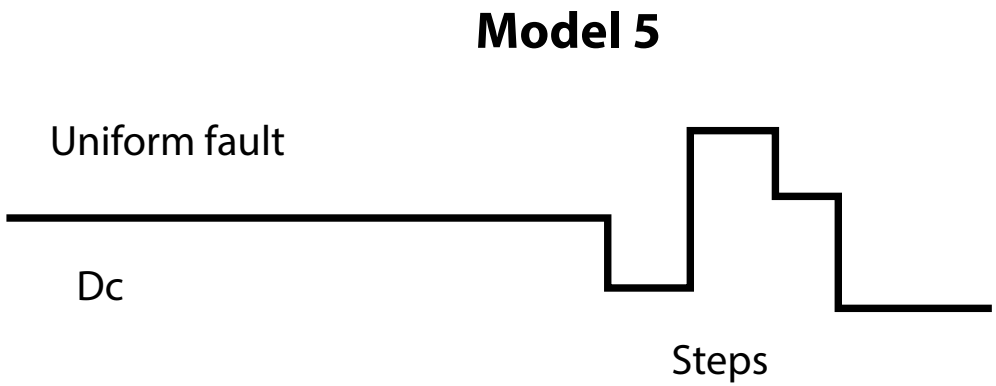


Discussion

Apple to apple

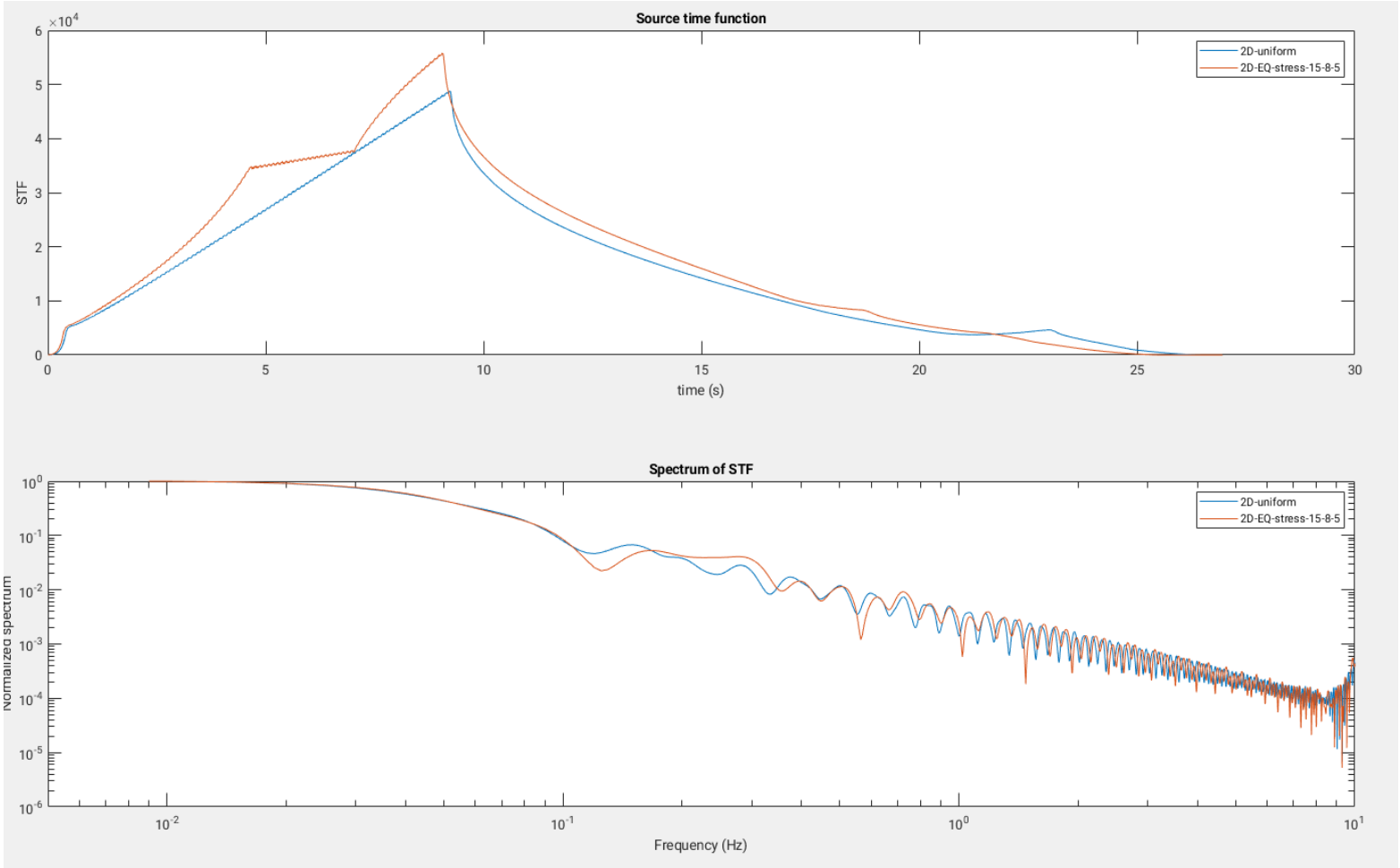
- model 1 vs. model 4
- model 1 vs. model 5
- 2D vs. 2.5D





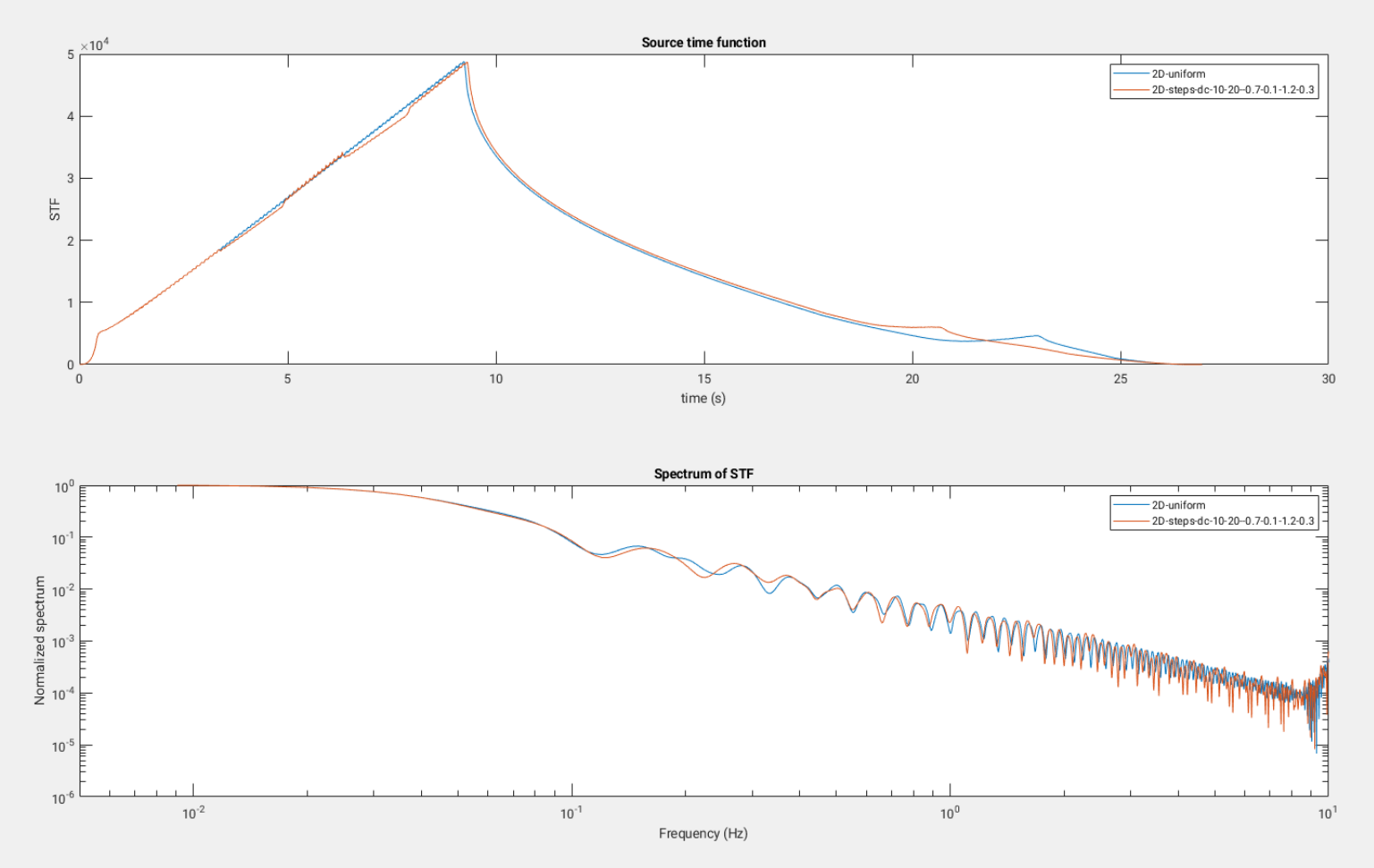
Discussion

- model 1 vs. model 4



Discussion

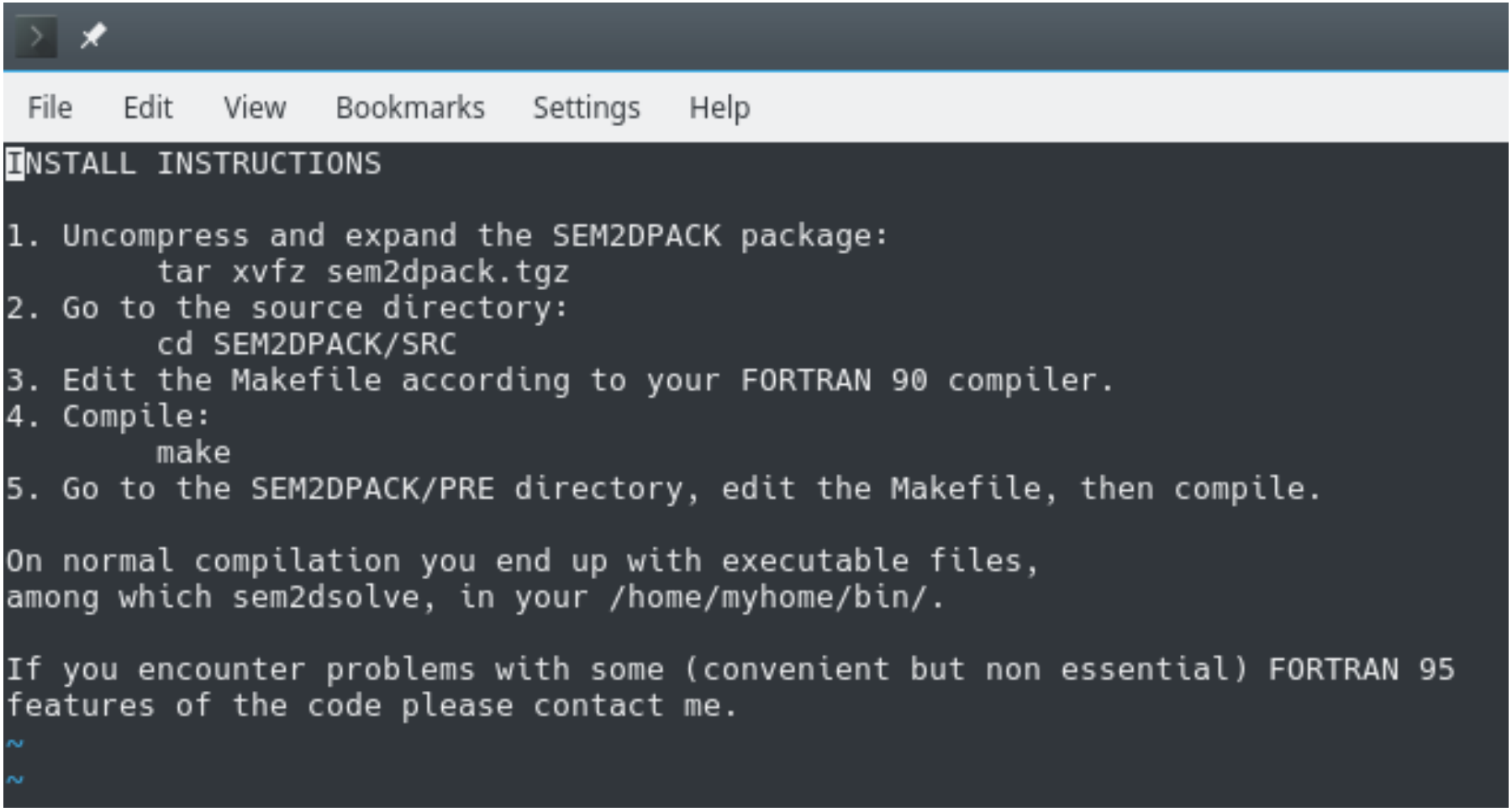
- model 1 vs. model 5



Tutorial of SEMLAB

Tutorial of sem2dpack

Installation of sem2dpack



How to run sem2dpack?

cd ./sem2dpack-25D/EXAMPLES/2.5D_inplane

open this file by vim or other method:

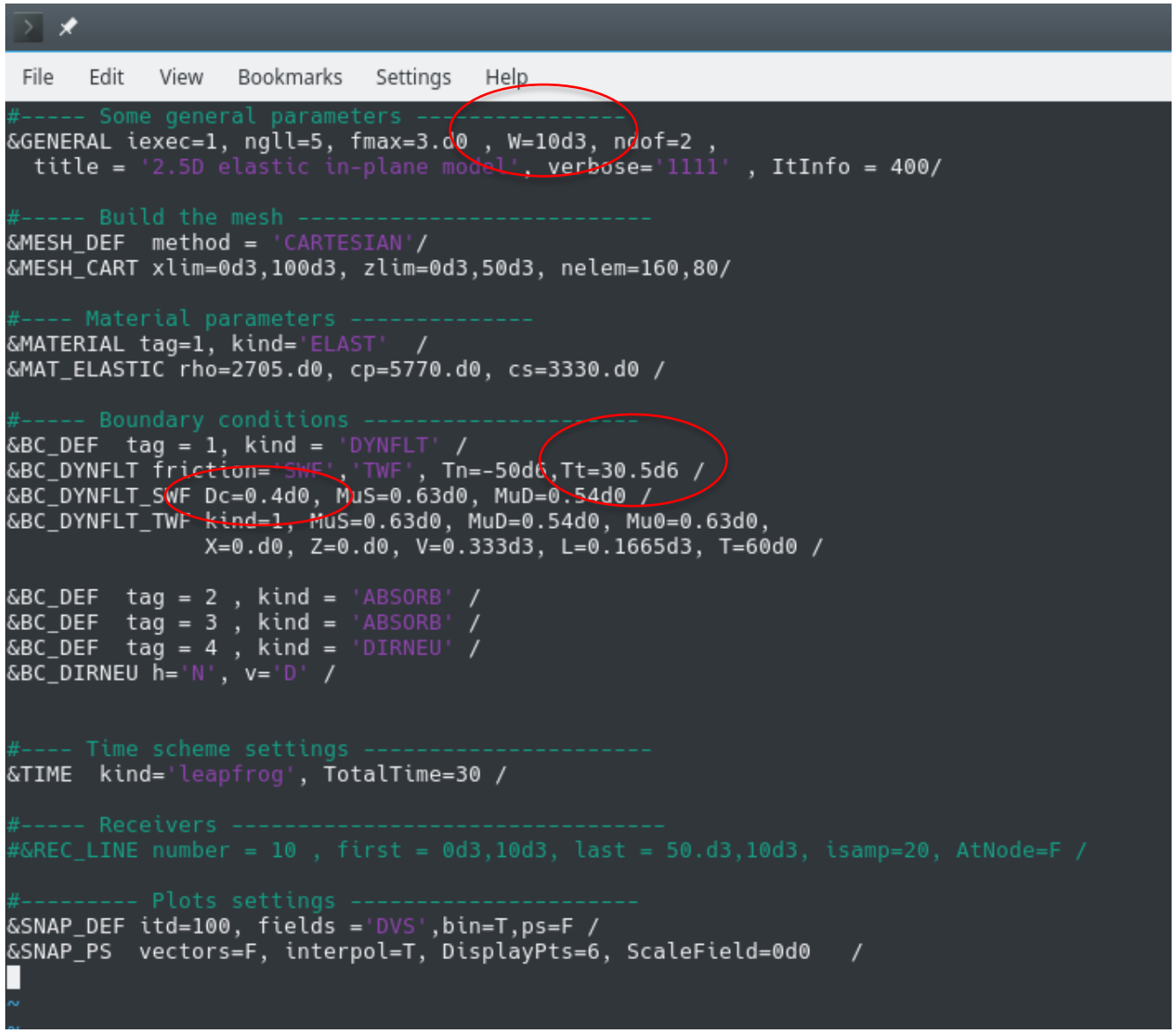
vi Par.inp

Parameter setup in sem2dpack

File Edit View Bookmarks Settings Help

```
#----- Some general parameters -----------------
&GENERAL iexec=1, ngll=5, fmax=3.d0 , W=10d3, ndof=2 ,
  title = '2.5D elastic in-plane model', verbose='1111' , ItInfo = 400/

#----- Build the mesh ---------------------------
&MESH_DEF  method = 'CARTESIAN'/
&MESH_CART xlim=0d3,100d3, zlim=0d3,50d3, nelem=160,80/

#---- Material parameters --------------
&MATERIAL tag=1, kind='ELAST'  /
&MAT_ELASTIC rho=2705.d0, cp=5770.d0, cs=3330.d0 /

#----- Boundary conditions ----------------------
&BC_DEF  tag = 1, kind = 'DYNFLT' /
&BC_DYNFLT friction='SWF','TWF', Tn=-50d6,Tt=30.5d6 /
&BC_DYNFLT_SWF Dc=0.4d0, MuS=0.63d0, MuD=0.54d0 /
&BC_DYNFLT_TWF kind=1, MuS=0.63d0, MuD=0.54d0, Mu0=0.63d0,
               X=0.d0, Z=0.d0, V=0.333d3, L=0.1665d3, T=60d0 /

&BC_DEF  tag = 2 , kind = 'ABSORB' /
&BC_DEF  tag = 3 , kind = 'ABSORB' /
&BC_DEF  tag = 4 , kind = 'DIRNEU' /
&BC_DIRNEU h='N', v='D' /


#---- Time scheme settings ----------------------
&TIME  kind='leapfrog', TotalTime=30 /

#----- Receivers ---------------------------------
#&REC_LINE number = 10 , first = 0d3,10d3, last = 50.d3,10d3, isamp=20, AtNode=F /

#--------- Plots settings ----------------------
&SNAP_DEF itd=100, fields ='DVS',bin=T,ps=F /
&SNAP_PS  vectors=F, interpol=T, DisplayPts=6, ScaleField=0d0   /
```

Parameter setup in sem2dpack



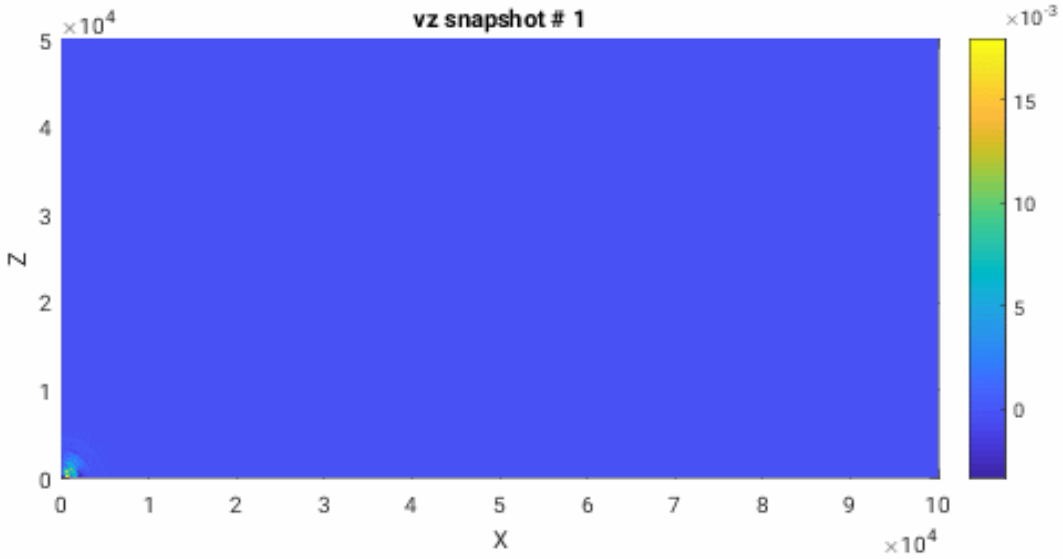
How to present results?

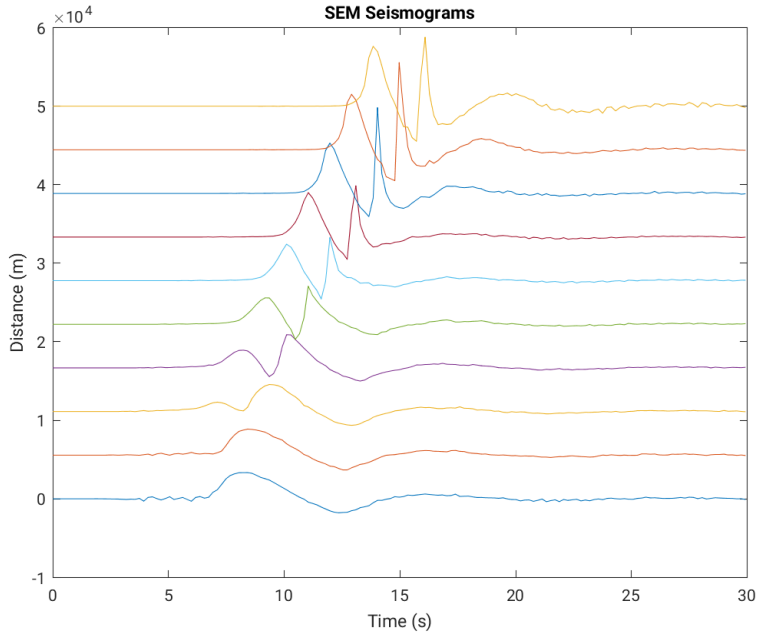
cd ${work_dir}/sem2dpack-25D/POST

open the script by MATLAB:

create_movie.m

run it by MATLAB


vz snapshot # 1
×10^4
5
4
3
2
1
0
Z
0
1
2
3
4
5
6
7
8
9
10
X
×10^4
×10^-3
15
10
5
0


SEM Seismograms
×10^4
6
5
4
3
2
1
0
-1
Distance (m)
0
5
10
15
20
25
30
Time (s)

Discussion

- Find seismic phases, such as P wave front, S wave, Rayleigh wave, etc.

- What parameters may control the formation of supershear rupture?

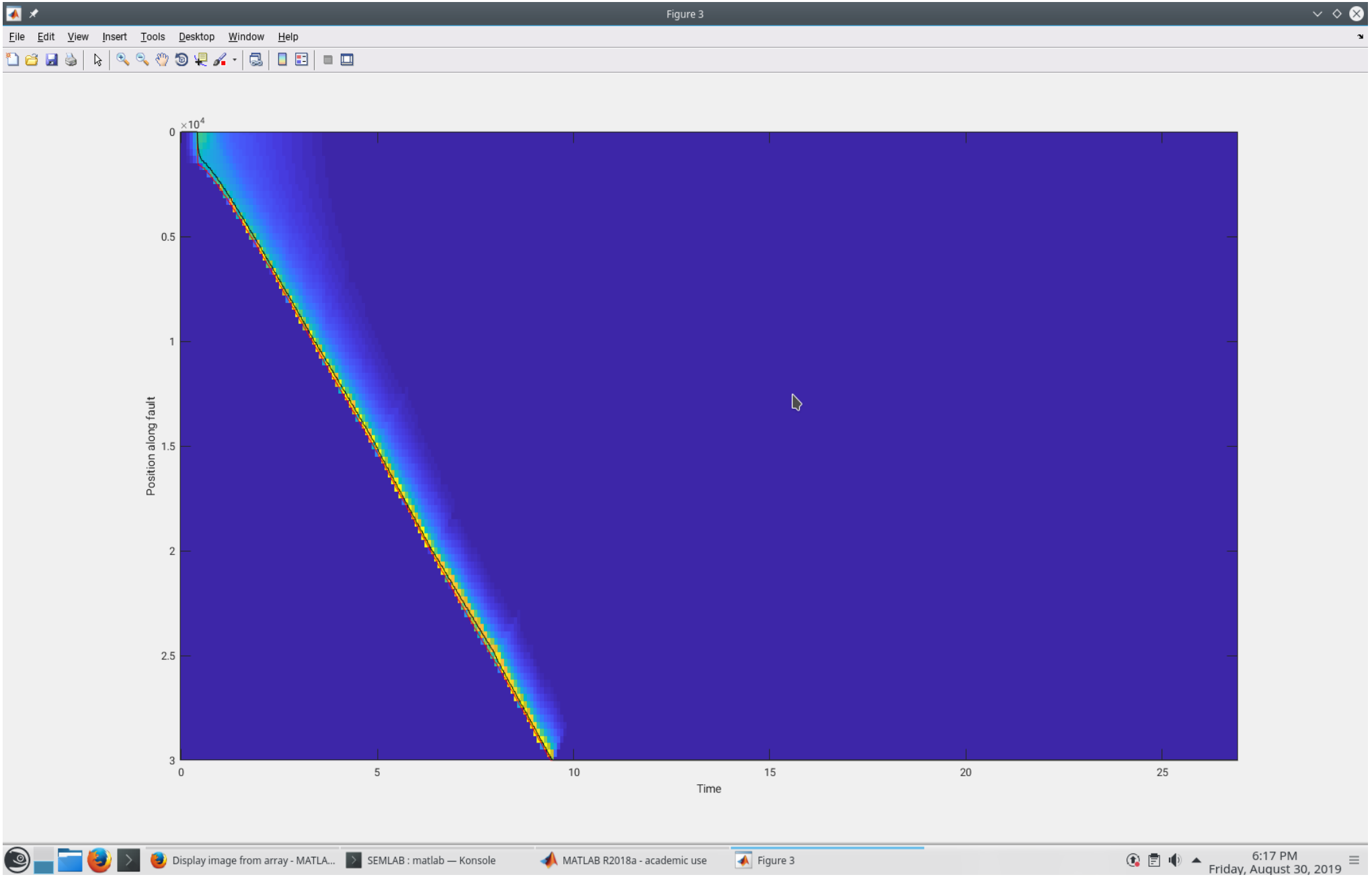


Figure 3
File Edit View Insert Tools Desktop Window Help
×10^4
0
0.5
1
1.5
2
2.5
3
Position along fault
0
5
10
15
20
25
Time
Display image from array - MATLA...
SEMLAB : matlab — Konsole
MATLAB R2018a - academic use
Figure 3
6:17 PM
Friday, August 30, 2019

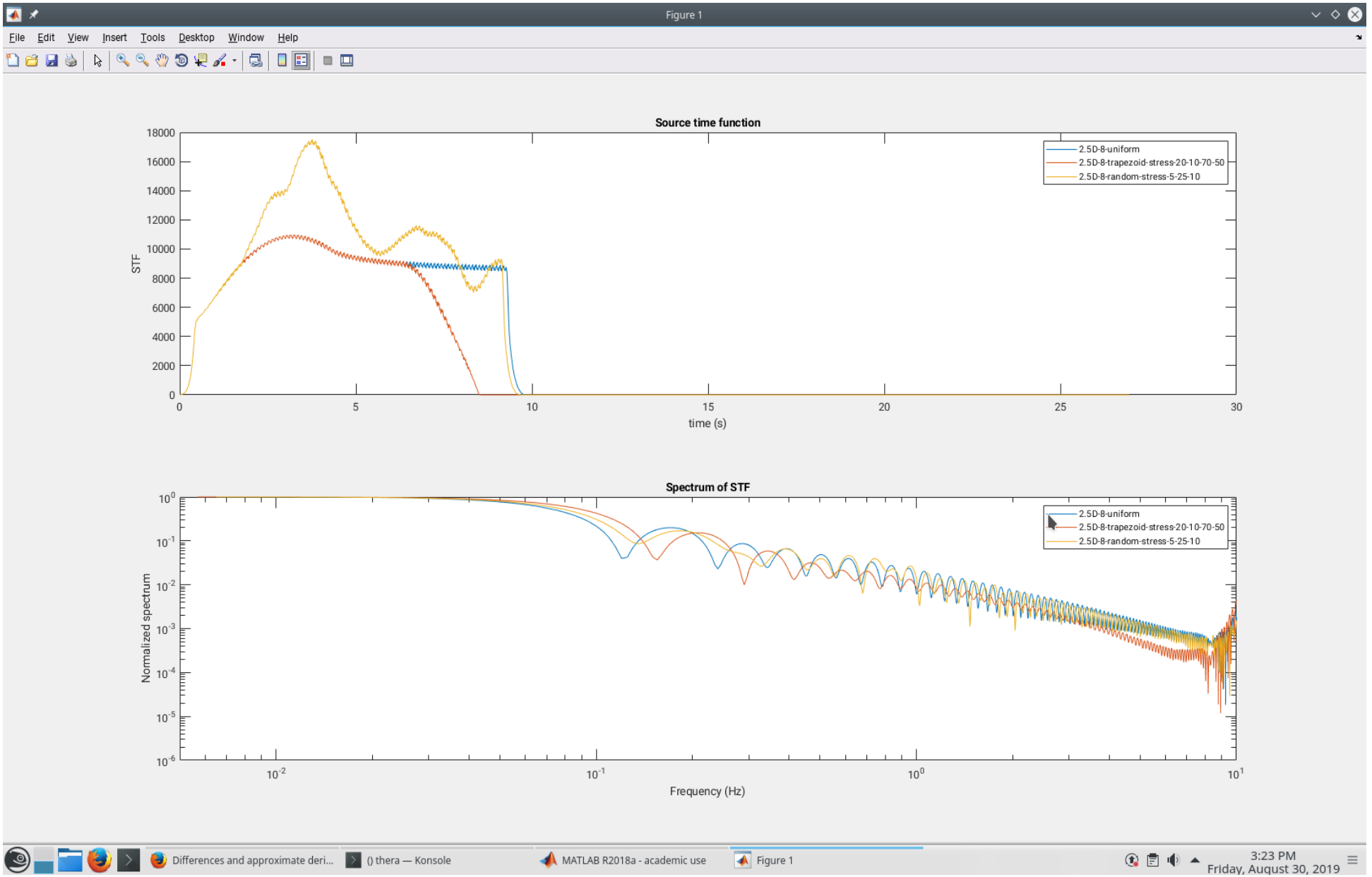


Figure 1
File Edit View Insert Tools Desktop Window Help
Source time function
STF
time (s)
2.5D-8-uniform
2.5D-8-trapezoid-stress-20-10-70-50
2.5D-8-random-stress-5-25-10
Spectrum of STF
Normalized spectrum
Frequency (Hz)
2.5D-8-uniform
2.5D-8-trapezoid-stress-20-10-70-50
2.5D-8-random-stress-5-25-10
Differences and approximate deri...
() thera — Konsole
MATLAB R2018a - academic use
Figure 1
3:23 PM
Friday, August 30, 2019

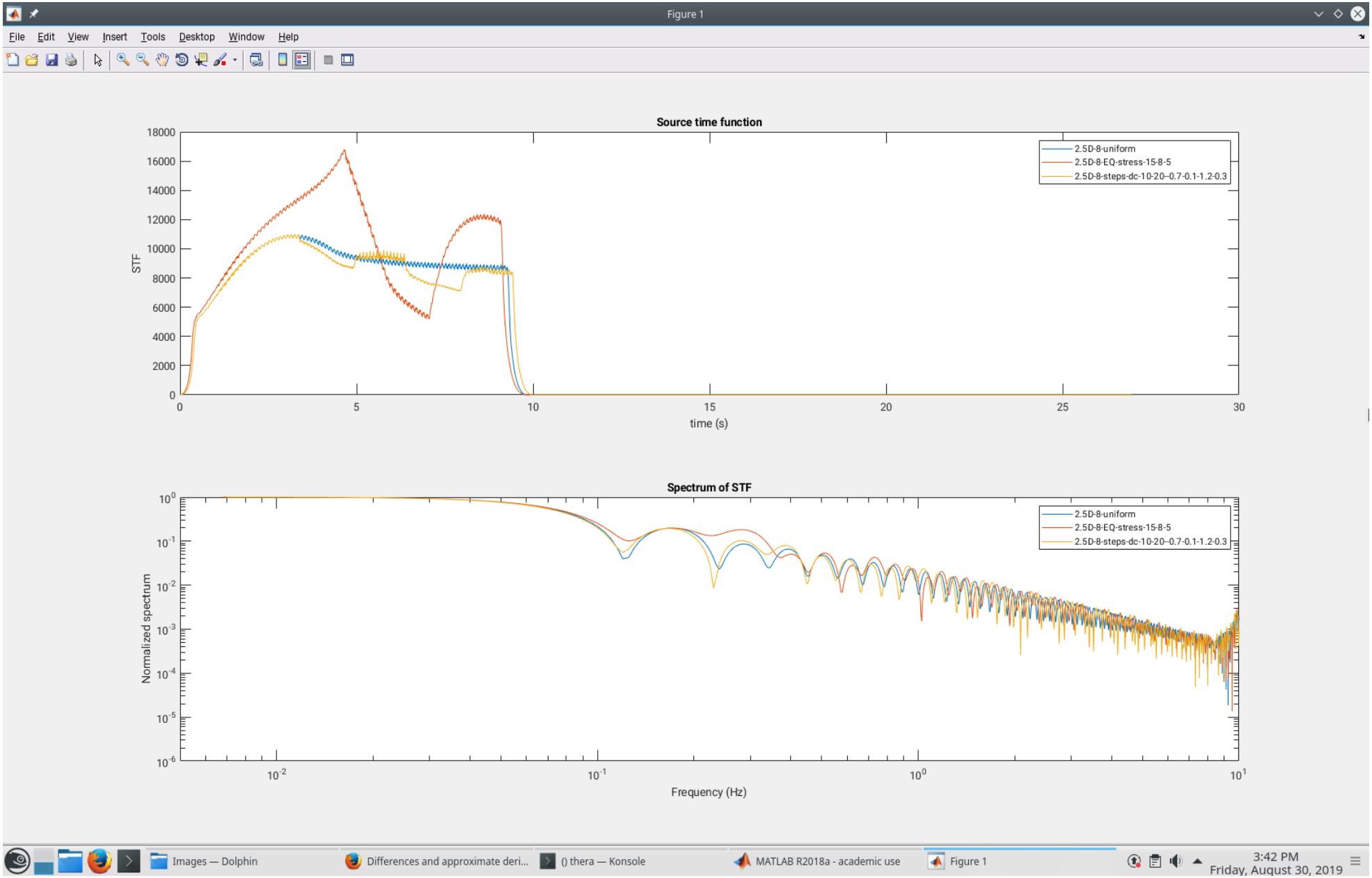


Figure 1
File Edit View Insert Tools Desktop Window Help
Source time function
STF
time (s)
2.5D-8-uniform
2.5D-8-EQ-stress-15-8-5
2.5D-8-steps-dc-10-20--0.7-0.1-1.2-0.3
Spectrum of STF
Normalized spectrum
Frequency (Hz)
2.5D-8-uniform
2.5D-8-EQ-stress-15-8-5
2.5D-8-steps-dc-10-20--0.7-0.1-1.2-0.3
Images — Dolphin
Differences and approximate deri...
() thera — Konsole
MATLAB R2018a - academic use
Figure 1
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Friday, August 30, 2019