In this homework, you will use a finite-differences modeling code, similar to the one you wrote in the preceding homework, to implement basic reverse time migration. I do not expect you to be concerned with the efficiency of your implementation at this time. This implementation of reverse-time migration does not require that you write any new C code. You will use pre-existing Madagascar programs, but you will modify the `SConstruct` file to combine those programs.

This is an individual assignment and absolutely no collaboration on code is allowed.

Figure 1: Velocity.

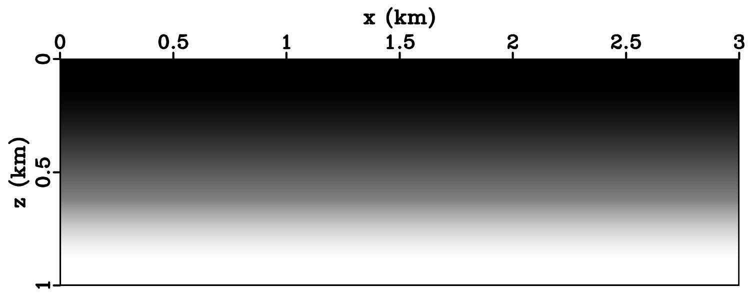


Figure 2: Density.

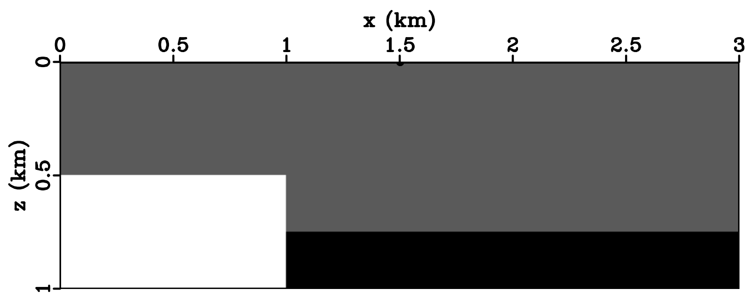
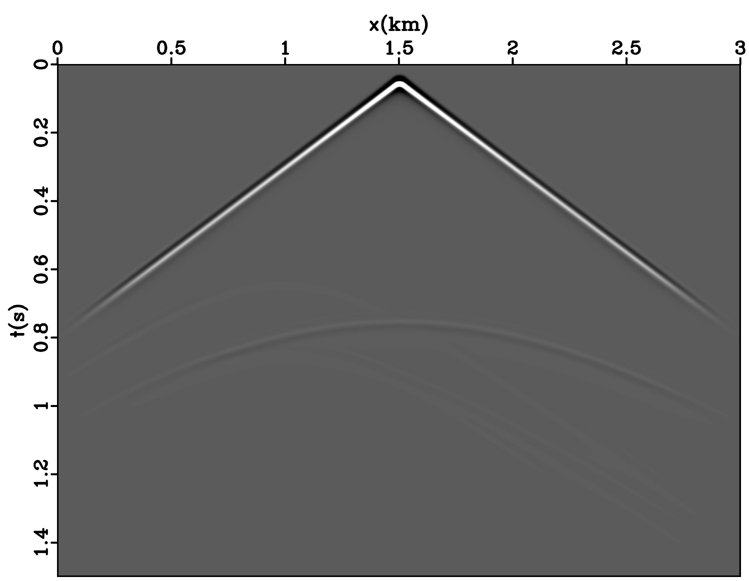


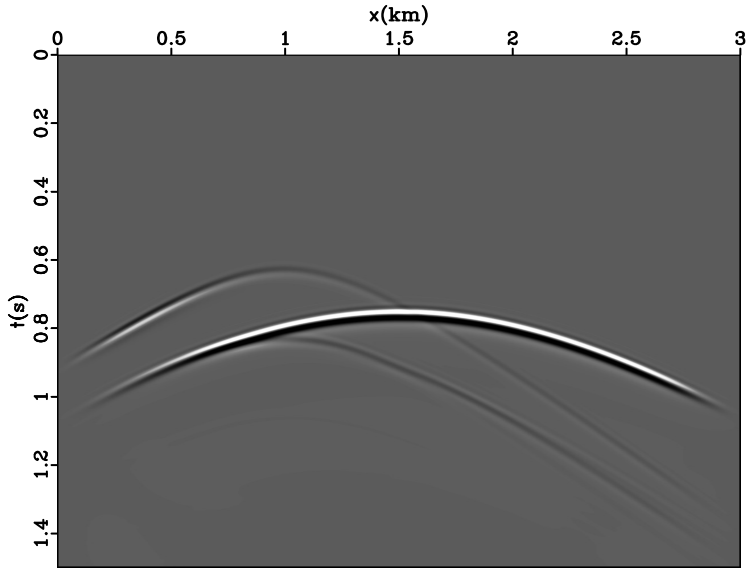
Figure 3: Data w/ direct arrival.



EXERCISE

Using the finite-differences modeling function `awefd`, construct an image of the subsurface. This function takes the following parameters:

Figure 4: Data w/o direct arrival.




```
awefd(odat,owfl,idat,velo,dens,sou,rec,custom,par)
```

- `odat`: output data $d(x,t)$
- `owfl`: output wavefield $u(z,x,t)$
- `idat`: input data (wavelet)
- `velo`: velocity model $v(z,x)$
- `dens`: density model $\rho(z,x)$
- `sou`: source coordinates
- `rec`: receiver coordinates
- `custom`: custom parameters
- `par`: parameter dictionary

Design an imaging procedure following the generic scheme developed in class. Your task is to identify Madagascar programs necessary to implement reverse-time migration in two different ways and generate the appropriate `Flows` in the `SConstruct`. Explain in detail how your imaging procedures work.

1. Use your imaging procedure to generate images based on recorded data in Figures 3 and 4. For this exercise, use the constant density `rb.rsf` for imaging. Include those two images in this document. Are the images different from each-other? How? Why?

2. Use your imaging procedure to generate images based on recorded data in Figures 3 and 4. For this exercise, use the variable density `ra.rsf` for imaging. Include those two images in this document. Are the images different from each-other? How? Why? How do your images compare with the ones from the preceding exercise?

WRAP-UP

After you are satisfied that your document looks ok, print it from the PDF viewer and bring it to class.

SCONSTRUCT

```
##
 # GPGN 658 - reverse-time migration
 ##
from rsf.proj import *
import fdm

# ------------------------------------------------------------
par = dict(
    nt=1500, ot=0, dt=0.001, lt='t', ut='s',
    nx=601,  ox=0, dx=0.005, lx='x', ux='km',
    nz=201,  oz=0, dz=0.005, lz='z', uz='km',
    kt=50,nb=100,jsnap=50,jdata=1,frq=35
    )
fdm.param(par)

par['xk']=50
par['xl']=par['nx']-50

par['xsou']=par['ox']+par['nx']/2*par['dx']
par['zsou']=par['oz']

# ------------------------------------------------------------
# wavelet
fdm.wavelet('wav_',par['frq'],par)
Flow(  'wav', 'wav_','transp')
Result('wav','window n2=500 |' + fdm.waveplot('',par))

# ------------------------------------------------------------
# sources coordinates
fdm.point('ss',par['xsou'],par['zsou'],par)
Plot('ss',fdm.ssplot('',par))

# receivers coordinates
fdm.horizontal('rr',0,par)
Plot('rr',fdm.rrplot('',par))

# ------------------------------------------------------------
# velocity
Flow('vo',None,
     '''
     math output="2.0+0.25*x1"
     n1=%(nz)d o1=%(oz)g d1=%(dz)g
     n2=%(nx)d o2=%(ox)g d2=%(dx)g
     ''' % par)

Plot(  'vo',fdm.cgrey('allpos=y bias=2.0 pclip=100',par))
Result('vo',['vo','ss','rr'],'Overlay')

# ------------------------------------------------------------
# density
Flow('ra',None,
     '''
     spike nsp=2 mag=+0.5,-0.5
     n1=%(nz)d o1=%(oz)g d1=%(dz)g k1=101,151 l1=%(nz)d,%(nz)d
     n2=%(nx)d o2=%(ox)g d2=%(dx)g k2=1,201   l2=200,%(nx)d |
     add add=2
     ''' % par)
Plot(  'ra',fdm.cgrey('allpos=y bias=1.5 pclip=100',par))
Result('ra',['ra','ss','rr'],'Overlay')

Flow('rb','ra','math output=1')

# ------------------------------------------------------------
# edge taper
Flow('taper',None,
     '''
     spike nsp=1 mag=1
     n1=%(nx)d d1=%(dx)g o1=%(ox)g k1=%(xk)d l1=%(xl)d
     n2=%(nt)d d2=%(dt)g o2=%(ot)g |
     smooth rect1=50
     ''' % par)
Result('taper','transp |'+fdm.dgrey('pclip=99',par))

# ------------------------------------------------------------
# finite-differences modeling
fdm.awefd('dd','ww','wav','vo','ra','ss','rr','jsnap=1 fsrf=n',par)
fdm.awefd('do','wo','wav','vo','rb','ss','rr','jsnap=1 fsrf=n',par)

Result('ww','window j3=%(jsnap)d |'%par + fdm.wgrey('pclip=99.9',par))
Result('wo','window j3=%(jsnap)d |'%par + fdm.wgrey('pclip=99.9',par))

# data w/  direct arrivals
Flow(  'dr0','dd taper',
       'add mode=p ${SOURCES[1]}')

# data w/o direct arrivals
Flow(  'dr1','dd do taper',
       'math r=${SOURCES[0]} d=${SOURCES[1]} t=${SOURCES[2]} output="(r-d)*t"')

for j in range(2):
    dtag="%d"%j
    Result('dr'+dtag,'transp |' + fdm.dgrey('pclip=99.9',par))

# ------------------------------------------------------------
##
 # Here add rules for your assignment.
 #
 # use Flow()
 # use Result()
 #
 # find Madagascar programs using the command "sfdoc -k ."
 # find the documentation of Madagascar programs by typing the program name
 ##

End()
```