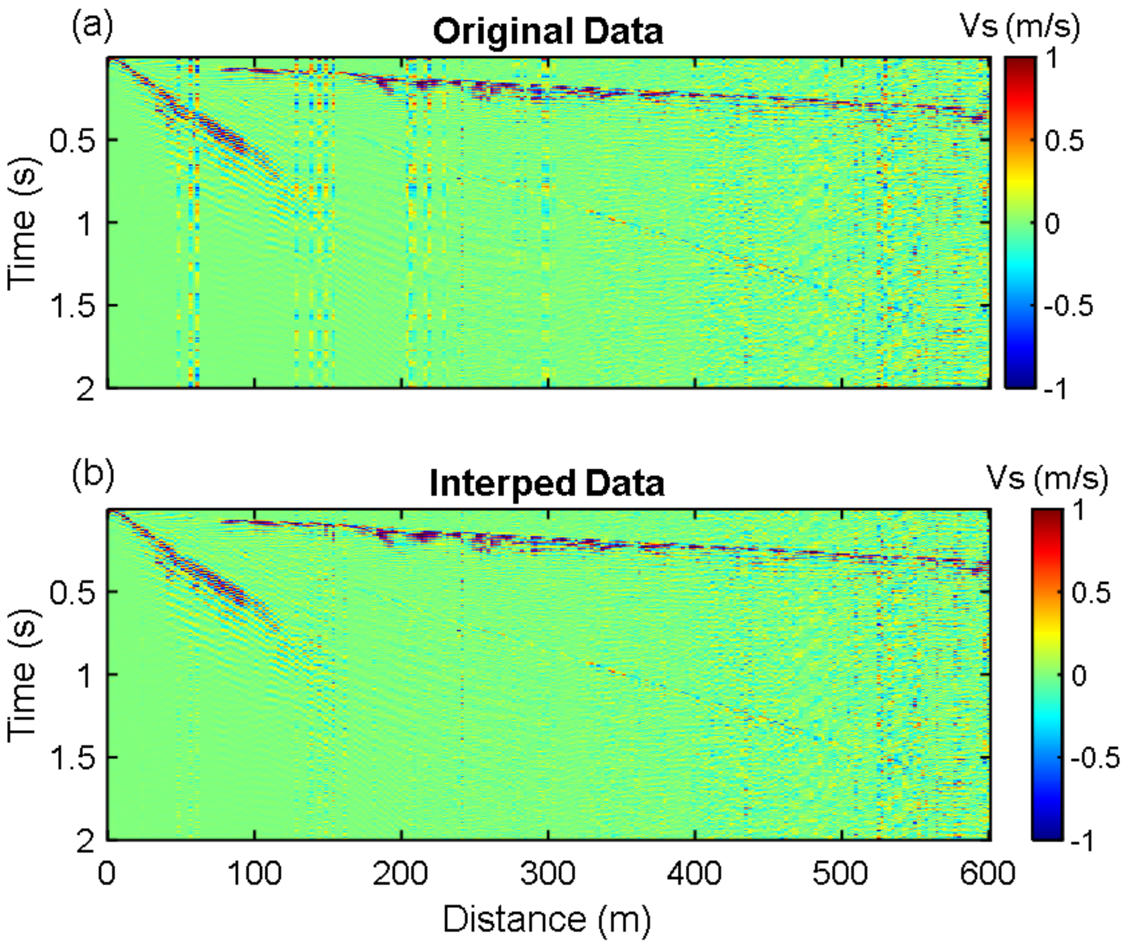
prapare the data

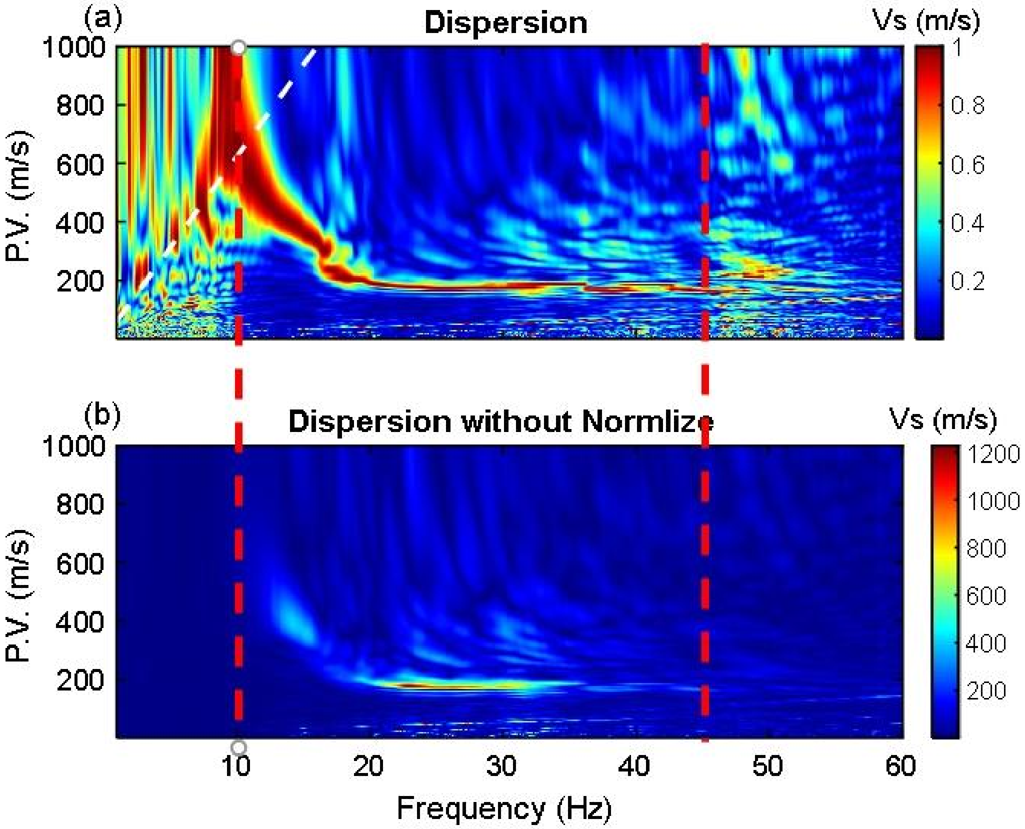
simple preprocess

```
load('testdatamat.mat')
% imagesc(seismo_v_d)
% imagesc(seismoPocs)
```

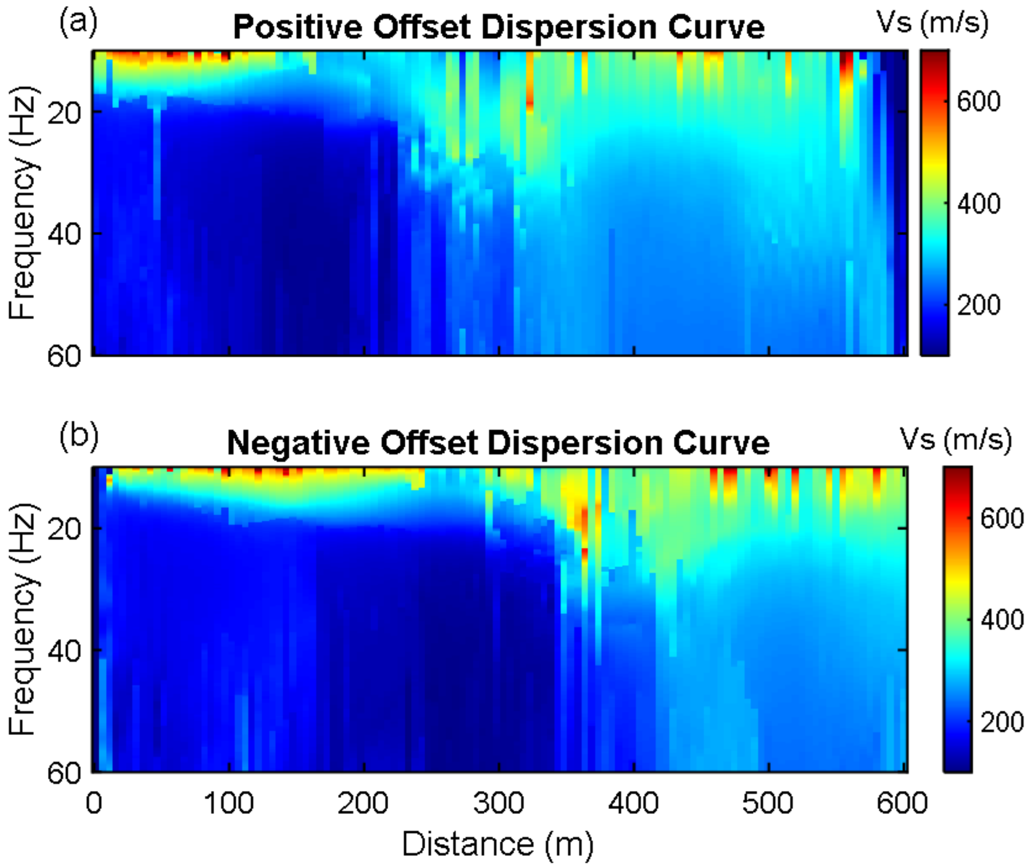


Extract dispersions

```
clc;
clear
close all;
load('manualDispfile3of3.mat')
addpath('./core');
```



$$\text{Inversion Depth} \approx \frac{\lambda}{2} = \frac{1}{2}\frac{\mathrm{PV_{max}}}{\mathrm{fr}} \approx \frac{65}{10 * 2} = 32.5$$



```
vsmin=100;vsmax=1200;% vsmin=vsmin,vsmax=vsmax*1.6
vpmin=vsmin*.1732;vpmax=vsmax*1.732;
```

Maxoffset=39; Minoffset=6;offset=offset-3;

Dispersion number:12*2*120= 2880

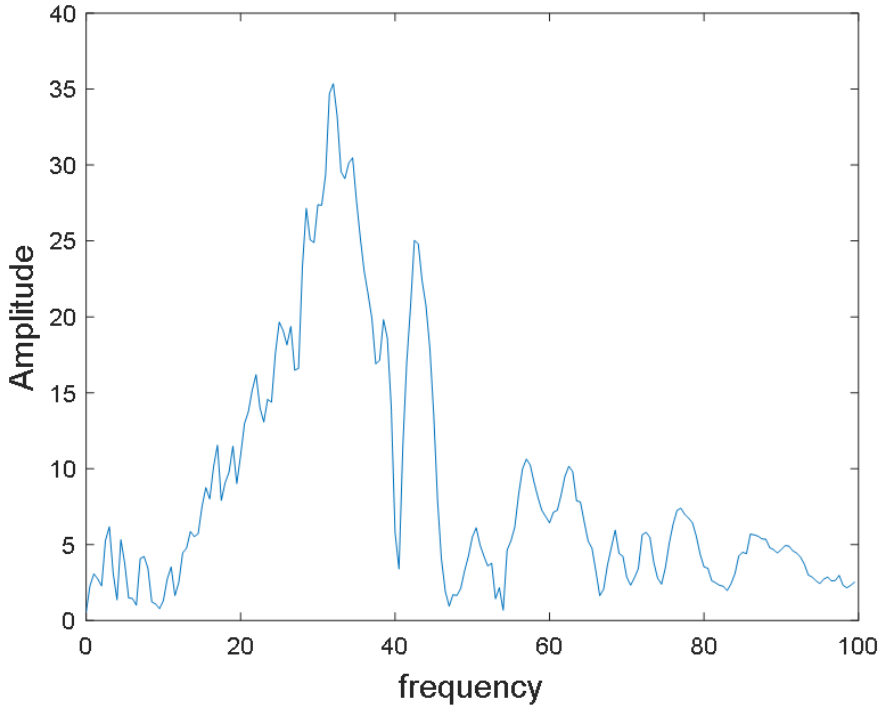
Maxoffset > Inversion Depth

Maxoffset < The maximum offset that dispersion looks good

Determine the frequency

Prediction data main frequency = observation data center frequency

```
fr=30;
```



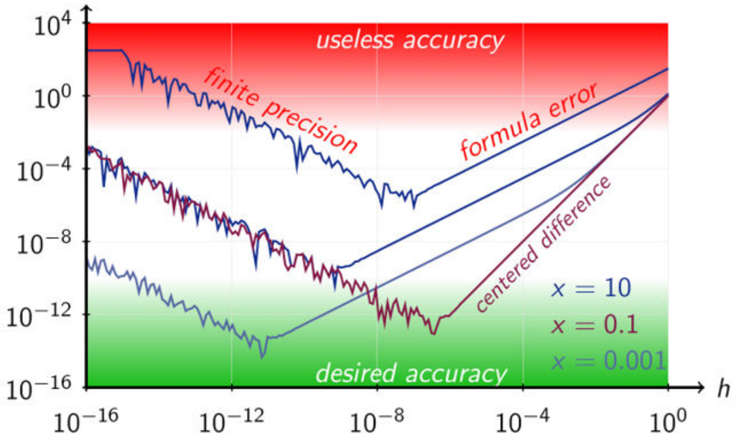
Determine dx

$$\mathrm{dx} = \frac{\mathrm{vs_{min}}}{\mathrm{fr} \times 12} = \frac{100}{30 * 12} = 0.2778 > 0.25$$

The geophones are placed on a grid so that dx can only be selected: $\frac{1}{n}$

If dx=0.5

$$\mathrm{vs_{min}} = \mathrm{dx} \times \mathrm{fr} \times 12 = 180$$



```
dx=0.25;%dx=(min(vs_d(:))/fr/12);
nz=120;nx=2400;% 30/dx;600/dx
```

```
dt=dx/vpmax*0.5;
dtx=dt/dx;
```

prapare the data

```
for i=1:nx
    vs(:,i)=linspace(200,1100,nz);
end
vp=vs*1.732;
pickMethod=1;  %1==FDC 2==argmax
nt=8500;  % time step
[s,nw]=ricker(fr,dt,nt); s =single(s); % source wavelet
nbc=40;   % boundary layer
```

•Easy equation to calculate memory usage:

$$(\mathrm{nz}+\mathrm{nbc})*(\mathrm{nx}+\mathrm{nbc}*2)*\mathrm{nt/in\_wf}\ *4*4(8)/1024/1024/1024*\mathrm{ns\_parallel}\approx 301.5518\mathrm{GB}$$

Inversiontime: 4h (AMD EPYC 9684X 96-Core Processor)

The near-surface grid is finer and the computational requirements depend on the velocity range.

```
% define acquisition geometry
ds=20; sx=single(1:ds:nx); sz=zeros(size(sx),'single')+1;[~,ns]=size(sx);
dg=10;gx=single(1:dg:nx);  gz=zeros(size(gx),'single')+1;  ng=numel(gx);
M=ds/dg;refsx=floor(sx/dg)+1;
dg=dg*dx;
% define wavefield record
dt_wf=dt*10; nt_wf=floor((nt-1)*dt/dt_wf)+1;
pur=-0.05;
offset=floor(1.5*nz*dx);   % multi-offset &the maximum offset
offset=39;
offmin=3;offmax=floor(1.5*nz*dx);
NN=(offset-offmin)/3;   % offset change number
parameter_type=0;
fd_order=22;fsz=0;source_type='w';
isfs=1;

parallel_init(ns/2);

% Set Radon Transform papramter to cal. phase velocity
vmin=100;
vmax=1000;
np=vmax-vmin+1;
df1=0.1;
df=1/nt/dt;
N=df/df1;
df=df1;
fre1=(df*(0:floor(nt)-1));
fmin=10;
```

```
fmax=60;
m=0;FK=0;w=3;  % dot not need to change,w=3 is the min. traces for your multi-
offset dispersion. You can increase the number
err=0.01;
a=nt;b=ng;
iteration=190;
```

++++Start SWD iversion ++++

```
%%--------------------------------------------------------------
k =1;kk=1;
vs_all=zeros(nz,nx,100);
dk_vs_all=zeros(nz,nx,100);
ind=find(fre1==fmin);
freq=(fmin:df:fmax);
[~,npair]=size(freq);
win=npair+2*ind;
SoftArgNorm = 1e+4;
offsets = zeros(iteration,1);

for i =1:npair
    space_M(:,i) = linspace(1,np,np);
end
[s,nw]=ricker(fr,dt,nt); s =single(s); % source wavelet

while (k<=iteration)
    tic;
    display(['Elastic_LSM, k=',num2str(k),' iteration=',num2str(iteration)]);

fre=2*pi*linspace(fmin,fmax,(fmax-fmin)/df+1);

ml = zeros(np,npair,ns);
ml1 = zeros(np,npair,ns);
```

Cal. the obsdata dispersion curve two sides(Left and right)

```
fband = round((fmax-1)/df+1);
fstart = round((fmin-1)/df+1);
cr_0 = smooth2a(crObsManualSR(fstart:fband,:,offset/3),2,1);
cr_0l = smooth2a(crObsManualSL(fstart:fband,:,offset/3),2,1);

cr_pre_r = 1.*ones(npair,ns);
cr_pre_l = 1.*ones(npair,ns);
   g_cl=zeros(nz,nx);
   g_cm=zeros(nz,nx);
   g_illum=zeros(nz,nx);
```

```
parfor is=1:ns
```

```
[~,seismo_v,wavefield_gradient]=staggerfd_eigen(is,nbc,nt,dtx,dx,dt,sx(is),sz(is),gx
,gz,s,vp,vs,isfs,fsz,fd_order,source_type,parameter_type,dt_wf,nt_wf);
   seismo_v = norm_trace(seismo_v);
   saveForBackwardr = 0;
   saveForBackwardl = 0;
        if is<=ns-floor(m/M)-round(w/M)

[mlr,dataLen,saveForBackwardr]=RTrAD(seismo_v,is,df,dt,np,vmin,vmax,fmin,fmax,a,b,dg
,offset,m,FK,M); % Cal. the predicetd data dispersion curve for two sides
            [res_r(is),cr_pre_r(:,is)] =
LHDispPick(mlr,npair,vmin,cr_0(:,is),saveForBackwardr,pickMethod);
            saveForBackwardr.cr_r = cr_pre_r(:,is)-vmin;
        end

        if is>=round(w/M)+floor(m/M)+1

[mll,dataLen,saveForBackwardl]=RTlAD(seismo_v,is,df,dt,np,vmin,vmax,fmin,fmax,a,b,dg
,offset,m,FK,M); % Cal. the predicetd data dispersion curve for two sides
            [res_l(is),cr_pre_l(:,is)] =
LHDispPick(mll,npair,vmin,cr_0l(:,is),saveForBackwardl,pickMethod);
            saveForBackwardl.cr_l = cr_pre_l(:,is)-vmin;
        end
        grad_outputr = cr_pre_r(:,is)-cr_0(:,is);
        grad_outputl = cr_pre_l(:,is)-cr_0l(:,is);
%
[seismo_v_d1]=weight_data_muti3(seismo_v,seismo_v,is,dt,df,offset,dg,0,w,M,m,ns,refs
x,win,np,vmin,vmax,fmin,fmax, ...
%     cr_0(:,is),cr_0l(:,is),cr_pre_r(:,is),cr_pre_l(:,is),FK,ind); %The key step
to calculate the backprohated data
[seismo_v_d1]=ADWDgrad_1(nt,ng,ns,npair,is,w,m,M,SoftArgNorm,grad_outputr,grad_outpu
tl,space_M,saveForBackwardr,saveForBackwardl);

[cl_img,cm_img,illum_div]=e2drtm_eigen(wavefield_gradient,single(seismo_v_d1),is,nbc
,nt,dtx,dx,dt,gx,gz,s,vp,vs,isfs,fsz,fd_order,parameter_type,dt_wf);
        g_cl = g_cl+cl_img;g_cm = g_cm+cm_img;g_illum = g_illum+illum_div;
end

    % Use the penality method to build the objective function
  residual(k)=mean(mean(res_l));%+mean(mean(res_l));
    display(['residual = ',num2str( residual(k) ),' k=',num2str(k)]);
    res0=residual(k);
    g_cl=g_cl./g_illum;g_cm=g_cm./g_illum;
    dk_vs = -4*vs.*g_cl+2*vs.*g_cm;
    dk_vs=single(smooth2a(double(dk_vs),1,13));  % Smooth the Vs gradient

    if k==1
        f1=0.5;
    end
    v_mean=(sum(vs(:).*vs(:)))^0.5;
    g_mean=(sum(dk_vs(:).*dk_vs(:)))^0.5;
    alpha=v_mean/g_mean*pur;
    display(['v_mean=',num2str(v_mean),' g_mean=',num2str(g_mean),'
alpha=',num2str(alpha)]);
    vs1=vs+alpha*f1*dk_vs;
    vs1(vs1<vsmin)=vsmin;vs1(vs1>vsmax)=vsmax;
    vp=vs1*1.732;
    %vs1(vp./vs1<1.3)=vp(vp./vs1<1.3)/1.3;
```

```
parfor is=1:ns

[~,seismo_v,~]=staggerfd_eigen(is,nbc,nt,dtx,dx,dt,sx(is),sz(is),gx,gz,s,vp,vs1,isfs
,fsz,fd_order,source_type,parameter_type,dt_wf,nt_wf);
    seismo_v = norm_trace(seismo_v);
    if is<=ns-floor(m/M)-round(w/M)

[mlr,dataLen,saveForBackwardr]=RTrAD(seismo_v,is,df,dt,np,vmin,vmax,fmin,fmax,a,b,dg
,offset,m,FK,M); % Cal. the predicetd data dispersion curve for two sides
        [res_r(is),cr_pre_r(:,is)] =
LHDispPick(mlr,npair,vmin,cr_0(:,is),saveForBackwardr,pickMethod);
    end
    if is>=round(w/M)+floor(m/M)+1

[mll,dataLen,saveForBackwardl]=RTlAD(seismo_v,is,df,dt,np,vmin,vmax,fmin,fmax,a,b,dg
,offset,m,FK,M); % Cal. the predicetd data dispersion curve for two sides
        [res_l(is),cr_pre_l(:,is)] =
LHDispPick(mll,npair,vmin,cr_0l(:,is),saveForBackwardl,pickMethod);
    end


end
   res1=mean(mean(res_l));%+mean(mean(res_l));
    display(['f1= ',num2str(f1),' res1= ',num2str(res1)]);
 clear seismo_v cr_1 deta_c deta_c3

    if res1>res0
        while res1>res0 && f1>0.0001
            f2=f1; res2=res1;
            f1=f1*0.5;
            vs1=vs+alpha*f1*dk_vs;
            vs1(vs1<vsmin)=vsmin;vs1(vs1>vsmax)=vsmax;
            vp=vs1*1.732;
                %vs1(vp./vs1<1.3)=vp(vp./vs1<1.3)/1.3;


parfor is=1:ns

[~,seismo_v,~]=staggerfd_eigen(is,nbc,nt,dtx,dx,dt,sx(is),sz(is),gx,gz,s,vp,vs1,isfs
,fsz,fd_order,source_type,parameter_type,dt_wf,nt_wf);
```

```
   seismo_v = norm_trace(seismo_v);
   if is<=ns-floor(m/M)-round(w/M)

[mlr,dataLen,saveForBackwardr]=RTrAD(seismo_v,is,df,dt,np,vmin,vmax,fmin,fmax,a,b,dg
,offset,m,FK,M); % Cal. the predicetd data dispersion curve for two sides
        [res_r(is),cr_pre_r(:,is)] =
LHDispPick(mlr,npair,vmin,cr_0(:,is),saveForBackwardr,pickMethod);
    end
    if is>=round(w/M)+floor(m/M)+1

[mll,dataLen,saveForBackwardl]=RTlAD(seismo_v,is,df,dt,np,vmin,vmax,fmin,fmax,a,b,dg
,offset,m,FK,M); % Cal. the predicetd data dispersion curve for two sides
        [res_l(is),cr_pre_l(:,is)] =
LHDispPick(mll,npair,vmin,cr_0l(:,is),saveForBackwardl,pickMethod);
    end

end
   res1=mean(mean(res_l));%+mean(mean(res_l));
    display(['f1= ',num2str(f1),' res1= ',num2str(res1)]);
 clear seismo_v cr_1 deta_c deta_c3
        end
    else
        f2=f1*2;
        vs1=vs+alpha*f2*dk_vs;
        vs1(vs1<vsmin)=vsmin;vs1(vs1>vsmax)=vsmax;
        vp=vs1*1.732;
            %vs1(vp./vs1<1.3)=vp(vp./vs1<1.3)/1.3;

        %vp=vs1*1.7;
```

```
parfor is=1:ns

[~,seismo_v,~]=staggerfd_eigen(is,nbc,nt,dtx,dx,dt,sx(is),sz(is),gx,gz,s,vp,vs1,isfs
,fsz,fd_order,source_type,parameter_type,dt_wf,nt_wf);
    seismo_v = norm_trace(seismo_v);
    if is<=ns-floor(m/M)-round(w/M)

[mlr,dataLen,saveForBackwardr]=RTrAD(seismo_v,is,df,dt,np,vmin,vmax,fmin,fmax,a,b,dg
,offset,m,FK,M); % Cal. the predicetd data dispersion curve for two sides
        [res_r(is),cr_pre_r(:,is)] =
LHDispPick(mlr,npair,vmin,cr_0(:,is),saveForBackwardr,pickMethod);
    end
    if is>=round(w/M)+floor(m/M)+1

[mll,dataLen,saveForBackwardl]=RTlAD(seismo_v,is,df,dt,np,vmin,vmax,fmin,fmax,a,b,dg
,offset,m,FK,M); % Cal. the predicetd data dispersion curve for two sides
        [res_l(is),cr_pre_l(:,is)] =
LHDispPick(mll,npair,vmin,cr_0l(:,is),saveForBackwardl,pickMethod);
    end
```

```
end
   res2=mean(mean(res_l));%+mean(mean(res_l));
 clear seismo_v deta_c cr_1 deta_c3
        display(['f2= ',num2str(f2),' res2= ',num2str(res2)]);

end
    gama=(f1^2*(res0-res2)+f2^2*(res1-res0))/(2*res0*(f1-f2)+2*res1*f2-2*res2*f1);

    if isinf(gama)
        gama=0;
    end
    display(['gama= ',num2str(gama),' numerical step_length=
',num2str(gama*alpha)]);
    vs1=vs+alpha*gama*dk_vs;
    vs1(vs1<vsmin)=vsmin;vs1(vs1>vsmax)=vsmax;
    vp=vs1*1.732;
    %vs1(vp./vs1<1.3)=vp(vp./vs1<1.3)/1.3;

     %vp=vs1*1.7;
```

```
parfor is=1:ns

[~,seismo_v,~]=staggerfd_eigen(is,nbc,nt,dtx,dx,dt,sx(is),sz(is),gx,gz,s,vp,vs1,isfs
,fsz,fd_order,source_type,parameter_type,dt_wf,nt_wf);
   seismo_v = norm_trace(seismo_v);
   if is<=ns-floor(m/M)-round(w/M)

[mlr,dataLen,saveForBackwardr]=RTrAD(seismo_v,is,df,dt,np,vmin,vmax,fmin,fmax,a,b,dg
,offset,m,FK,M); % Cal. the predicetd data dispersion curve for two sides
        [res_r(is),cr_pre_r(:,is)] =
LHDispPick(mlr,npair,vmin,cr_0(:,is),saveForBackwardr,pickMethod);
    end
    if is>=round(w/M)+floor(m/M)+1

[mll,dataLen,saveForBackwardl]=RTlAD(seismo_v,is,df,dt,np,vmin,vmax,fmin,fmax,a,b,dg
,offset,m,FK,M); % Cal. the predicetd data dispersion curve for two sides
        [res_l(is),cr_pre_l(:,is)] =
LHDispPick(mll,npair,vmin,cr_0l(:,is),saveForBackwardl,pickMethod);
    end
end

   res3=mean(mean(res_l));%+mean(mean(res_l));
 clear seismo_v deta_c cr_1 deta_c3
    display(['res3= ',num2str(res3)]);
    if (res3>res1 || res3>res2)
        if res1>res2
            res0=res2;
            gama=f2;
        else
```

```
            res0=res1;
            gama=f1;
        end
        vs1=vs+alpha*gama*dk_vs;
       vs1(vs1<vsmin)=vsmin;vs1(vs1>vsmax)=vsmax;
       vp=vs1*1.732;
    %vs1(vp./vs1<1.3)=vp(vp./vs1<1.3)/1.3;

     %vp=vs1*1.7;
    else
        res0=res3;
    end
    vs=vs1;
    vp=vs*1.732;
   vs_all(:,:,k) = vs1;
    dk_vs_all(:,:,k) = dk_vs;
    offsets(k) = offset;

  if (k>1) && ((residual(k) - res0)/residual(k)) < err
    offset = offset - 3
    f1=0.5;
  end
       k = k +1;
       kk = kk + 1;

   if offset==3 ||offset==51
       break
   end

  clear cr_0 cr_0l

end

 toc;
```