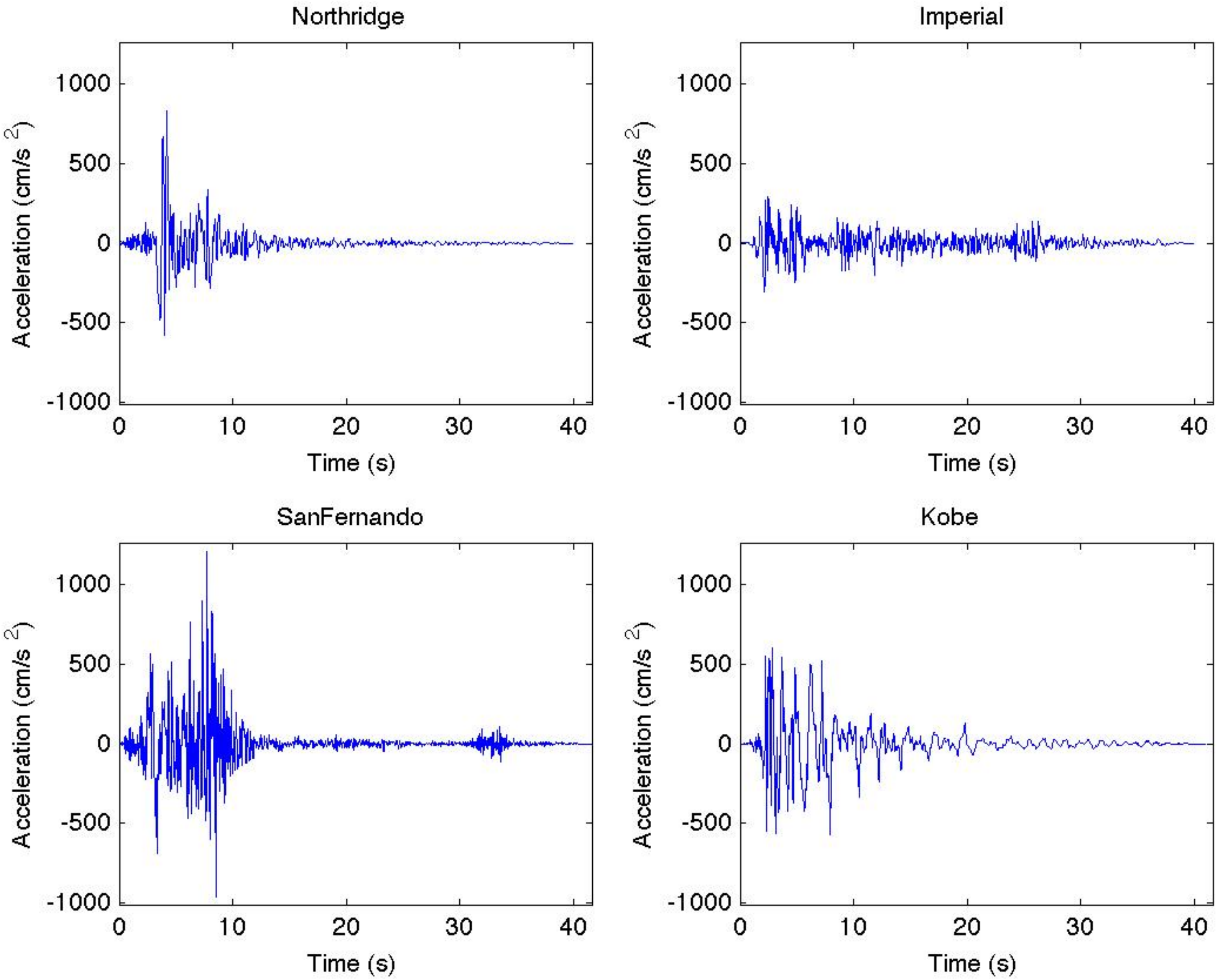
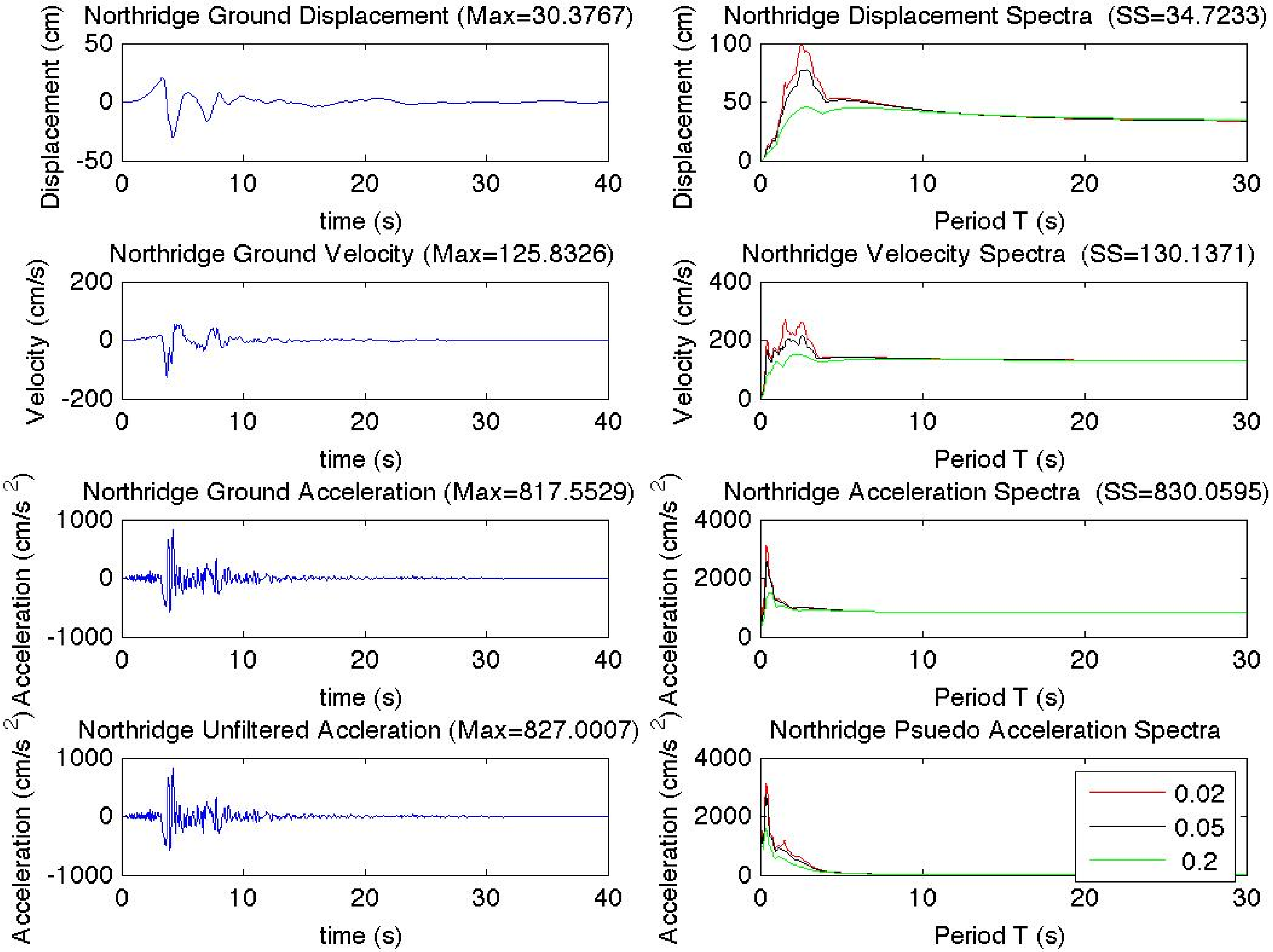
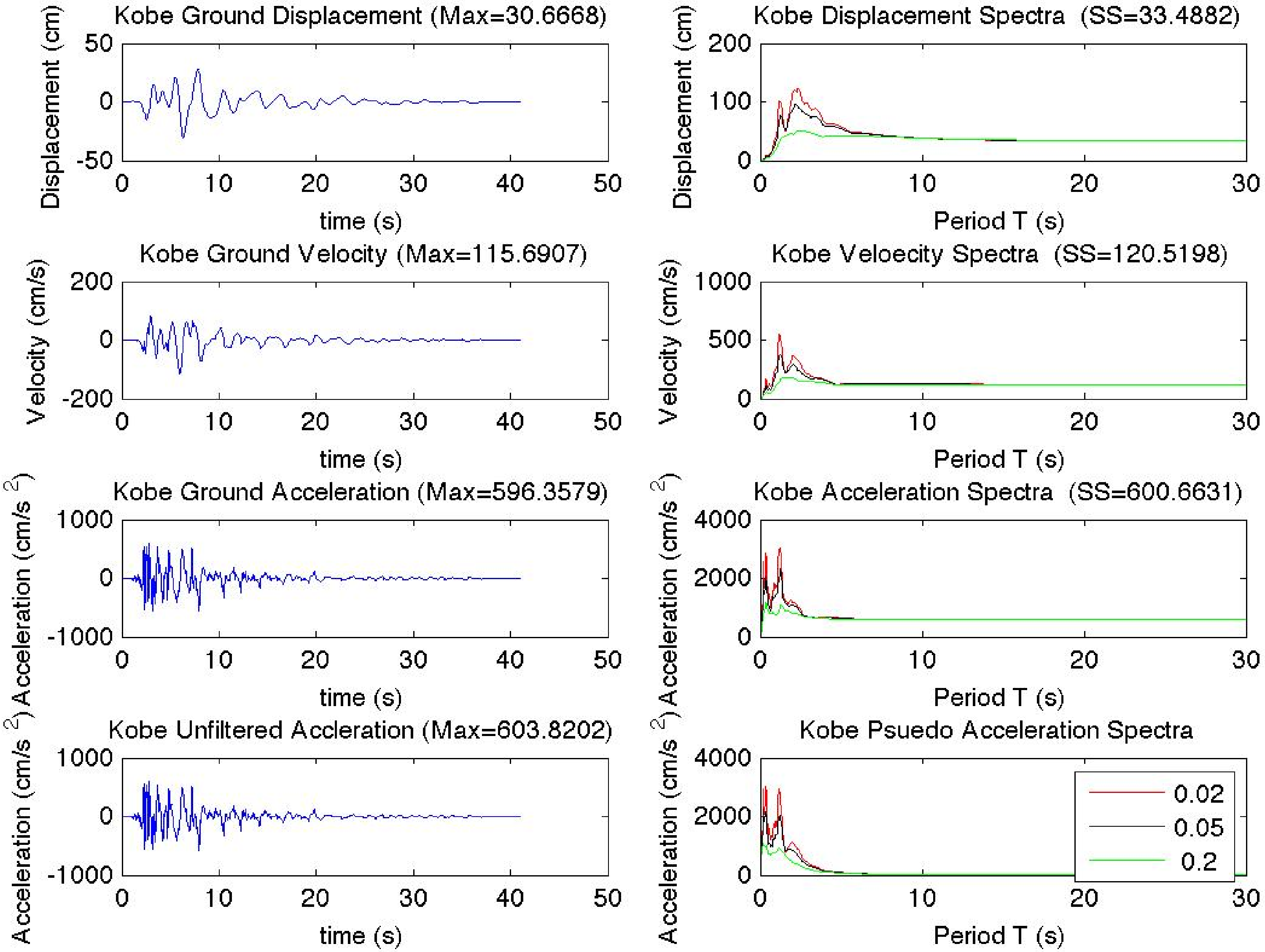
1. Find the following earthquake records
    a. 1994 Northridge, Symlmar Free Field, N-S component
    b. 1995 Kobe, Takatori, E-W component
    c. 1940 Imperial Valley, El Centro N-S component
    d. 1971 San Fernando, Pacoita Dam, N76W component

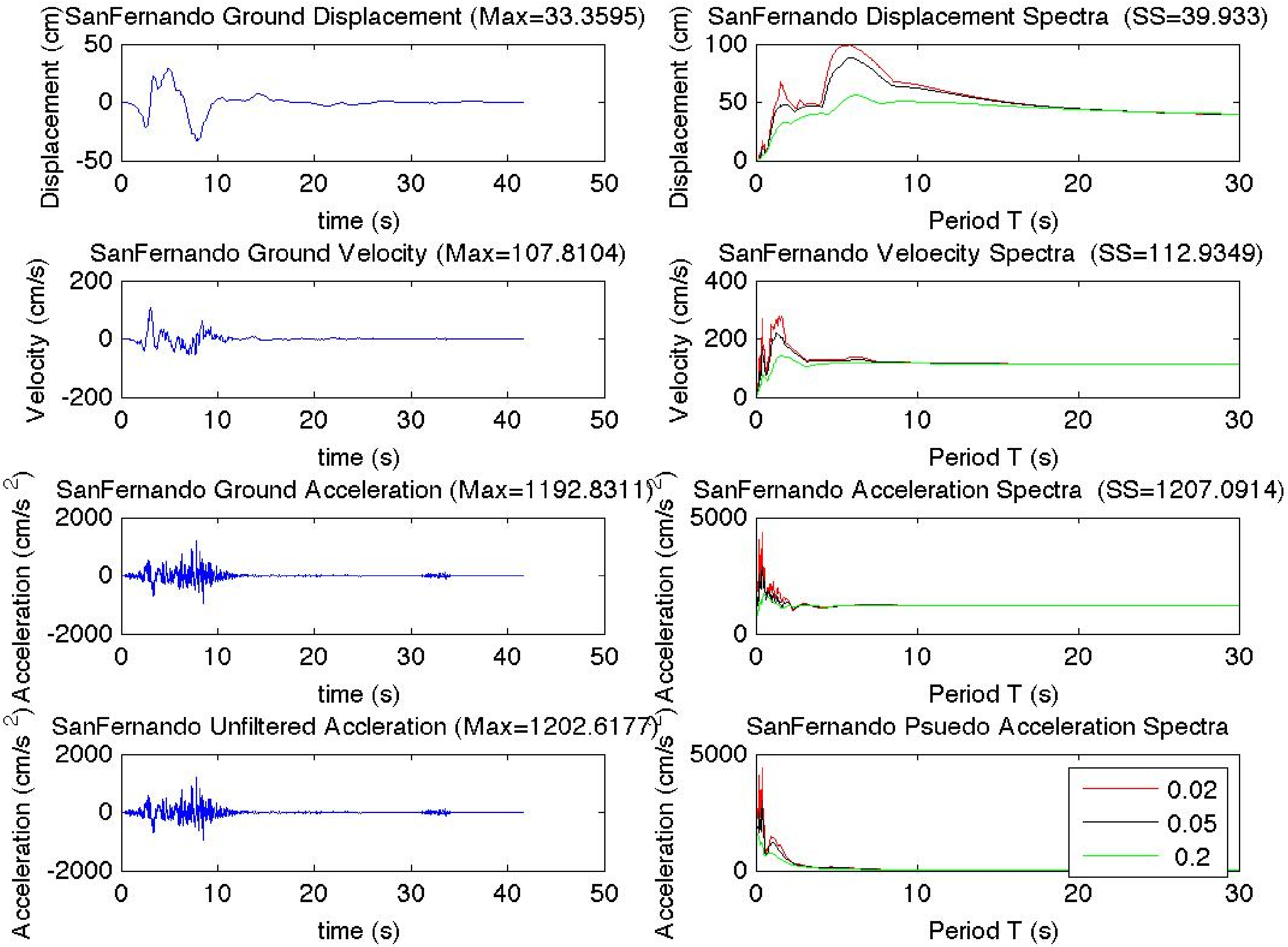
2) Convert all records to units of cm/s$^2$ and plot to the same X and Y axis.

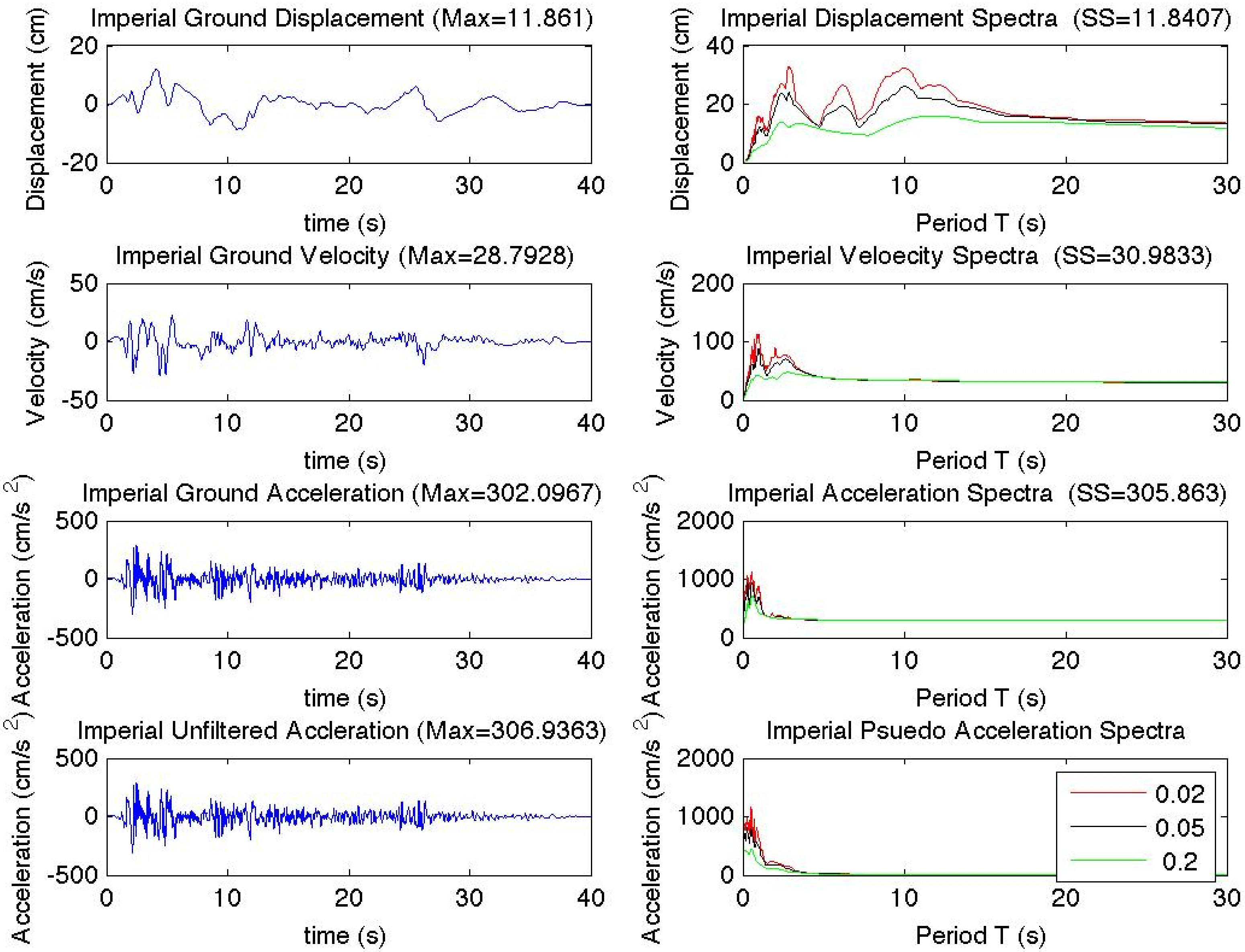


3) Integrate all records to find time histories of velocity and displacement.
4) Create a table of peak values for each record.
5) Create pseudo Acceleration, velocity, and displacement response spectra for all records. Compare the values with the table from part 4


Northridge Ground Displacement (Max=30.3767)
Displacement (cm)
50
0
-50
0
10
20
30
40
time (s)
Northridge Displacement Spectra (SS=34.7233)
Displacement (cm)
100
50
0
0
10
20
30
Period T (s)
Northridge Ground Velocity (Max=125.8326)
Velocity (cm/s)
200
0
-200
0
10
20
30
40
time (s)
Northridge Veloecity Spectra (SS=130.1371)
Velocity (cm/s)
400
200
0
0
10
20
30
Period T (s)
Northridge Ground Acceleration (Max=817.5529)
Acceleration (cm/s $^2$)
1000
0
-1000
0
10
20
30
40
time (s)
Northridge Acceleration Spectra (SS=830.0595)
Acceleration (cm/s $^2$)
4000
2000
0
0
10
20
30
Period T (s)
Northridge Unfiltered Accleration (Max=827.0007)
Acceleration (cm/s $^2$)
1000
0
-1000
0
10
20
30
40
time (s)
Northridge Psuedo Acceleration Spectra
Acceleration (cm/s $^2$)
4000
2000
0
0
10
20
30
Period T (s)
0.02
0.05
0.2


Kobe Ground Displacement (Max=30.6668)
Displacement (cm)
50
0
-50
0
10
20
30
40
50
time (s)
Kobe Displacement Spectra (SS=33.4882)
Displacement (cm)
200
100
0
0
10
20
30
Period T (s)
Kobe Ground Velocity (Max=115.6907)
Velocity (cm/s)
200
0
-200
0
10
20
30
40
50
time (s)
Kobe Veloecity Spectra (SS=120.5198)
Velocity (cm/s)
1000
500
0
0
10
20
30
Period T (s)
Kobe Ground Acceleration (Max=596.3579)
Acceleration (cm/s 2)
1000
0
-1000
0
10
20
30
40
50
time (s)
Kobe Acceleration Spectra (SS=600.6631)
Acceleration (cm/s 2)
4000
2000
0
0
10
20
30
Period T (s)
Kobe Unfiltered Accleration (Max=603.8202)
Acceleration (cm/s 2)
1000
0
-1000
0
10
20
30
40
50
time (s)
Kobe Psuedo Acceleration Spectra
Acceleration (cm/s 2)
4000
2000
0
0
10
20
30
Period T (s)
0.02
0.05
0.2


SanFernando Ground Displacement (Max=33.3595)
Displacement (cm)
50
0
-50
0
10
20
30
40
50
time (s)
SanFernando Displacement Spectra (SS=39.933)
Displacement (cm)
100
50
0
0
10
20
30
Period T (s)
SanFernando Ground Velocity (Max=107.8104)
Velocity (cm/s)
200
0
-200
0
10
20
30
40
50
time (s)
SanFernando Veloecity Spectra (SS=112.9349)
Velocity (cm/s)
400
200
0
0
10
20
30
Period T (s)
SanFernando Ground Acceleration (Max=1192.8311)
Acceleration (cm/s $^2$)
2000
0
-2000
0
10
20
30
40
50
time (s)
SanFernando Acceleration Spectra (SS=1207.0914)
Acceleration (cm/s $^2$)
5000
0
0
10
20
30
Period T (s)
SanFernando Unfiltered Accleration (Max=1202.6177)
Acceleration (cm/s $^2$)
2000
0
-2000
0
10
20
30
40
50
time (s)
SanFernando Psuedo Acceleration Spectra
Acceleration (cm/s $^2$)
5000
0
0
10
20
30
Period T (s)
0.02
0.05
0.2


Imperial Ground Displacement (Max=11.861)
Displacement (cm)
20
0
-20
0
10
20
30
40
time (s)
Imperial Displacement Spectra  (SS=11.8407)
Displacement (cm)
40
20
0
0
10
20
30
Period T (s)
Imperial Ground Velocity (Max=28.7928)
Velocity (cm/s)
50
0
-50
0
10
20
30
40
time (s)
Imperial Veloecity Spectra  (SS=30.9833)
Velocity (cm/s)
200
100
0
0
10
20
30
Period T (s)
Imperial Ground Acceleration (Max=302.0967)
Acceleration (cm/s 2)
500
0
-500
0
10
20
30
40
time (s)
Imperial Acceleration Spectra  (SS=305.863)
Acceleration (cm/s 2)
2000
1000
0
0
10
20
30
Period T (s)
Imperial Unfiltered Accleration (Max=306.9363)
Acceleration (cm/s 2)
500
0
-500
0
10
20
30
40
time (s)
Imperial Psuedo Acceleration Spectra
Acceleration (cm/s 2)
2000
1000
0
0
10
20
30
Period T (s)
0.02
0.05
0.2

**Conclusions:**

| Record | Northridge | Kobe | Imperial Valley | San Fernando |
|---|---|---|---|---|
| PGA | 817.5529 | 596.3579 | 302.0967 | 1192.8311 |
| LPAR | 830.0595 | 600.6631 | 305.863 | 1207.0914 |
| % diff A | **1.51** | **0.72** | **1.23** | **1.18** |
| PGV | 125.8326 | 115.6907 | 28.7928 | 107.8104 |
| LPVR | 130.1371 | 120.5198 | 30.9833 | 112.9349 |
| % diff V | **3.31** | **4.01** | **7.07** | **4.54** |
| PGD | 30.3767 | 30.6668 | 11.861 | 33.3595 |
| LPDR | 34.7233 | 33.4882 | 11.8407 | 39.933 |
| % diff D | **12.52** | **8.43** | **-0.17** | **16.46** |

Table 1 All values are given in cm and s as appropriate for d,v,a.
PGD, PGV, PGA mean Peak Ground Displacement, Velocity and Acceleration respectively
LPDR, LPVR, LPAR mean Long Period Displacement, Velocity, and Acceleration Respnse respectively.

After tweaking the filter limits and order I was able to get fairly good agreement between the peak ground values for the filtered data and the long period responses from the spectra of the unfiltered data. The results change very little if I run filtered data in to the spectra instead of unfiltered data. The biggest changes come from changing the filter bounds and order of approximation. The best results were generated using the following:

```
FilterOrder=20;
m=[0 0 1 1 0 0];
f=[0 0.001 0.002 0.99 0.999 1]; %Change based on ratio with nyquist
b=fir2(FilterOrder,f,m); %forward and back filter, 100th order log approximation of the shape we want
                %lower order has more rounded corners
amf=filtfilt(b,1,(curQuakeData-mean(curQuakeData)));%forward and back, -mean fixes digital integration problem
v=cumsum(amf)*dt; %cumulative sum is digital integration /50 for timestep or .02
vmf=filtfilt(b,1,(v-mean(v)));
d=cumsum(vmf)*dt;
dmf=filtfilt(b,1,(d-mean(d)));
```

The full program has been attached as Appendix A.

```
% Austin Stoker 15 Oct 2013,
% This program integrates earthquake accleration data to find the velocity
% and displacement histories of the earth quake measurement
% It also takes the acceleration history and creates response spectra for
% 2%,5%,20% damping

close all
clearvars
clc
addpath('UseThisData');
load Northridge.mat
load ImperialValley.mat
load SanFernando.mat
load Kobe.mat
dtList=[.02,.01,.01,.01];
QuakeNames(1,:)='Northridge ';
QuakeNames(2,:)='Imperial   ';
QuakeNames(3,:)='SanFernando';
QuakeNames(4,:)='Kobe       ';
NumPeriods=1000;
MaxPeriod=30;%seconds
MaxA=0;
MinA=0;
MaxT=0;
DampingList=[.02,.05,.2];
DampingColors=['r','k','g'];
FilterOrder=20;

doPlot=true;
useFilteredSpectra=false;
doSavePlots=true;

PlotPrefix='Results';
SaveType='jpg';

numQuakes=size(QuakeNames,1);
numDampings=size(DampingList,2);

for k=1:numQuakes
    clearvars -except dtList QuakeNames NumPeriods MaxPeriod DampingList DampingCo
    switch k
        case 1
            curQuakeData=Northridge;
        case 2
            curQuakeData=ImperialValley;
        case 3
            curQuakeData=SanFernando;
        case 4
            curQuakeData=Kobe;
    end

    dt=dtList(k);

    numPoints=size(curQuakeData,2);
    t=0:dt:dt*(numPoints -1);

    figure(1)
    subplot(2,2,k)
    plot(t,curQuakeData)
    title(QuakeNames(k,:))
    BigT=dt*numPoints;

    m=[0 0 1 1 0 0];
```

```
f=[0 0.001 0.002 0.99 0.999 1]; %Change based on ratio with nyquist
b=fir2(FilterOrder,f,m); %forward and back filter, 100th order log approximati
                    %lower order has more rounded corners
amf=filtfilt(b,1,(curQuakeData-mean(curQuakeData)));%forward and back, -mean f
v=cumsum(amf)*dt; %cumulative sum is digital integration /50 for timestep or .
vmf=filtfilt(b,1,(v-mean(v)));
d=cumsum(vmf)*dt;
dmf=filtfilt(b,1,(d-mean(d)));
amfMax=max(abs(amf));
vmfMax=max(abs(vmf));
dmfMax=max(abs(dmf));
unfilteredMax=max(abs(curQuakeData));
BigA=max(curQuakeData);
LittleA=min(curQuakeData);

if doPlot==true;
    figure(k+1);
    set(figure(k+1), 'Position', [0 0 1200 1200])
    subplot(4,2,1)
    plot(t,dmf);
    title(strcat(QuakeNames(k,:),' Ground Displacement (Max=',num2str(dmfMax),
    xlabel('time (s)');
    ylabel('Displacement (cm)');

    subplot(4,2,3)
    plot(t,vmf);
    title(strcat(QuakeNames(k,:),' Ground Velocity (Max=',num2str(vmfMax),')')
    ylabel('Velocity (cm/s)');
    xlabel('time (s)');

    subplot(4,2,5)
    plot(t,amf);
    title(strcat(QuakeNames(k,:),' Ground Acceleration (Max=',num2str(amfMax),
    ylabel('Acceleration (cm/s^2)');
    xlabel('time (s)');

    subplot(4,2,7)
    plot(t,curQuakeData);
    title(strcat(QuakeNames(k,:),' Unfiltered Accleration (Max=',num2str(unfil
    ylabel('Acceleration (cm/s^2)');
    xlabel('time (s)');

end
if useFilteredSpectra==true
    acc=amf;
else
    acc=curQuakeData;
end
dt2=dt*dt;
Dmax=zeros(1,numDampings);
Vmax=zeros(1,numDampings);
Amax=zeros(1,numDampings);
PAmax=zeros(1,numDampings);
PVmax=zeros(1,numDampings);
for p=1:numDampings
    Damping=DampingList(p);
    Dmax=zeros(1,numDampings);
    Vmax=zeros(1,numDampings);
    Amax=zeros(1,numDampings);
    PAmax=zeros(1,numDampings);
    PVmax=zeros(1,numDampings);
    for i=2:NumPeriods
        P(i)=i*MaxPeriod/NumPeriods;
        w=2*pi/P(i);
        wd=w*Damping;
```

```
            Den=w*w/4+wd/dt+1/dt2;
            D=zeros(numPoints,1);
            V=zeros(numPoints,1);
            A=zeros(numPoints,1);
            Dmax(i)=0;
            Vmax(i)=0;
            Amax(i)=0;
            A(i-1)=acc(i-1);
            for n=2:numPoints
                D(n)=(acc(n)/4+(1/dt2+wd/dt)*D(n-1)+(1/dt+wd/2)*(V(n-1))+A(n-1)/4)
                A(n)=4*(D(n)-D(n-1))/dt2-4*V(n-1)/dt-A(n-1);
                V(n)=V(n-1)+dt*(A(n)+A(n-1))/2;
                if abs(D(n))>Dmax(i)
                    Dmax(i)=abs(D(n));
                end
                if abs(V(n))>Vmax(i)
                    Vmax(i)=abs(V(n));
                end
                if abs(A(n))>Amax(i)
                    Amax(i)=abs(A(n));
                end
            end
        PVmax(i)=Dmax(i)*w;
        PAmax(i)=Dmax(i)*w*w;
        end



        DmaxSS=Dmax(end);
        VmaxSS=Vmax(end);
        AmaxSS=Amax(end);

        if doPlot==true;
            subplot(4,2,2);
            plot(P,Dmax,DampingColors(p));
            hold on
            ylabel('Displacement (cm)');
            xlabel('Period T (s)');
            title(strcat(QuakeNames(k,:),' Displacement Spectra  (SS=',num2Str(Dma

            subplot(4,2,4);
            plot(P,Vmax,DampingColors(p));
            hold on
            ylabel('Velocity (cm/s)');
            xlabel('Period T (s)');
            title(strcat(QuakeNames(k,:),' Veloecity Spectra  (SS=',num2Str(VmaxSS

            subplot(4,2,6);
            plot(P,Amax,DampingColors(p));
            hold on
            ylabel('Acceleration (cm/s^2)');
            xlabel('Period T (s)');
            title(strcat(QuakeNames(k,:),' Acceleration Spectra  (SS=',num2Str(Ama

            subplot(4,2,8);
            plot(P,PAmax,DampingColors(p));
            hold on
            ylabel('Acceleration (cm/s^2)');
            xlabel('Period T (s)');
            title(strcat(QuakeNames(k,:),' Psuedo Acceleration Spectra'));
        end
    end
    DampingStrings(:,:)=num2str(DampingList');
    legend(DampingStrings);
    if doSavePlots==true
```

```
        saveas(figure(k+1),strcat(PlotPrefix,QuakeNames(k,:),'.',SaveType),SaveTyp
    end
    if BigT>MaxT
        MaxT=BigT;
    end
    if BigA>MaxA
        MaxA=BigA;
    end
    if LittleA<MinA
        MinA=LittleA;
    end
end
for j=1:numQuakes
    figure(1)
    subplot(2,2,j)
    xlim([0,MaxT]);
    ylim([MinA-50,MaxA+50]);
    xlabel('Time (s)');
    ylabel('Acceleration (cm/s^2)');

end
set(figure(1), 'Position', [0 0 1200 600])
if doSavePlots==true
    saveas(figure(1),strcat(PlotPrefix,'QuakeComparison','.',SaveType),SaveType)
end
```

*Published with MATLAB® 7.10*