In [14]:
```
#!/usr/bin/env python3
# -*- coding: utf-8 -*-
"""
Created on Tue Sep  6 14:07:56 2022

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"""

# Code to preprocess data
# Comparing synthetics following steps from ShakeMovie : https://global.shakemovie.princeton.edu/science.jsp
# Synthetic data downloaded from shakemovie

from obspy import signal
from obspy import read
import numpy as np
import matplotlib.pyplot as plt

Data1_x = read('C2022090612143A.1D.sac/1U.AATO.LXE.modes.sac', debug_headers=True)
Data1_y = read('C2022090612143A.1D.sac/1U.AATO.LXN.modes.sac', debug_headers=True)
Data1_z = read('C2022090612143A.1D.sac/1U.AATO.LXZ.modes.sac', debug_headers=True)

Data2_x = read('C2022090612143A.3D.sac/1U.AATO.MXE.sem.sac', debug_headers=True)
Data2_y = read('C2022090612143A.3D.sac/1U.AATO.MXN.sem.sac', debug_headers=True)
Data2_z = read('C2022090612143A.3D.sac/1U.AATO.MXZ.sem.sac', debug_headers=True)

# Merge in one stream to get data
Data1Merged = Data1_x + Data1_y + Data1_z
Data2Merged = Data2_x + Data2_y + Data2_z

#-------------------------------------------------------------------------------
# Station name and starting time
#-------------------------------------------------------------------------------
Data1_Network=Data1_x[0].stats.network
Data1_Station=Data1_x[0].stats.station
Data1_ST=Data1_x[0].stats.starttime
Data1_ET=Data1_x[0].stats.endtime

Data2_Network=Data2_x[0].stats.network
Data2_Station=Data2_x[0].stats.station
Data2_ST=Data2_x[0].stats.starttime
Data2_ET=Data2_x[0].stats.endtime

print('1D data at station:', Data1_Network+Data1_Station,'at stating time:',Data1_ST)
print('3D data at station:', Data2_Network+Data2_Station,'at stating time:',Data2_ST)

#-------------------------------------------------------------------------------
# Time step for each case
#-------------------------------------------------------------------------------
Data1_dt=Data1_x[0].stats.delta
Data2_dt=Data2_x[0].stats.delta

#-------------------------------------------------------------------------------
# Number of points for each case
#-------------------------------------------------------------------------------
Data1_npts=Data1_x[0].stats.npts
Data2_npts=Data2_x[0].stats.npts

#-------------------------------------------------------------------------------
# Plots before filtering
#-------------------------------------------------------------------------------
Data1Merged.plot(outfile='A_1D_beforeProcessing.png',)
Data2Merged.plot(outfile='A_3D_beforeProcessing.png',)

# Figures
fig, axes = plt.subplots(nrows=3, sharex=True, figsize=(12, 6))
axes[0].plot(Data1Merged[0].times(), Data1Merged[0].data, "k", label="synt 1D-EW" )
axes[0].plot(Data2Merged[0].times(), Data2Merged[0].data, "--r", label='synt 3D-EW')
axes[0].set_ylabel('Displacement (m)')

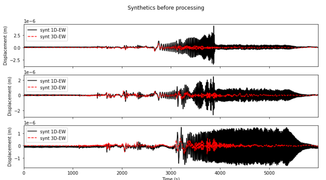
axes[1].plot(Data1Merged[1].times(), Data1Merged[1].data, "k", label="synt 1D-EW" )
axes[1].plot(Data2Merged[1].times(), Data2Merged[1].data, "--r", label='synt 3D-EW')
axes[1].set_ylabel('Displacement (m)')

axes[2].plot(Data1Merged[2].times(), Data1Merged[2].data, "k", label="synt 1D-EW" )
axes[2].plot(Data2Merged[2].times(), Data2Merged[2].data, "--r", label='synt 3D-EW')
axes[2].set_ylabel('Displacement (m)')
axes[2].set_xlabel('Time (s)')
axes[2].set_xlim(0, np.max([np.max(Data1Merged[0].times()),np.max(Data2Merged[0].data)]))

axes[0].legend(loc=2)
axes[1].legend(loc=2)
axes[2].legend(loc=2)
fig.suptitle('Synthetics before processing',fontsize=12)
```

```
1D data at station: 1UANTO at stating time: 2022-09-06T12:14:14.600000Z
3D data at station: 1UANTO at stating time: 2022-09-06T12:14:13.387750Z
```

Out[14]:
```
Text(0.5, 0.98, 'Synthetics before processing')
```



In [18]:
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#-------------------------------------------------------------------------------
# Resample and cutting signal to a common window (Resample at 1Hz)
#-------------------------------------------------------------------------------
print('Stream data before resampling----------------------------------------------------------------------')
print(Data1Merged)
print(Data2Merged)

# Cut signal to common starting time and end time
Common_startime=np.max([Data1_ST,Data2_ST])
Common_endtime=np.min([Data1_ET,Data1_ET])
Data1Merged.trim(Common_startime,Common_endtime)
Data2Merged.trim(Common_startime,Common_endtime)

# Resample
fstep=1.
Data1Merged.resample(fstep)
Data2Merged.resample(fstep)

print('Stream data after resampling----------------------------------------------------------------------')
print(Data1Merged)
print(Data2Merged)
```

```
Stream data before resampling----------------------------------------------------------------------
3 Trace(s) in Stream:
1U.AATO.S1.LXE | 2022-09-06T12:14:14.600000Z - 2022-09-06T13:54:13.600000Z | 1.0 Hz, 6000 samples
1U.AATO.S1.LXN | 2022-09-06T12:14:14.600000Z - 2022-09-06T13:54:13.600000Z | 1.0 Hz, 6000 samples
1U.AATO.S1.LXZ | 2022-09-06T12:14:14.600000Z - 2022-09-06T13:54:13.600000Z | 1.0 Hz, 6000 samples
3 Trace(s) in Stream:
1U.AATO.S3.MXE | 2022-09-06T12:14:14.679750Z - 2022-09-06T13:54:11.679750Z | 1.0 Hz, 5998 samples
1U.AATO.S3.MXN | 2022-09-06T12:14:14.679750Z - 2022-09-06T13:54:11.679750Z | 1.0 Hz, 5998 samples
1U.AATO.S3.MXZ | 2022-09-06T12:14:14.679750Z - 2022-09-06T13:54:11.679750Z | 1.0 Hz, 5998 samples
Stream data after resampling----------------------------------------------------------------------
3 Trace(s) in Stream:
1U.AATO.S1.LXE | 2022-09-06T12:14:14.600000Z - 2022-09-06T13:54:12.600000Z | 1.0 Hz, 5999 samples
1U.AATO.S1.LXN | 2022-09-06T12:14:14.600000Z - 2022-09-06T13:54:12.600000Z | 1.0 Hz, 5999 samples
1U.AATO.S1.LXZ | 2022-09-06T12:14:14.600000Z - 2022-09-06T13:54:12.600000Z | 1.0 Hz, 5999 samples
3 Trace(s) in Stream:
1U.AATO.S3.MXE | 2022-09-06T12:14:14.679750Z - 2022-09-06T13:54:11.679750Z | 1.0 Hz, 5998 samples
1U.AATO.S3.MXN | 2022-09-06T12:14:14.679750Z - 2022-09-06T13:54:11.679750Z | 1.0 Hz, 5998 samples
1U.AATO.S3.MXZ | 2022-09-06T12:14:14.679750Z - 2022-09-06T13:54:11.679750Z | 1.0 Hz, 5998 samples
```

In [16]:
```
#-------------------------------------------------------------------------------
# Remove the trend and mean from the the observed and synthetic records and taper them.
#-------------------------------------------------------------------------------
Data1Merged.detrend("demean")
Data1Merged.detrend("linear")
Data1Merged.taper(0.05)

Data2Merged.detrend("demean")
Data2Merged.detrend("linear")
Data2Merged.taper(0.05)

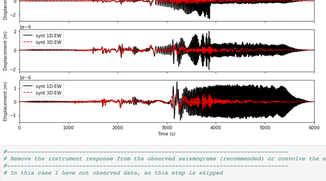
# Figures
fig, axes = plt.subplots(nrows=3, sharex=True, figsize=(12, 6))
axes[0].plot(Data1Merged[0].times(), Data1Merged[0].data, "k", label="synt 1D-EW" )
axes[0].plot(Data2Merged[0].times(), Data2Merged[0].data, "--r", label='synt 3D-EW')
axes[0].set_ylabel('Displacement (m)')

axes[1].plot(Data1Merged[1].times(), Data1Merged[1].data, "k", label="synt 1D-EW" )
axes[1].plot(Data2Merged[1].times(), Data2Merged[1].data, "--r", label='synt 3D-EW')
axes[1].set_ylabel('Displacement (m)')

axes[2].plot(Data1Merged[2].times(), Data1Merged[2].data, "k", label="synt 1D-EW" )
axes[2].plot(Data2Merged[2].times(), Data2Merged[2].data, "--r", label='synt 3D-EW')
axes[2].set_ylabel('Displacement (m)')
axes[2].set_xlabel('Time (s)')
axes[2].set_xlim(0, np.max([len(Data1Merged[2].times()),len(Data2Merged[2].data)]))

axes[0].legend(loc=2)
axes[1].legend(loc=2)
axes[2].legend(loc=2)
fig.suptitle('Resampled and cutted signals, trend and mean removed, tapered 5% - unfiltered',fontsize=12)
```

Out[16]:
```
Text(0.5, 0.98, 'Resampled and cutted signals, trend and mean removed, tapered 5% - unfiltered')
```



In [17]:
```
#-------------------------------------------------------------------------------
# Remove the instrument response from the observed seismograms (recommended) or convolve the synthetic seismograms with the instrument response.
#-------------------------------------------------------------------------------
# In this case I have not observed data, so this step is skipped

#-------------------------------------------------------------------------------
# Filtering signals
#-------------------------------------------------------------------------------
# Make sure that you apply the exact same filtering operations to both observed
# and synthetic seismograms. Preferably, avoid filtering your records more than once,
# and if you do filter more than once, make sure you filter both the data and the
# synthetics with the same filter, such that data and synthetics are always subjected
# to the same filtering operations.

Tmin1,Tmax1 = 17, 50
Tmin2,Tmax2 = 40, 100
Tmin3,Tmax3 = 90, 250


for i in (1,2,3):
    if i == 1 :
        tmin=Tmin1
        tmax=Tmax1
        Data1_windowed=Data1Merged.copy()
        Data2_windowed=Data2Merged.copy()
    elif i == 2 :
        tmin=Tmin2
        tmax=Tmax2
        Data1_windowed=Data1Merged.copy()
        Data2_windowed=Data2Merged.copy()
    elif i == 3 :
        tmin=Tmin3
        tmax=Tmax3
        Data1_windowed=Data1Merged.copy()
        Data2_windowed=Data2Merged.copy()

    fregmin=1/tmax
    fregmax=1/tmin

    Data1_windowed.filter("bandpass", freqmin=fregmin, freqmax=fregmax,corners=4, zerophase=True)
    Data2_windowed.filter("bandpass", freqmin=fregmin, freqmax=fregmax,corners=4, zerophase=True)

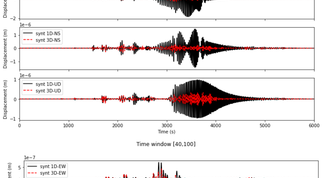
    fig, axes = plt.subplots(nrows=3, sharex=True, figsize=(12, 6))
    axes[0].plot(Data1_windowed[0].times(), Data1_windowed[0].data, "k", label='synt 1D-EW')
    axes[0].plot(Data2_windowed[0].times(), Data2_windowed[0].data, "--r", label='synt 3D-EW')
    axes[0].set_ylabel('Displacement (m)')

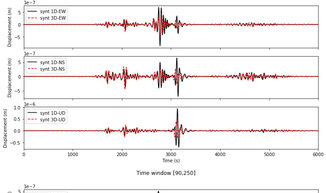
    axes[1].plot(Data1_windowed[1].times(), Data1_windowed[1].data, "k", label='synt 1D-NS')
    axes[1].plot(Data2_windowed[1].times(), Data2_windowed[1].data, "--r", label='synt 3D-NS')
    axes[1].set_ylabel('Displacement (m)')

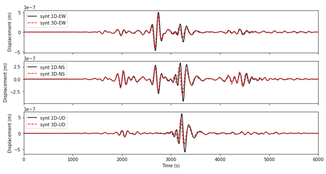
    axes[2].plot(Data1_windowed[2].times(), Data1_windowed[2].data, "k", label='synt 1D-UD')
    axes[2].plot(Data2_windowed[2].times(), Data2_windowed[2].data, "--r", label='synt 3D-UD')
    axes[2].set_ylabel('Displacement (m)')
    axes[2].set_xlabel('Time (s)')
    axes[2].set_xlim(0, np.max([len(Data1Merged[i-1].times()),len(Data2Merged[i-1].data)]))

    axes[0].legend(loc=2)
    axes[1].legend(loc=2)
    axes[2].legend(loc=2)
    fig.suptitle('Time window ['+str(tmin)+','+str(tmax)+']',fontsize=12)

#-------------------------------------------------------------------------------
# END
#-------------------------------------------------------------------------------
```







In [ ]: