Removing the instrument response from a seismogram
SAC, Shell scripts, Fortran code, and SOD
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Short course on USArray data processing for the next generation of seismologists III
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Preparatory:
Go to a work directory/folder (YourWork, for example) and unpack the set of files for this exercise.

```
> tar xvf /Volumes/usarray/tmp/Monday1.tar
```

Make and go to a data subdirectory, and grab a(ny) SEED volume, for example from /Users/usarray/data/SEED. This example uses station last year's earthquake in Ottawa.

```
> mkdir data
> cd data
```

Unpack the waveform data from the SEED volume in this new "data" directory with "rdseed" and make sure that you request both the Pole & Zero files and the RESPonse files. The "d" indicates that you'd like to extract the data (i.e. waveforms) from the SEED volume. Here's what it looks like in my terminal window:

```
comboimac28[]$ rdseed –d –R –p –f  /Volumes/usarray/data/SEED/ottawa.seed
```

This SEED volume only has broadband vertical component (BHZ) data. If your SEED volume has horizontal components you can rotate them to radial and transverse components with the "rot" command in sac; beware that for a proper rotation both traces need to have the exact same number of samples and begin time.

This is normally the point where I'll want to look at the data I received in this SEED volume – i.e. visualize the waveforms. However, you have so many files now that you'll first want to know a bit more about what you got. We'll run some queries on the directory contents. There are two example queries in the directory "codes" that you created at the start of this exercise.

```
> ../codes/query1.csh
> ../codes/query2.csh
```

What did you learn about the contents of your directory?

Let's visually inspect the data or a subset of the data.

```
> sac
SAC>
SAC> r *.TA.*.SAC
SAC> p1 perplot 6
```

Now gather the hypocenter parameteres for the earthquake associated with your SEED volume. For the Ottawa data the parameters are in file "event.list". Edit its contents to reflect the parameters for your earthquake. In this file, accurate values are essential only for parameters lat, lon, depth, year, julian day, hr, mn, and sec. Then

```
> cp ../event.list .
>../codes/evinhdr *.SAC
```

Try the reading (r), plotting (p1), and zooming (xlim) again now that the seismograms are all referenced to the same time. You know you're a real seismologist if you enjoy the view when keeping the space bar pressed during "p1".

At this point (or earlier) you could make an(other) effort to move "bad" data and duplicate data to a different folder (or trash).

After some more browsing and quality control I usually start editing the traces so I can analyze them. I remove the mean and trend and the instrument response. The following example is for a single SAC file. You can now create your own script & macro to do this for all SAC files! Choose a single, decent quality, sac file; let's call it I23A.BHZ. Find the corresponding SAC_PZ* file and name it PZ.I23A.

Note that to get a list of SAC commands you can type "help" within SAC. I suggest you view the seismogram after each adjustment.

```
SAC>  r I23A.BHZ
SAC> p
SAC> rmean
SAC> p
SAC> rtrend
SAC> p
SAC>taper
SAC> p
SAC> w over
```

This overwrites the contents of I23A.BHZ! This is useful for when you need to start over, but dangerous if the raw data are important to recover. Luckily you can always get the raw data back again from the SEED volume, or from the IRIS DMC.

Now you can remove the instruments response. We'll go through three examples of how to do that, but there are more ways, for example SOD can deliver instrument-response corrected data in SAC format to your computer, skipping the SEED stage altogether.

Example 1
One way to correct for the instrument response is through SAC. This takes away a counts/Volts scaling factor from the digitizer as well as the frequency-dependent sensor response, which determines the response drop off at low frequencies:

```
SAC> r I23A.BHZ
SAC> transfer from polezero subtype PZ.I23A to none FREQ 0.0036 0.006 2 2.8
SAC> p
SAC> w I23A.dz
```

Change the frequencies to see their effect on the result. The frequencies make sure that your deconvolution (or spectral division) with the instrument response takes place within the band where it is non-zero. Because the "transfer" command only takes the low-frequency response drop-off into account, the upper frequency can be nearly as high as the Nyquist frequency, but to allow a comparison with other results within a seismically interesting band we'll keep the frequencies in this example as listed above.

Example 2
Another way to correct for the instrument response is through using program "responsee", which calls IRIS' "evalresp". This will take the complete response (the sensor response as well as the digitizer response; the digitizer response determines the response behavior and drop off at high frequencies) into account. To make this easier I provide a shell script "seedresp" but you can also call "responsee" from the command line. If you choose the verbose option at the first prompt, it will explain subsequent choices for answers to its questions in detail.

```
> ../codes/seedresp I23A.BHZ I23A.vz RESP.TA.I23A..BHZ
```

Instead of "RESP.TA.I23A..BHZ" you of course type the RESP file name for the station that you chose.

Evalresp can also be invoked from within SAC in the "transfer" command.

Compare I23A.out1 and I23A.out2. Why are they different? Edit "seedresp" to output ground displacement in the same units as the output from SAC's transfer command above.

Example 3
Lastly, you have learned by now that you can bypass the processing of the SEED volume and the SAC files it produces by directly asking for a ground motion record with "sod". Of course you have to provide sod with similar parameters as above. However, like SAC's transfer command "sod" will only remove the sensor response (not the digitizer response) and thus one could systematically choose the upper frequencies as the Nyquist frequency while finding the optimal low-pass filter parameters after the record has been obtained and viewed. Because we want to compare with our previous two response deconvolution results I have set the same frequencies as above in sod request "ottawa_sod.xml", which Meghan provided for this course last year. Note that the "lowPass" value in the sod request is actually the corner frequency of the high pass filter that, together with the low-pass filter, constitutes the 6 mHz to 2 Hz band pass filter. Likewise the value labeled "highPass" is actually the corner frequency of this low-pass filter. The spectrum is set to zero for frequencies less than the "lowCut" value and higher than the "highCut" value.

Run the sod request:

```
> sod –f ottawa_sod.xml
> cd seismograms/201006231741/
> sac
SAC> r 201006231741.TA.I23A.BHZ.sac
SAC> p
SAC> r more ../../I23A.v2dz ../../I23A.dz
SAC> p1
```

The latter commands allow you to compare all three ground motion records. Are they the same? Explain differences. Now retrace some of your steps and try to make the choices that will make the results come out the same (or close enough). Make a list of the default units and ground motion type used by each method and of the steps needed to get the output in the type and units you need.