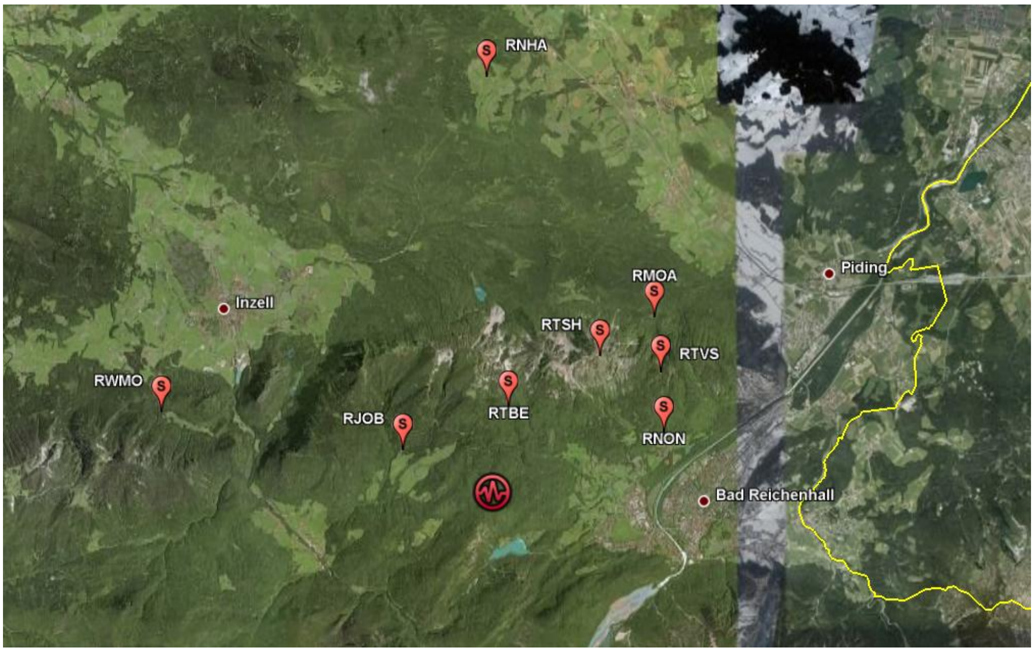
Exercise

In this exercise the task is to calculate local magnitudes for an earthquake in the Hochstaufen massif. Using this example, we will see how to develop an easily readable and extensible, automated processing workflow using ObsPy. For every part of the exercise there is a Python file with a few comments and tips to build upon, as well as a file with a complete solution.



[http://earth.google.com]

Exercise 1 (*Calculate the Local Magnitude*)
Use the file `RJOB_WA_CUT.MSEED` to read `MiniSEED` waveform data from the earthquake. These data have already been simulated to displacement on a Wood-Anderson seismometer and trimmed to the right time span. Estimate the peak-to-peak amplitude amp_{pp} as the mean of the maximum minus minimum amplitude on North and East components in the given short time window. Estimate the local magnitude M_l using a hypocentral distance of $d_{hypo} = 7.1$ (km) given the formula:

$$M_l = \log_{10}(\frac{amp_{pp}}{2 * 1000}) + \log_{10}(\frac{d_{hypo}}{100}) + 0.00301 * (d_{hypo} - 100) + 3$$

Exercise 2 (*Simulate the Wood-Anderson Seismometer*)
Use the file `RJOB.MSEED` to read the original `MiniSEED` waveform data. Set up two dictionaries containing the response information of both the original instrument (an `STS-2`) and the Wood-Anderson seismometer in poles-and-zeros formulation. Each `paz` dictionary needs to contain `sensitivity` (overall sensitivity), `gain` (normalization factor), `poles` and `zeros`. After the instrument simulation, trim the waveform to a short time window around the origin time (`2008-04-17T16:00:32Z`) and calculate M_l like in exc. 1. Use the following values (can be found in the Python file XXX):

```
STS-2: 'sensitivity': 2516778600.0
       'gain': 60077000.0
       'poles': [-0.037004+0.037016j, -0.037004-0.037016j, -251.33+0j,
                 -131.04-467.29j, -131.04+467.29j]
       'zeros': [0j, 0j]
Wood-Anderson: 'sensitivity': 1
               'gain': 2800
               'poles': [-6.2832-4.7124j, -6.2832+4.7124j]
               'zeros': [0j]
```

Exercise 3 (*Compare to EMSC Catalog*)
Fetch a list of events from NERIES/EMSC for the time of the earthquake in the Hochstaufen region (47.75 N, 12.85 E) using `obspy.neries`. Check the magnitude information in the catalog.

Exercise 4 (*Fetch Data from WebDC*)
Modify exc. 2 to fetch the data via ArcLink from WebDC using `obspy.arclink`. Use option `getPAZ=True` to fetch response information along with the waveform. During instrument simulation use option `paz_remove='self'` to use the attached `paz` information fetched from WebDC. Calculate M_l like in exc. 2.

Exercise 5 (*Compute Hypocentral Distance*)
Modify exc. 4 to fetch coordinate information for station `RJOB` along with the waveform. Use exc. 3 to fetch the event information from NERIES/EMSC. Use the origin time (stored as `datetime` in the event dictionary) during the data request instead of the previously hardcoded value. Also calculate the hypocentral distance dynamically. Use function `utlGeoKm` from module `obspy.signal` to compute horizontal distances from geographic coordinates. Calculate M_l like in exc. 4 using the computed hypocentral distance.

Exercise 6 (*Determine Event Onset Using a Triggering Algorithm*)
Read waveform data from file `RJOB.MSEED` and run a recursive STA/LTA trigger on the Z component of the data. Compute the approximate event onset time from `starttime` and `sampling_rate` of the traces and from the position of the maximum in the triggered data. Store this time in an `UTCDateTime` object.

Exercise 7 (*Use Trigger Time in Magnitude Estimation*)
Modify exc. 5 to use a dynamically determined trigger time like in exc. 6 for trimming operations on the data. Calculate M_l like in exc. 5.

Exercise 8 (*Estimate Magnitudes for a List of Stations*)
Modify exc. 7 and use a list of stations (e.g. `RJOB`, `RMOA` and `RNON`). Loop over this list and estimate the magnitude for each station individually. (The event onset time and hypocentral

distance should be computed dynamically like in exc. 7.)

Exercise 9 (*Fetch List of Available Stations from WebDC*)
Fetch a list of available stations in network `BW` (BayernNetz) for the time around the earthquake (`2008-04-17T16:00:32Z`) via ArcLink from WebDC. Print the station code for every station in the list.

Exercise 10 (*Estimate Magnitudes at All Available Stations*)
Modify exc. 8 to fetch a list of stations like in exc. 9. Loop over this list, fetch the data and estimate the magnitude for each of the stations.
Note: There is a bug in the station request via arclink such that not all stations in the response really have data available, you can put the `getWaveform()` call inside a `try/except` statement like this:

```
try:
    client.getWaveform(..., station=sta, ...)
except:
    print "problem with station:", sta
    continue
```

Exercise 11 (*Try Program with Events in Vogtland Swarm Region*)
By now, the program is rather flexible. We can now change to a completely different set of events. Modify exc. 10 and change the event request from EMSC to use events in the Vogtland swarm area (roughly 50.2 N, 12.2 E) at the north-eastern Bavarian border. There are two magnitude 4+ events in EMSC in 2008 that we can use, for example. Either use one single event like before or add an additional for loop going through all requested events.

Exercise 12 (*Organize Magnitude Estimation in New Python Module*)
At the end we can clean up the program we wrote by extracting the magnitude estimation steps in a separate, new Python module. Make a new Python file `mess_exercise_12_module.py` with a function called `estimate_magnitude(...)`. This function should take four arguments: *a*) a `Stream` object with Z, N and E traces with attached paz and coordinate information, *b*) the longitude of the event, *c*) the latitude of the event and *d*) the depth of the event. Move and adjust the signal processing steps to this new module and modify exc. 11 to import and use the function `estimate_magnitude(...)`.