Example of processing moment magnitudes for an entire earthqauke catalogue

This example shows how to use SeisSrcMoment to process an entire earthquake catalogue.

Notes for this example:

We do not include all the data to run for an entire earthquake catalogue, as that would be inappropriate to host on GitHub. However, instead we:

1. Include an example event to show how a full catalogue would be processed.
2. Include a python dictionary that is in the same format as the outputs from SeisSrcMoment, for a full earthquake catalogue from Uturuncu volcano, Bolivia, in order to show how the catalogue post-processing code works.
3. Shows example of how to analyse and plot temporal b-value variations.

In [1]:

```
# Import neccessary modules:
import SeisSrcMoment
import pandas as pd
%load_ext autoreload
%autoreload 2
```

1. Find magnitudes for small catalogue example:

In [8]:

```
# Specify parameters for processing catalogue:
inventory_fname = "data/IRISDMC-Plutons_dataless.dataless"  # The inventory fname, pointing to the dataless file for the network
mseed_dir = "data/mseed_data"
out_fname = 'small_vt_magnitudes_catalogue.pkl'
nonlinloc_hyp_files_dir = "data/NLLoc_data"
nonlinloc_hyp_files_list = ['loc.Tom_RunNLLoc000.20100516.063457.grid0.loc.hyp']
stations_not_to_process = []
window_before_after = [0.1, 0.6] # The time before and after the phase pick to use for calculating the magnitude within (in seconds)
filt_freqs = [0.5, 49.0] # The frequencies with which to filter the data prior to calculating the moment magnitude.
MT_six_tensor = [] # If not specified, assumes isotropic source.
density = 2750. # Density of medium, in kg/m3
Vp = 'from_depth' # P-wave velocity in m/s (or str if using from depth. If from_depth, will use vel_model_df to determine velocity model)
phase_to_process = 'P' # P or S. Phase to process. If P, will use L component, if S will use T component.
vel_model_df = pd.read_csv("data/1D_vel_model.csv") # Velocity model to use if Vp = 'from_depth'
verbosity_level = 1 # Verbosity level (1 for moment only) (2 for major parameters) (3 for plotting of traces)
plot_switch = False
remove_noise_spectrum = False # If True, removes noise using spectrum taken from window before trace.
```

In [10]:

```
# Process data for small catalogue (single event in this case):
small_mags_dict = SeisSrcMoment.catalogue.get_event_moment_magnitudes(nonlinloc_
hyp_files_dir, nonlinloc_hyp_files_list, mseed_dir, out_fname, window_before_aft
er, filt_freqs, density, Vp, phase_to_process=phase_to_process, MT_six_tensor=MT
_six_tensor, stations_not_to_process=stations_not_to_process, inventory_fname=in
ventory_fname, remove_noise_spectrum=remove_noise_spectrum, vel_model_df=vel_mod
el_df, verbosity_level=verbosity_level, plot_switch=plot_switch)
```

```
-----------------------------------------------------
Processing for event: data/NLLoc_data/loc.Tom_RunNLLoc000.20100516.0
63457.grid0.loc.hyp
Warning: Need to specify MT_six_tensor or MT_data_filename for accur
ate radiation pattern correction.
 Using average radiation pattern value instead.
Station (PLLO) or channel (HHN) not in instrument inventory, therefo
re not correcting for this component and removing it.
Station (PLLO) or channel (HHZ) not in instrument inventory, therefo
re not correcting for this component and removing it.
Station (PLLO) or channel (HHE) not in instrument inventory, therefo
re not correcting for this component and removing it.
Processing data for station: PLLO
Processing data for station: PLSM
Overall seismic moment (Nm): 15521566467248.895
Processing data for station: PLLA
Overall seismic moment (Nm): 13801855234245.54
Processing data for station: PLTM
Overall seismic moment (Nm): 25573773257795.145
Processing data for station: PLRR
Overall seismic moment (Nm): 19571298788186.605
Processing data for station: PLAR
Overall seismic moment (Nm): 5471550950741.204
Processing data for station: PL03
Overall seismic moment (Nm): 48727946216246.39
Average seismic moment for event: 21444665152410.63 +/- 556170557290
2.97
Moment magnitude and error: 2.887546179559715 (+/- 0.142394534453304
2 for n_obs= 6 )
-----------------------------------------------------
```

In [13]:

```
# And print example of output dict structure:
small_mags_dict
```

Out[13]:

```
{'data/NLLoc_data/loc.Tom_RunNLLoc000.20100516.063457.grid0.loc.hy
p': {'PLSM': {'M_0': 15521566467248.895,
   'Sigma_0': 7.462354882884014e-08,
   'f_c': 9.888233395707239,
   't_star': 0.03633999901647883,
   'Q': 99.04360807658419,
   'Sigma_0_stdev': 9.087859776600538e-09,
   'f_c_stdev': 8.742886810741158,
   't_star_stdev': 0.030655754236235826,
   'Q_stdev': 117.40845103191727},
  'PLLA': {'M_0': 13801855234245.54,
   'Sigma_0': 8.99397480658813e-08,
   'f_c': 6.304311684544616,
   't_star': 0.03392771408215964,
   'Q': 109.115014412225,
   'Sigma_0_stdev': 8.22116264693659e-09,
   'f_c_stdev': 3.6489702498794476,
   't_star_stdev': 0.03094900524682471,
   'Q_stdev': 119.61686592264596},
  'PLTM': {'M_0': 25573773257795.145,
   'Sigma_0': 9.875372519344738e-08,
   'f_c': 9.517629242631145,
   't_star': 0.030846363104357177,
   'Q': 136.32753906249513,
   'Sigma_0_stdev': 1.0967411233746552e-08,
   'f_c_stdev': 7.559368629234954,
   't_star_stdev': 0.028414495728912977,
   'Q_stdev': 147.99519270603068},
  'PLRR': {'M_0': 19571298788186.605,
   'Sigma_0': 7.810585924953551e-08,
   'f_c': 7.108672819864915,
   't_star': 0.03777633162509596,
   'Q': 157.31634259096046,
   'Sigma_0_stdev': 9.660738708169465e-09,
   'f_c_stdev': 5.790080943783466,
   't_star_stdev': 0.03937398267922096,
   'Q_stdev': 150.9330253985095},
  'PLAR': {'M_0': 5471550950741.204,
   'Sigma_0': 1.976462835659904e-08,
   'f_c': 6.432798077441835,
   't_star': 0.01776713900937713,
   'Q': 345.0070732783035,
   'Sigma_0_stdev': 1.1202250954183945e-09,
   'f_c_stdev': 2.0570103689026746,
   't_star_stdev': 0.015353403651592852,
   'Q_stdev': 399.2462368119944},
  'PL03': {'M_0': 48727946216246.39,
   'Sigma_0': 1.1051779336441324e-07,
   'f_c': -8.024389274295606,
   't_star': 0.04347152828263567,
   'Q': 159.6539439901699,
   'Sigma_0_stdev': 1.792139411948789e-08,
   'f_c_stdev': 8.865041390516696,
   't_star_stdev': 0.0478537004126364,
   'Q_stdev': 145.033735777104}}}
```

Note that one not only gets the seismic moment release, M_0 for each event (which can easily be converted into M_w), but also:

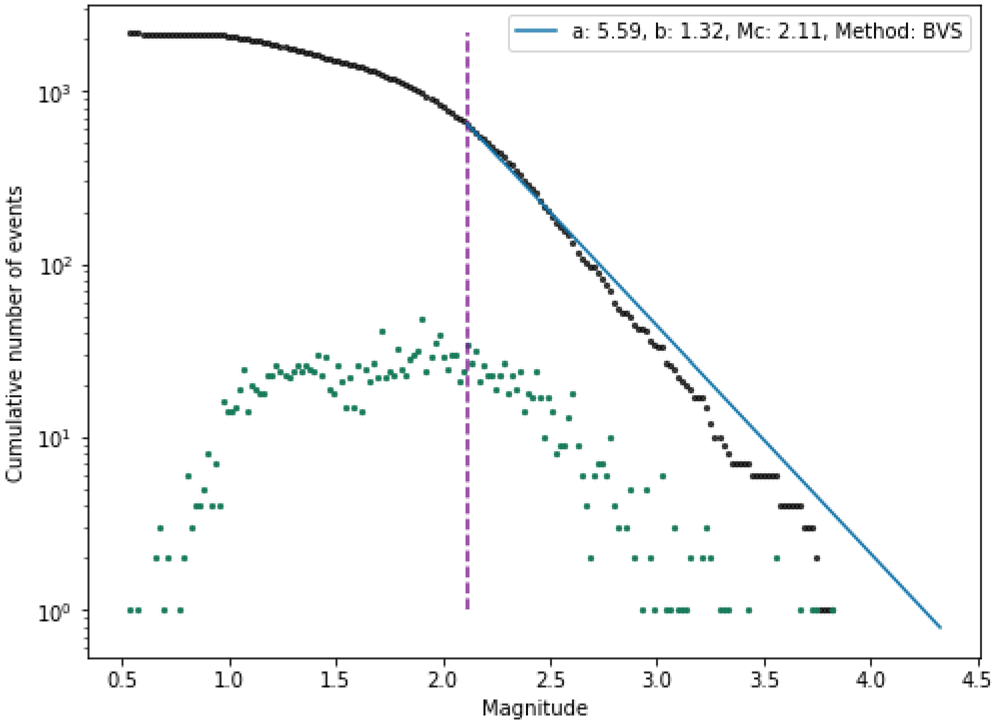
1. t^*, which can be used for attenuation tomography.
2. An approximation of the path-average Q, which can be used to assess the potential for attenuation tomography.
3. f_c, the corner frequency, which can be used for stress-drop or earthquake fault area calculations.

2. Plot up entire large VT catalogue as Gutenberg-Richter distribution:

Note that the code supports a number of ways to find the magnitude of completeness, Mc. The one we use here is the b-value stability method (BVS), detailed in Roberts et al 2015.

In [12]:

```
entire_large_mags_catalogue_fname = "data/catalogue_output_data/entire_vt_magnitudes_catalogue.pkl"
SeisSrcMoment.catalogue.plot_summary_Gutenberg_Richter(entire_large_mags_catalogue_fname, Q_filt=1000., upper_Mw_filt=4.0, Mc_method="BVS", fig_out_fname='')
```



3. Analyse and plot b-value temporal variaitons:

In [14]:

```
# Notes:
# Uses Roberts et al 2016 method

# Specify parameters for plotting b-value temporal variations:

# Note:
# Uses Smith1981 methog to find b-value (Aki maximum likelihood method)
# Set specific b-value through time parameters:
M_completeness = 2.11
eq_samp_size = 100 #100 # The window size for the moving calculation of b-value

# Get earthquake magnitudes dict:
entire_large_mags_catalogue_dict = SeisSrcMoment.catalogue.read_magnitude_catalo
gue(entire_large_mags_catalogue_fname)

# Set parameters:
Q_filt = 1000.
upper_Mw_filt = 4.0
min_max_mag_plot_lims = [-1.0, 4.5]
fig_out_fname = ''

# Sort nonlinloc event fnames into ascending order:
nonlinloc_fnames = list(entire_large_mags_catalogue_dict.keys())
nonlinloc_fnames_time_sorted = SeisSrcMoment.catalogue.sort_nonlinloc_fnames_int
o_chrono_order(nonlinloc_fnames)
```

In [17]:

```
# Calculate b-values through time, entire region:
event_times, b_values_through_time, b_values_errs_through_time = SeisSrcMoment.c
atalogue.calc_b_values_through_time_probabilistic(nonlinloc_fnames_time_sorted,
entire_large_mags_catalogue_dict,
                                                                     min_eq_samp_
size=50, max_eq_samp_size=500, number_of_eq_samp_windows=5000,
                                                                         Q_filt=Q
_filt, upper_Mw_filt=upper_Mw_filt)
```

```
/Users/eart0504/opt/anaconda3/lib/python3.7/site-packages/numpy/lib/
function_base.py:393: RuntimeWarning: Mean of empty slice.
  avg = a.mean(axis)
/Users/eart0504/opt/anaconda3/lib/python3.7/site-packages/numpy/cor
e/_methods.py:161: RuntimeWarning: invalid value encountered in doub
le_scalars
  ret = ret.dtype.type(ret / rcount)

Processing for eq samp window: 0 / 5000
Processing for eq samp window: 1000 / 5000
Processing for eq samp window: 2000 / 5000
Processing for eq samp window: 3000 / 5000
Processing for eq samp window: 4000 / 5000
```

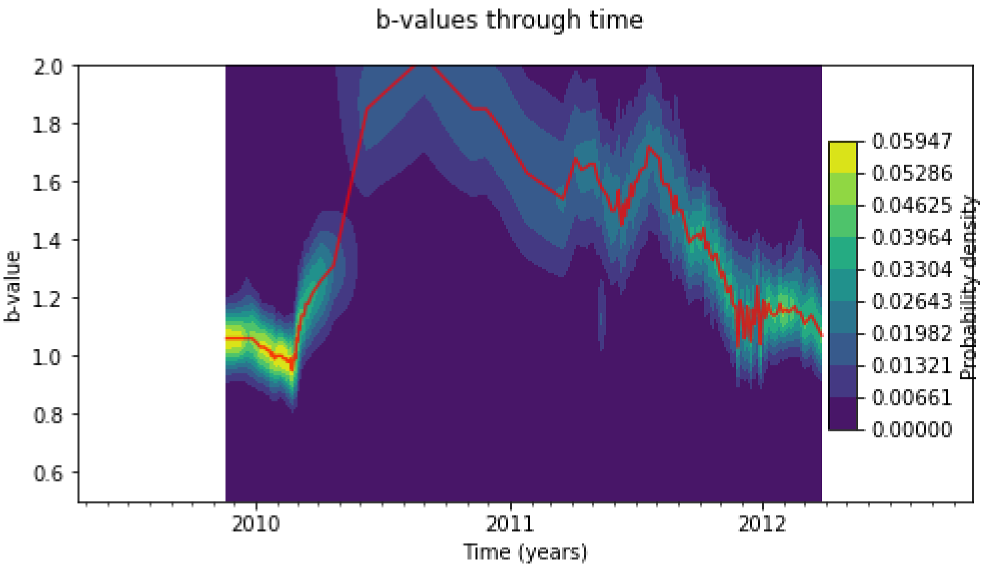
In [19]:

```
# And calc. event window pdfs:
time_labels, b_value_labels, b_value_time_array, b_values_through_time_pdfs = Se
isSrcMoment.catalogue.calc_event_window_pdf(event_times, b_values_through_time,
b_values_errs_through_time, num_samps_per_window=10, b_value_res=0.01)
```

In [25]:

```
# And plot b-values throguh time:
fig = SeisSrcMoment.catalogue.plot_temporal_b_values(time_labels, b_value_labels
, b_value_time_array)
fig.show()
```

```
/Users/eart0504/opt/anaconda3/lib/python3.7/site-packages/ipykernel_
launcher.py:3: UserWarning: Matplotlib is currently using module://i
pykernel.pylab.backend_inline, which is a non-GUI backend, so cannot
show the figure.
  This is separate from the ipykernel package so we can avoid doing
imports until
```



In [ ]: