sim_visualizations

November 30, 2018

1 Visualizations of UCERF3-ETAS and the N-test

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2 Overview

- Figures from UCERF3 catalogs
- Implemented N-test for stochastic event sets
- Evaluate the power of N-test following [Zechar et al., 2010]

3 Simulation List

Note: All times are UTC (+00:00)

3.0.1 UCERF3-ETAS

- Immediately following Landers (1992-06-28 11:57:35.0)
- Immediately following Big Bear (1992-06-28 15:48:42.8)
- 30 days following Big Bear (1992-07-28 15:48:42.8)

3.0.2 UCERF3-NoFaults

- Immediately following Landers (1992-06-28 11:57:35.0)

```
In [1]: import os
        import time
        import csep
        import csep.models
        from csep.core.evaluations import *
        from csep.utils.plotting import *
        import csep.utils.stats
        %pylab inline
```

```
Populating the interactive namespace from numpy and matplotlib
```

In [2]:
```
# Helping function to load catalogs
def comcat_loader(start_time, mw_min, verbose=False):
    t0 = time.time()
    comcat = csep.load_catalog(type='comcat', format='native',
                               start_epoch=start_time, duration_in_years=1.0,
                               min_magnitude=2.5,
                               min_latitude=31.50, max_latitude=43.00,
                               min_longitude=-125.40, max_longitude=-113.10,
                               name='Comcat').filter('magnitude > {}'.format(mw_min))
    t1 = time.time()

    # Statements about Comcat Downloads
    if verbose:
        print("Fetched Comcat catalog in {} seconds.\n"
              .format(t1-t0))
        print("Downloaded Comcat Catalog with following parameters")
        print("Start Date: {}\nEnd Date: {}"
              .format(str(comcat.start_time), str(comcat.end_time)))
        print("Min Latitude: {:.2f} and Max Latitude: {:.2f}"
              .format(comcat.min_latitude, comcat.max_latitude))
        print("Min Longitude: {:.2f} and Max Longitude: {:.2f}"
              .format(comcat.min_longitude, comcat.max_longitude))
        print("Min Magnitude: {:.2f} and Max Magnitude: {:.2f}\n"
              .format(comcat.min_magnitude, comcat.max_magnitude))

    return comcat
```

In [3]:
```
mw_min = 4.95
duration_in_years = 1.0

# Filenames of target simulations
project_root = '/Users/wsavran/Projects/CSEP2/u3etas_simulations/landers_experiment'
```

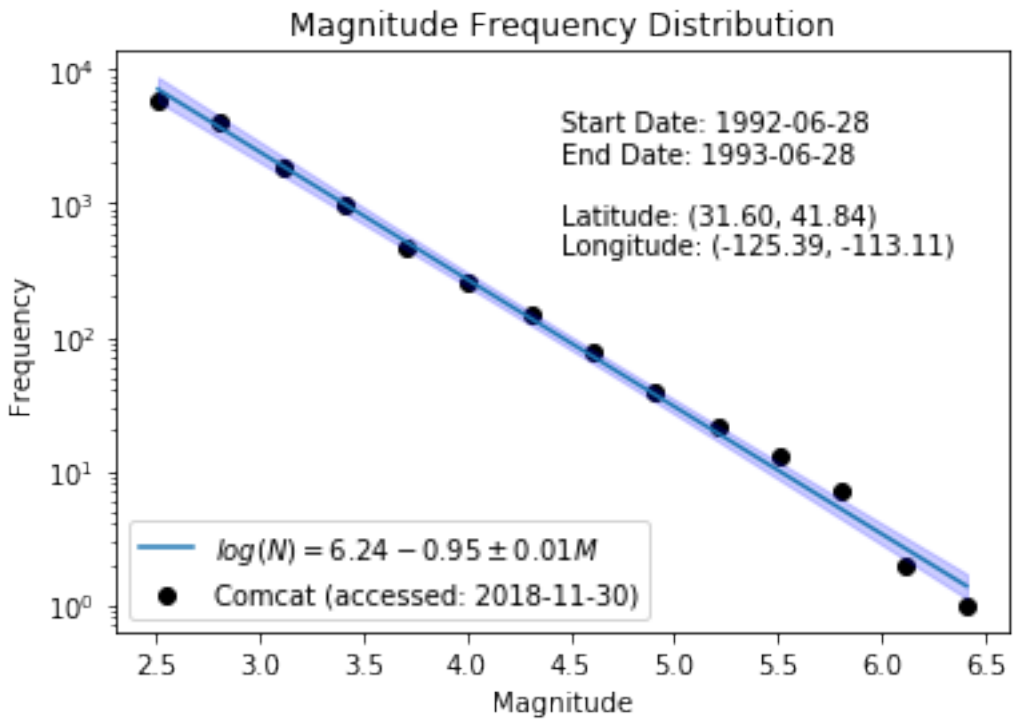
In [4]:
```
# Build Simulation Objects, catalogs are not filtered by default
landers = csep.models.Simulation(filename = os.path.join(project_root,
                                 '10-23-2018_landers-pt1/results_complete.bin'),
                                 min_mw = mw_min,
                                 start_time = 709732655000,
                                 sim_type = 'ucerf3',
                                 name = 'UCERF3-ETAS: Landers')
# bind filtered catalogs to simulation instance
landers.filt_catalogs = list(map(lambda x: x.filter('magnitude > {}'.format(landers.mi
                                 landers.catalogs))

bigbear = csep.models.Simulation(filename = os.path.join(project_root,
                                 '11-16-2018_big_bear-pt1/results_complete.bin'),
                                 min_mw = mw_min,
                                 start_time = 709746522800,
```

```
                                    sim_type = 'ucerf3',
                                    name = 'UCERF3-ETAS: Big Bear')
bigbear.filt_catalogs = list(map(lambda x: x.filter('magnitude > {}'.format(bigbear.mi
                                    bigbear.catalogs))

bigbear_p30 = csep.models.Simulation(filename = os.path.join(project_root,
                                    '11-16-2018_big_bear-pt2/results_complete.bin'),
                                    min_mw = mw_min,
                                    start_time = 712338522800,
                                    sim_type = 'ucerf3',
                                    name = 'UCERF3-ETAS: Big Bear + 1mo')
bigbear_p30.filt_catalogs = list(map(lambda x: x.filter('magnitude > {}'.format(bigbea
                                    bigbear_p30.catalogs))

nofaults = csep.models.Simulation(filename = os.path.join(project_root,
                                     '10-31-2018_landers-nofaults-pt1/results_complete.bi
                                     min_mw = mw_min,
                                     start_time = 709732655000,
                                     sim_type = 'ucerf3',
                                     name = 'UCERF3-NoFaults: Landers')
nofaults.filt_catalogs = list(map(lambda x: x.filter('magnitude > {}'.format(nofaults.
                                    nofaults.catalogs))
```

3.1 Comcat Catalog MFD

In [5]:
```
comcat = comcat_loader(landers.start_time, mw_min=2.5)
plot_mfd(comcat)
```

```
Computing MFD for catalog Comcat.
```



4 UCERF3-ETAS: Landers

1. Cumulative event counts
2. Histogram of event counts
3. N-test visualization
4. Events versus time for single catalog
5. MFD for single catalog

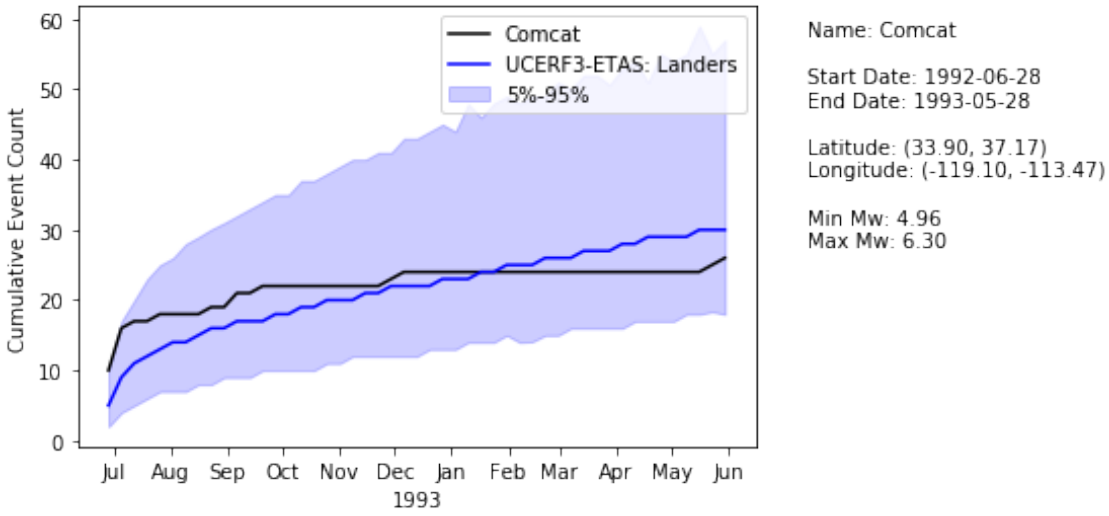
4.1 Load Comcat catalog for UCERF3-ETAS: Landers

```
In [6]: comcat = comcat_loader(landers.start_time, landers.min_mw, verbose = True)

Fetched Comcat catalog in 2.317103862762451 seconds.

Downloaded Comcat Catalog with following parameters
Start Date: 1992-06-28 12:00:59.904000+00:00
End Date: 1993-05-28 04:47:20.064000+00:00
Min Latitude: 33.90 and Max Latitude: 37.17
Min Longitude: -119.10 and Max Longitude: -113.47
Min Magnitude: 4.96 and Max Magnitude: 6.30
```

4.2 Cumulative Event Counts

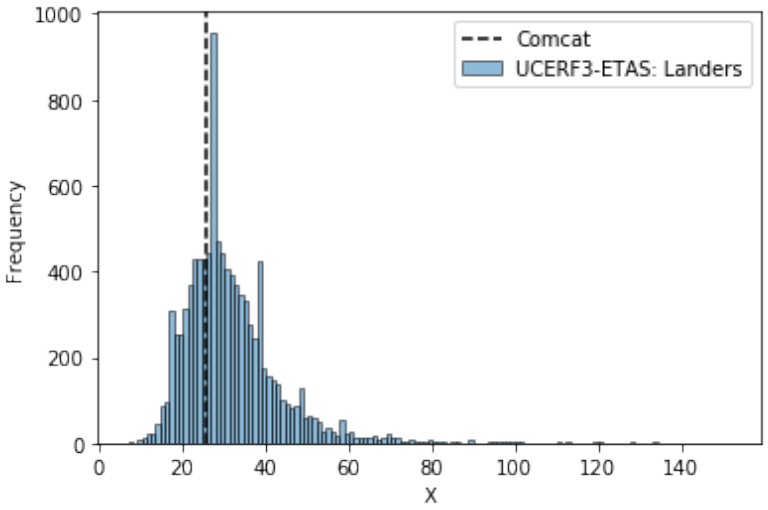
```
In [7]: ax = plot_cumulative_events_versus_time(landers.filt_catalogs,
                                                comcat,
                                                plot_args = {'sim_label': landers.name,
                                                             'obs_label': comcat.name})
```

```
Plotting cumulative event counts.
Converted 318682 ruptures from 10000 catalogs into a DataFrame in 50.573976039886475 seconds.
```



4.3 Histogram of Event Counts

```
In [8]: event_counts = [x.get_number_of_events() for x in landers.filt_catalogs]
        comcat_count = comcat.get_number_of_events()

        ax = plot_histogram(event_counts,
                            comcat_count,
                            catalog=comcat,
                            plot_args={'obs_label': comcat.name,
                            'sim_label': landers.name})
```



Name: Comcat

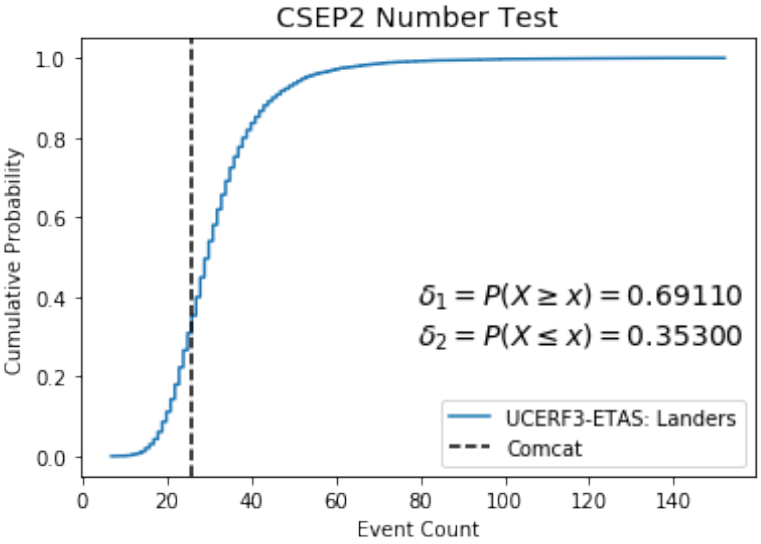
Start Date: 1992-06-28
End Date: 1993-05-28

Latitude: (33.90, 37.17)
Longitude: (-119.10, -113.47)

Min Mw: 4.96
Max Mw: 6.30

4.4 N-Test Results

```
In [9]: result = number_test(landers.filt_catalogs, comcat, plot=True)
```



Name: Comcat

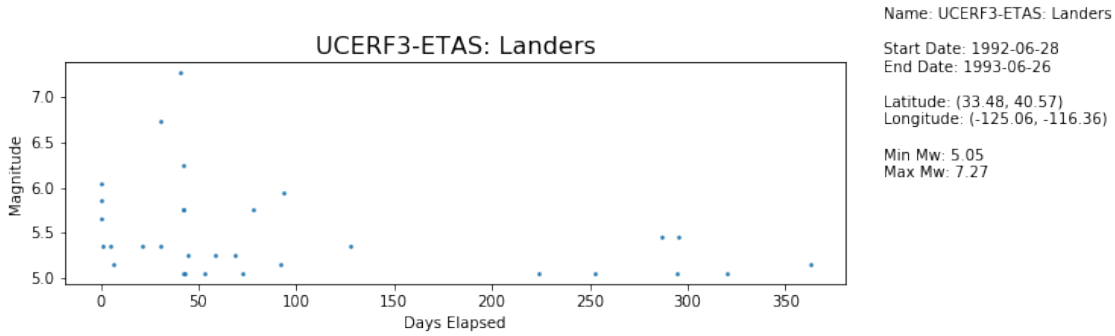
Start Date: 1992-06-28
End Date: 1993-05-28

Latitude: (33.90, 37.17)
Longitude: (-119.10, -113.47)

Min Mw: 4.96
Max Mw: 6.30

4.5 Magnitude versus time: UCERF3-ETAS

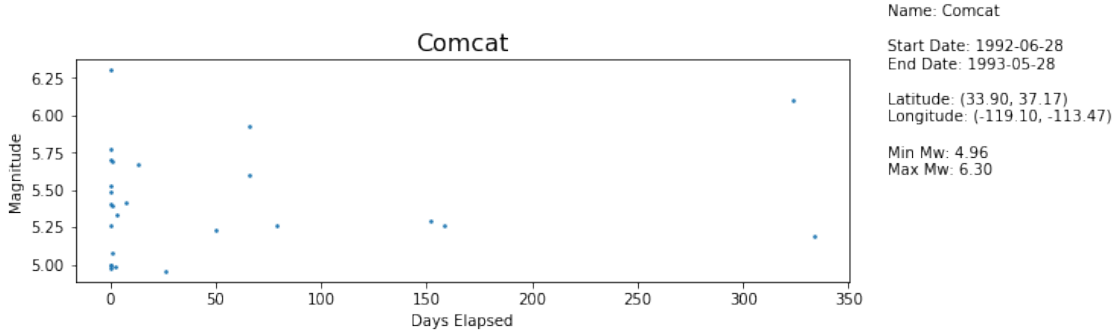
```
In [10]: ax = plot_magnitude_versus_time(landers.filt_catalogs[0])

Plotting magnitude versus time.
```



4.6 Magnitude versus time: Comcat

```
In [11]: ax = plot_magnitude_versus_time(comcat)
```

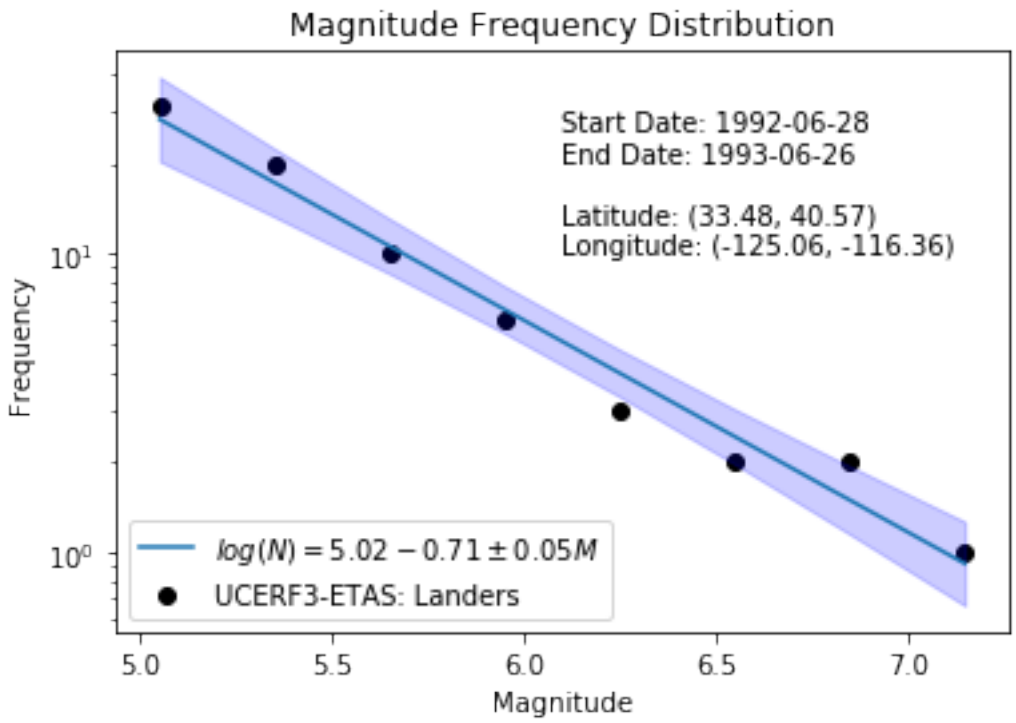
```
Plotting magnitude versus time.
```



4.7 Magnitude Frequency Distributions: UCERF3-ETAS

```
In [12]: ax = plot_mfd(landers.filt_catalogs[0])
```

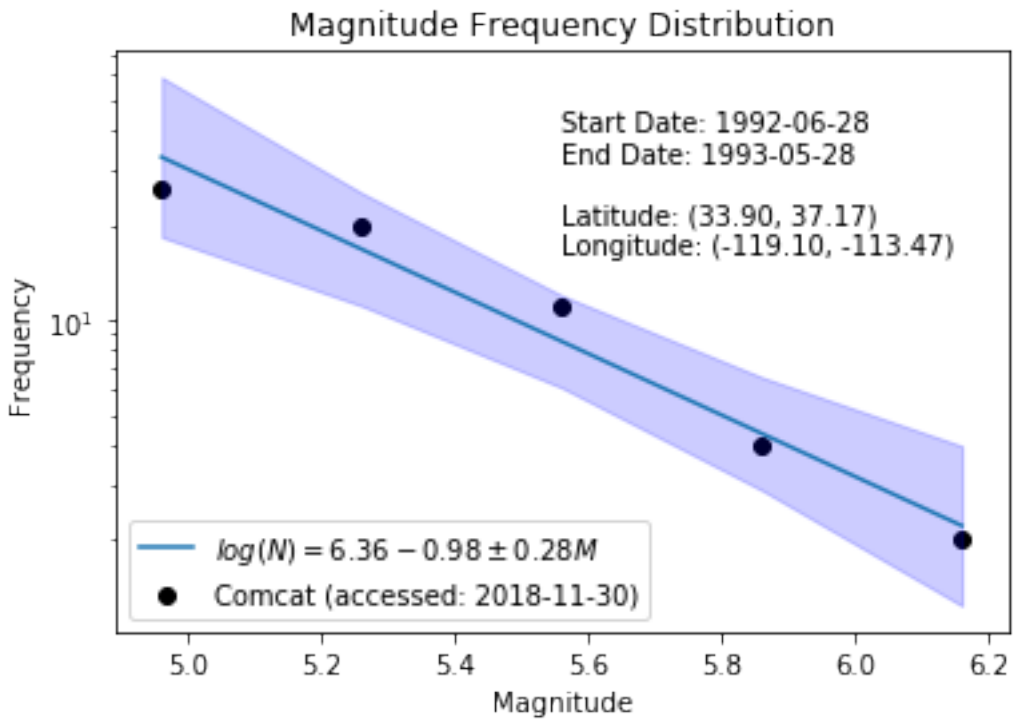
```
Computing MFD for catalog UCERF3-ETAS: Landers.
```



4.8 Magnitude Frequency Distribution: Comcat

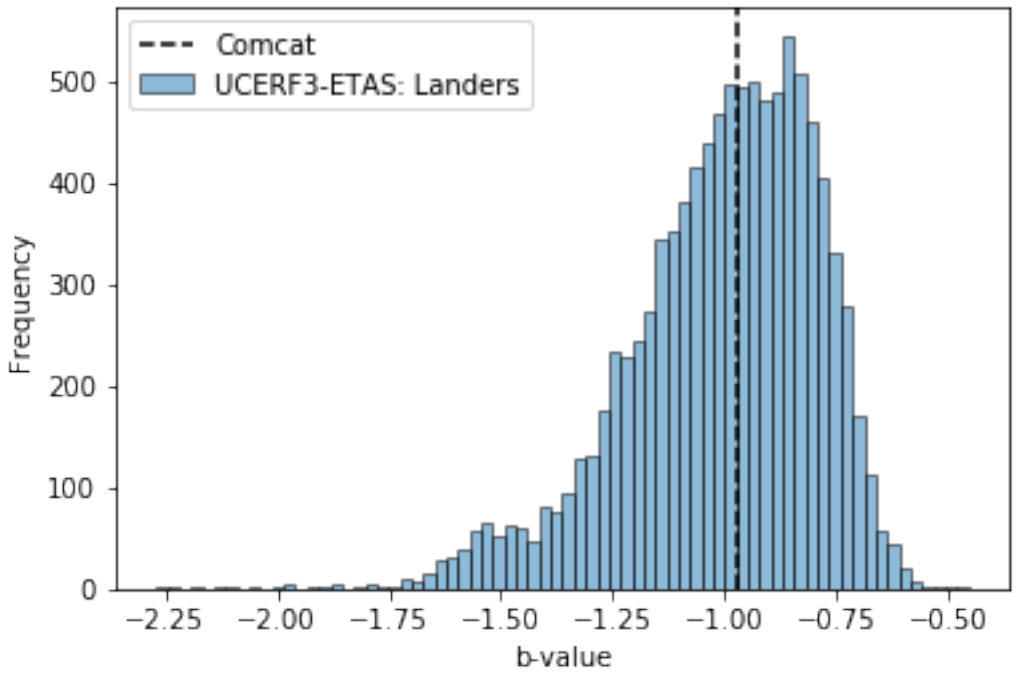
```
In [13]: ax = plot_mfd(comcat)
```

```
Computing MFD for catalog Comcat.
```



4.9 Distributions of *b*-values

```
In [14]: b_values = list(map(lambda x: x.get_mfd().loc[0,'b'], landers.filt_catalogs))
         comcat.mfd = comcat.get_mfd()
         ax = plot_histogram(b_values,
                             comcat.mfd.loc[0,'b'],
                             plot_args={'sim_label': landers.name,
                                        'obs_label': comcat.name,
                                        'xlabel': 'b-value'})
```



5 UCERF3-ETAS: Big Bear

1. Cumulative event counts
2. Histogram of event counts
3. N-test visualization
4. Events versus time for single catalog
5. MFD for single catalog

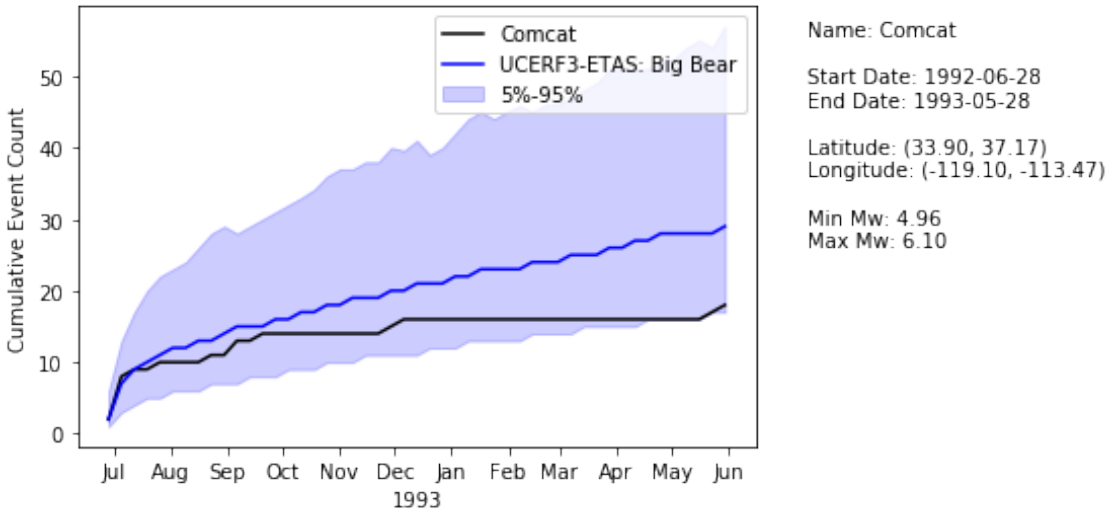
5.1 Load Comcat catalog for UCERF3-ETAS: Big Bear

```
In [15]: comcat = comcat_loader(bigbear.start_time, bigbear.min_mw, verbose = True)

Fetched Comcat catalog in 12.327759981155396 seconds.

Downloaded Comcat Catalog with following parameters
Start Date: 1992-06-28 17:01:22.304000+00:00
End Date: 1993-05-28 04:47:20.064000+00:00
Min Latitude: 33.90 and Max Latitude: 37.17
Min Longitude: -119.10 and Max Longitude: -113.47
Min Magnitude: 4.96 and Max Magnitude: 6.10
```

5.2 Cumulative Event Counts

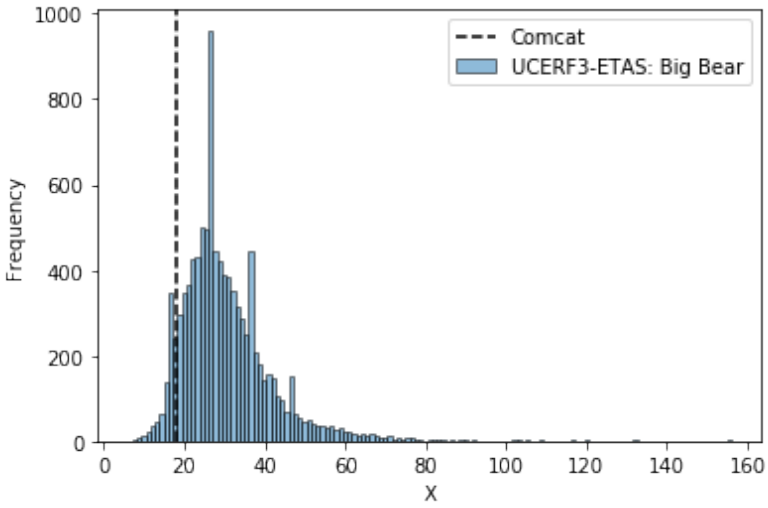
```
In [16]: ax = plot_cumulative_events_versus_time(bigbear.filt_catalogs,
                                                 comcat,
                                                 plot_args = {'sim_label': bigbear.name,
                                                              'obs_label': comcat.name})
```

```
Plotting cumulative event counts.
Converted 304006 ruptures from 10000 catalogs into a DataFrame in 56.554378032684326 seconds.
```



5.3 Histogram of Event Counts

```
In [17]: event_counts = [x.get_number_of_events() for x in bigbear.filt_catalogs]
         comcat_count = comcat.get_number_of_events()

         ax = plot_histogram(event_counts,
                             comcat_count,
                             catalog=comcat,
                             plot_args={'obs_label': comcat.name,
                                        'sim_label': bigbear.name})
```



Name: Comcat

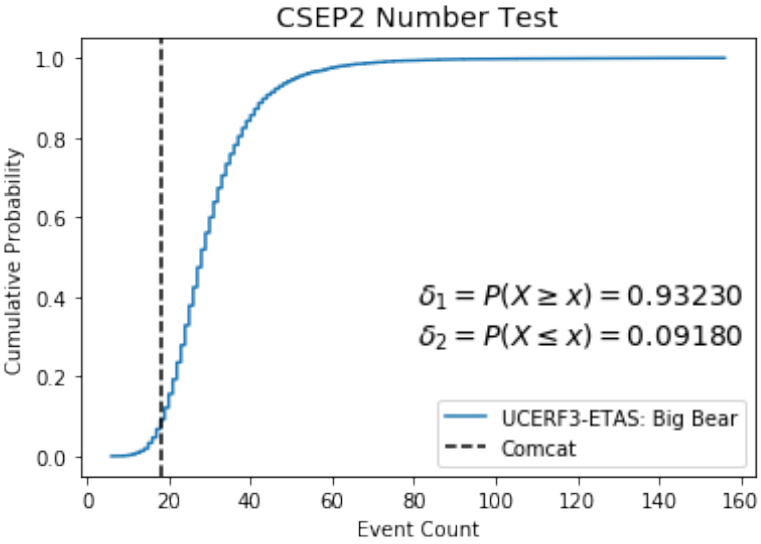
Start Date: 1992-06-28
End Date: 1993-05-28

Latitude: (33.90, 37.17)
Longitude: (-119.10, -113.47)

Min Mw: 4.96
Max Mw: 6.10

5.4 N-Test Results

```
In [18]: result = number_test(bigbear.filt_catalogs, comcat, plot=True)
```



Name: Comcat

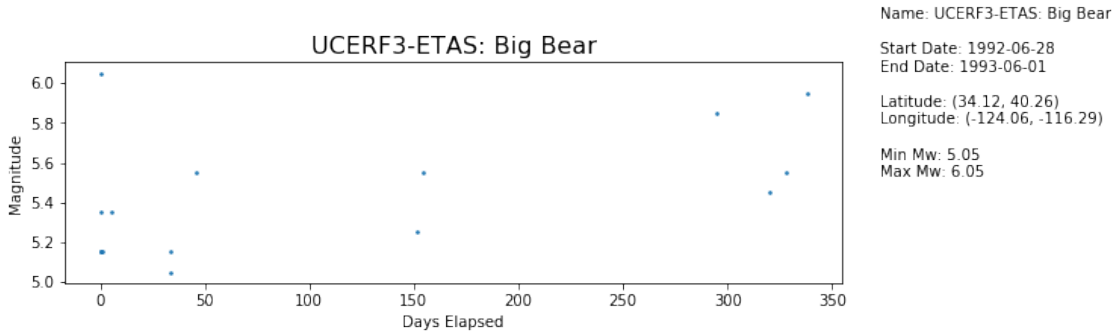
Start Date: 1992-06-28
End Date: 1993-05-28

Latitude: (33.90, 37.17)
Longitude: (-119.10, -113.47)

Min Mw: 4.96
Max Mw: 6.10

5.5 Magnitude versus time: UCERF3-ETAS

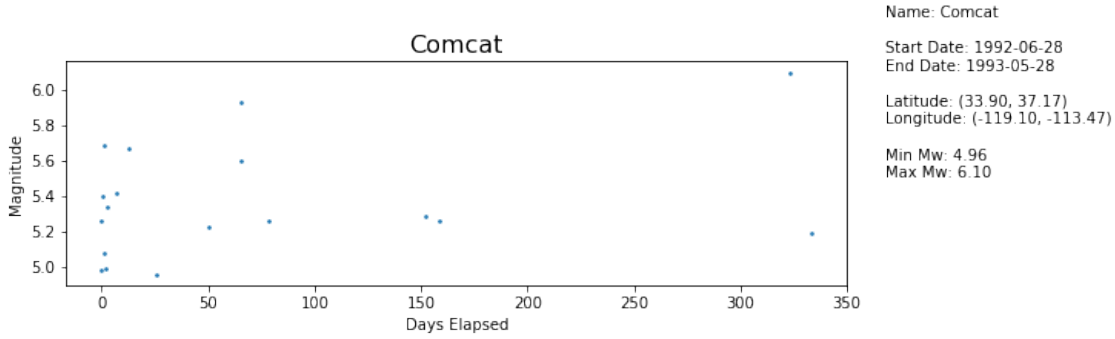
```
In [19]: ax = plot_magnitude_versus_time(bigbear.filt_catalogs[0])

Plotting magnitude versus time.
```



5.6 Magnitude versus time: Comcat

```
In [20]: ax = plot_magnitude_versus_time(comcat)
```

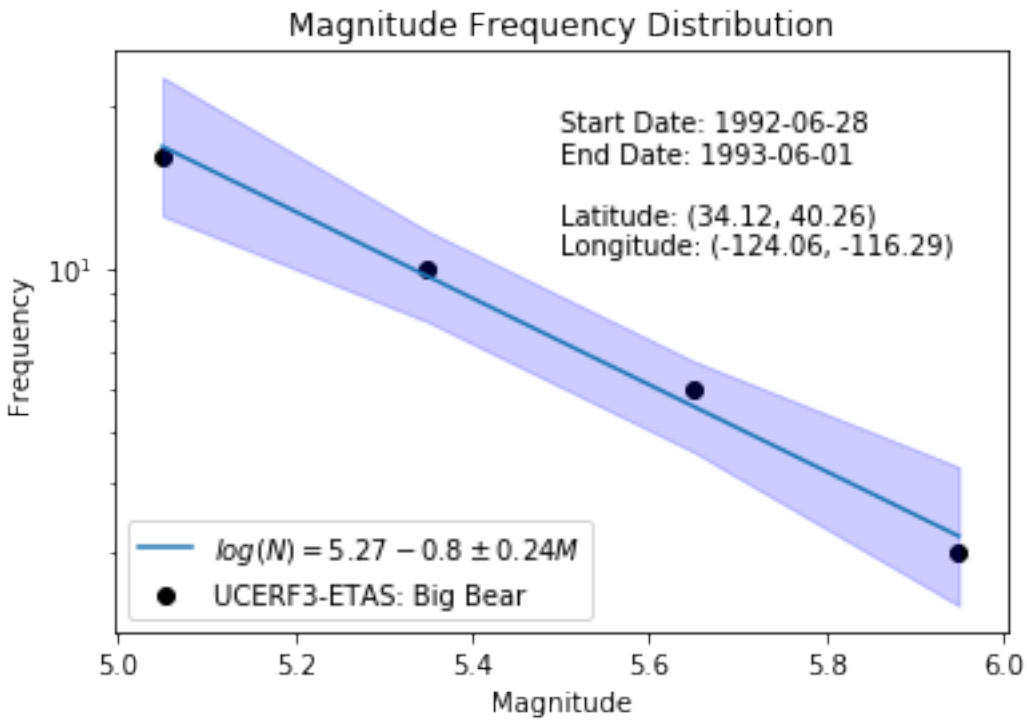
```
Plotting magnitude versus time.
```



5.7 Magnitude Frequency Distributions: UCERF3-ETAS

```
In [21]: ax = plot_mfd(bigbear.filt_catalogs[0])
```

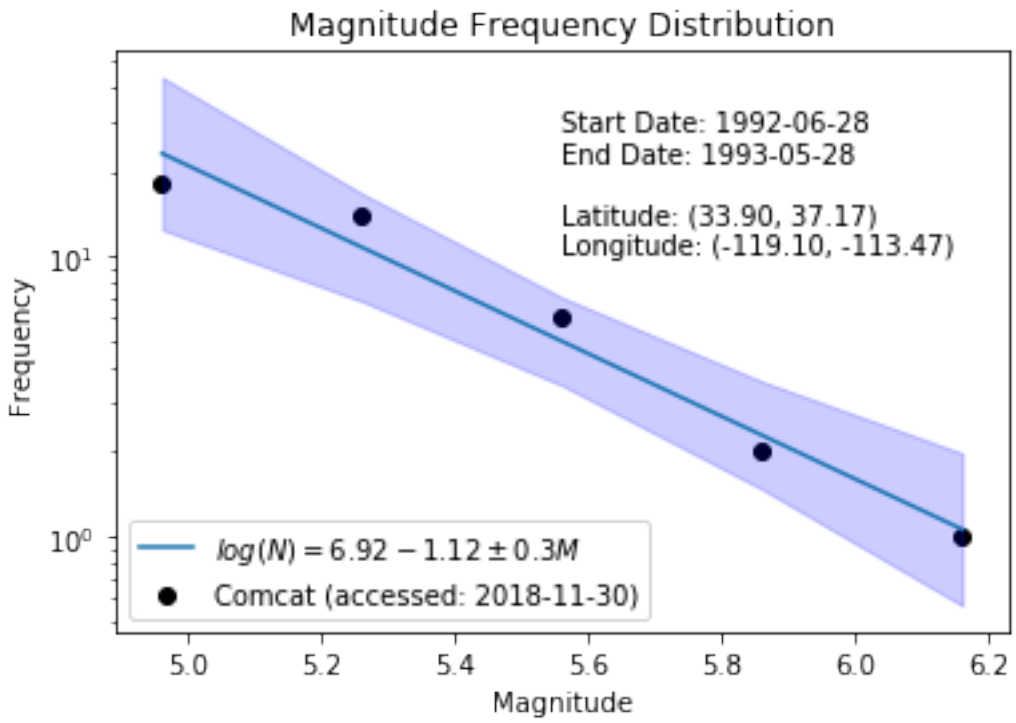
```
Computing MFD for catalog UCERF3-ETAS: Big Bear.
```



5.8 Magnitude Frequency Distribution: Comcat

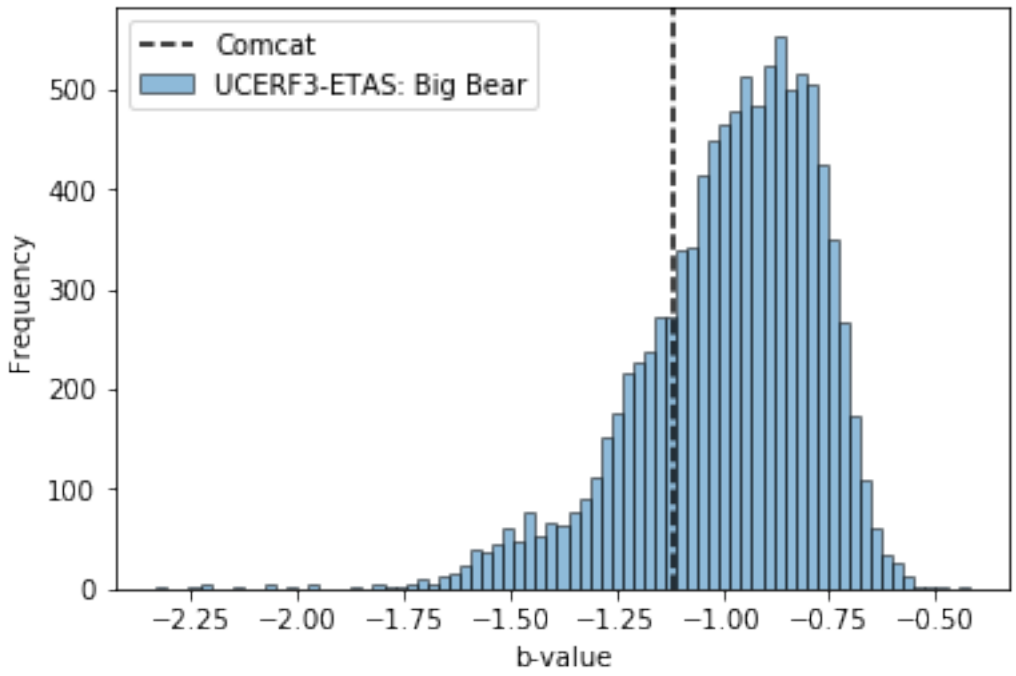
```
In [22]: ax = plot_mfd(comcat)
```

```
Computing MFD for catalog Comcat.
```



5.9 Distributions of *b*-values

```
In [23]: b_values = list(map(lambda x: x.get_mfd().loc[0,'b'], bigbear.filt_catalogs))
         comcat.mfd = comcat.get_mfd()
         ax = plot_histogram(b_values,
                             comcat.mfd.loc[0,'b'],
                             plot_args={'sim_label': bigbear.name,
                                        'obs_label': comcat.name,
                                        'xlabel': 'b-value'})
```



6 UCERF3-ETAS: Big Bear + 30 days

1. Cumulative event counts
2. Histogram of event counts
3. N-test visualization
4. Events versus time for single catalog
5. MFD for single catalog

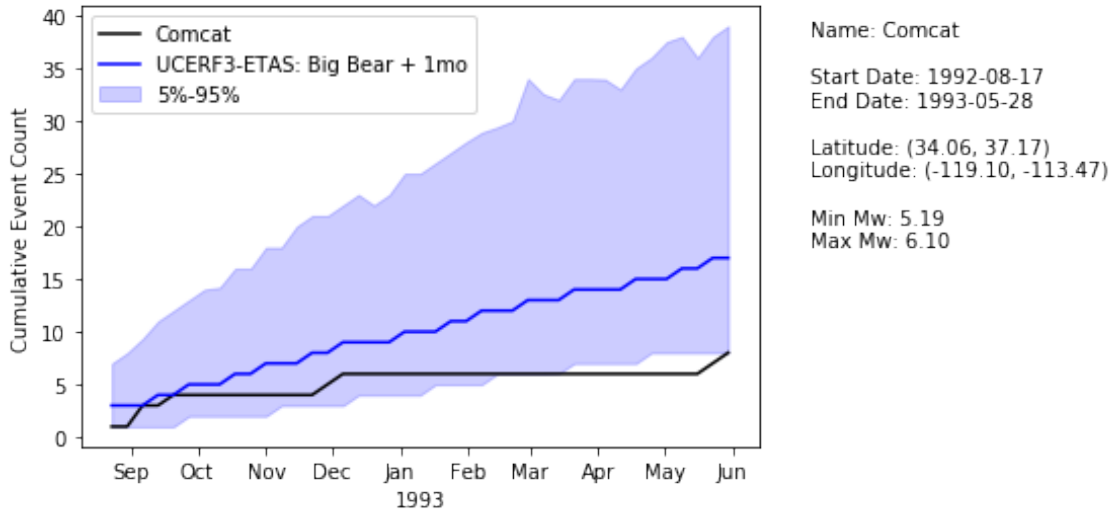
6.1 Load Comcat catalog for UCERF3-ETAS: Big Bear + 30 Days

```
In [24]: comcat = comcat_loader(bigbear_p30.start_time, bigbear_p30.min_mw, verbose = True)

Fetched Comcat catalog in 5.192399978637695 seconds.

Downloaded Comcat Catalog with following parameters
Start Date: 1992-08-17 20:42:02.624000+00:00
End Date: 1993-05-28 04:47:20.064000+00:00
Min Latitude: 34.06 and Max Latitude: 37.17
Min Longitude: -119.10 and Max Longitude: -113.47
Min Magnitude: 5.19 and Max Magnitude: 6.10
```

6.2 Cumulative Event Counts

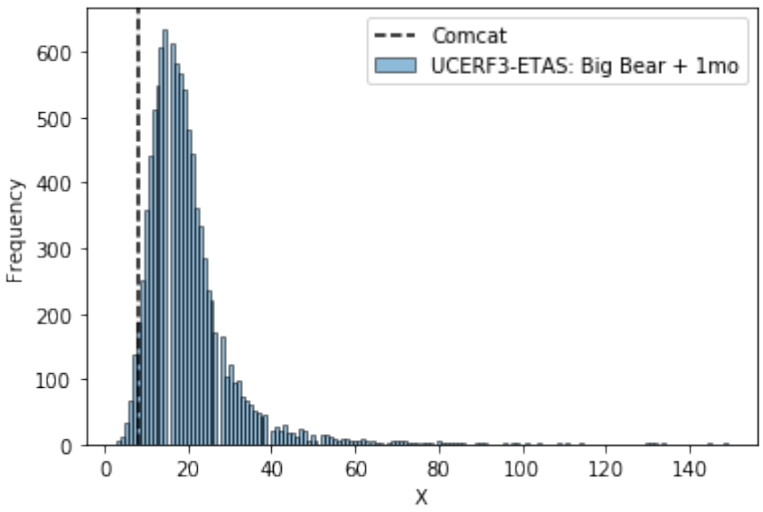
```
In [25]: ax = plot_cumulative_events_versus_time(bigbear_p30.filt_catalogs,
                                                 comcat,
                                                 plot_args = {'sim_label': bigbear_p30.name,
                                                              'obs_label': comcat.name,
                                                              'legend_loc': 'upper left'})
```

```
Plotting cumulative event counts.
Converted 195981 ruptures from 10000 catalogs into a DataFrame in 59.483938694000244 seconds.
```



6.3 Histogram of Event Counts

```
In [26]: event_counts = [x.get_number_of_events() for x in bigbear_p30.filt_catalogs]
         comcat_count = comcat.get_number_of_events()

         ax = plot_histogram(event_counts,
                             comcat_count,
                             catalog=comcat,
                             plot_args={'obs_label': comcat.name,
                             'sim_label': bigbear_p30.name})
```



Name: Comcat

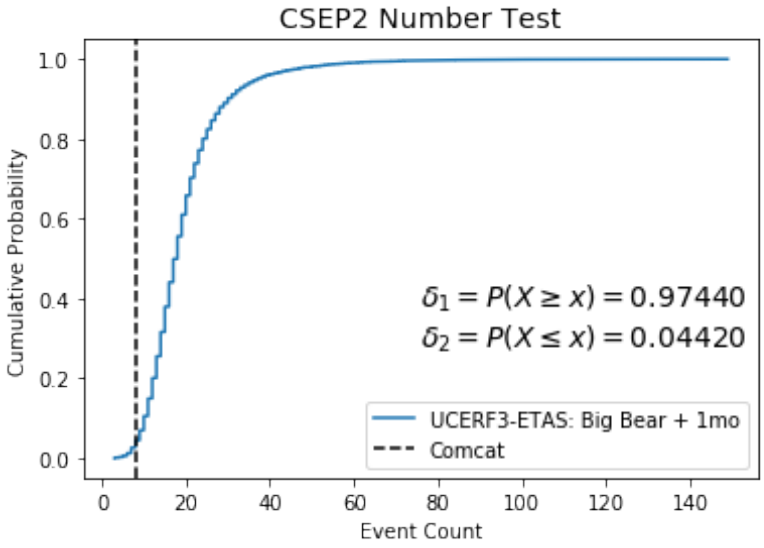
Start Date: 1992-08-17
End Date: 1993-05-28

Latitude: (34.06, 37.17)
Longitude: (-119.10, -113.47)

Min Mw: 5.19
Max Mw: 6.10

6.4 N-Test Results

```
In [27]: result = number_test(bigbear_p30.filt_catalogs, comcat, plot=True)
```



Name: Comcat

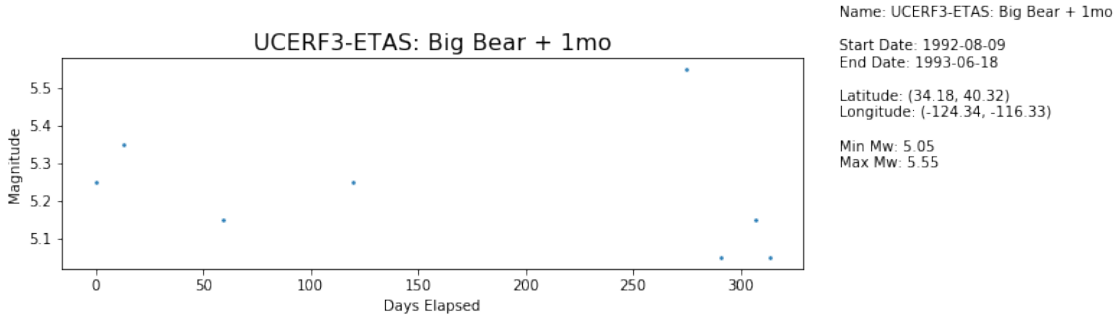
Start Date: 1992-08-17
End Date: 1993-05-28

Latitude: (34.06, 37.17)
Longitude: (-119.10, -113.47)

Min Mw: 5.19
Max Mw: 6.10

6.5 Magnitude versus time: UCERF3-ETAS

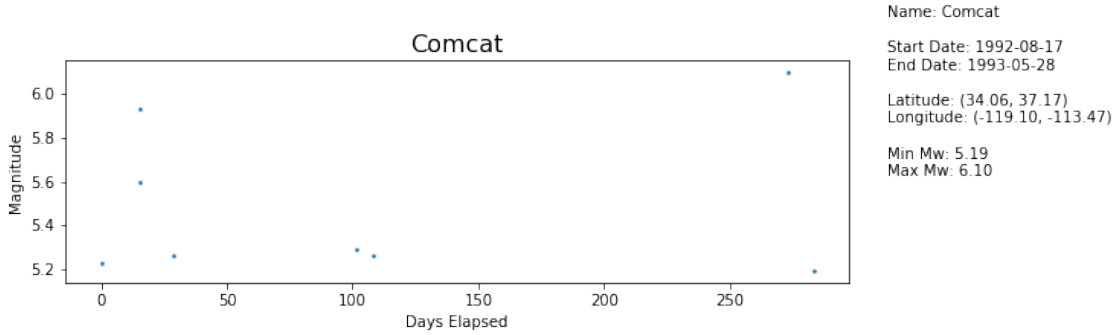
```
In [28]: ax = plot_magnitude_versus_time(bigbear_p30.filt_catalogs[0])

Plotting magnitude versus time.
```



6.6 Magnitude versus time: Comcat

```
In [29]: ax = plot_magnitude_versus_time(comcat)
```

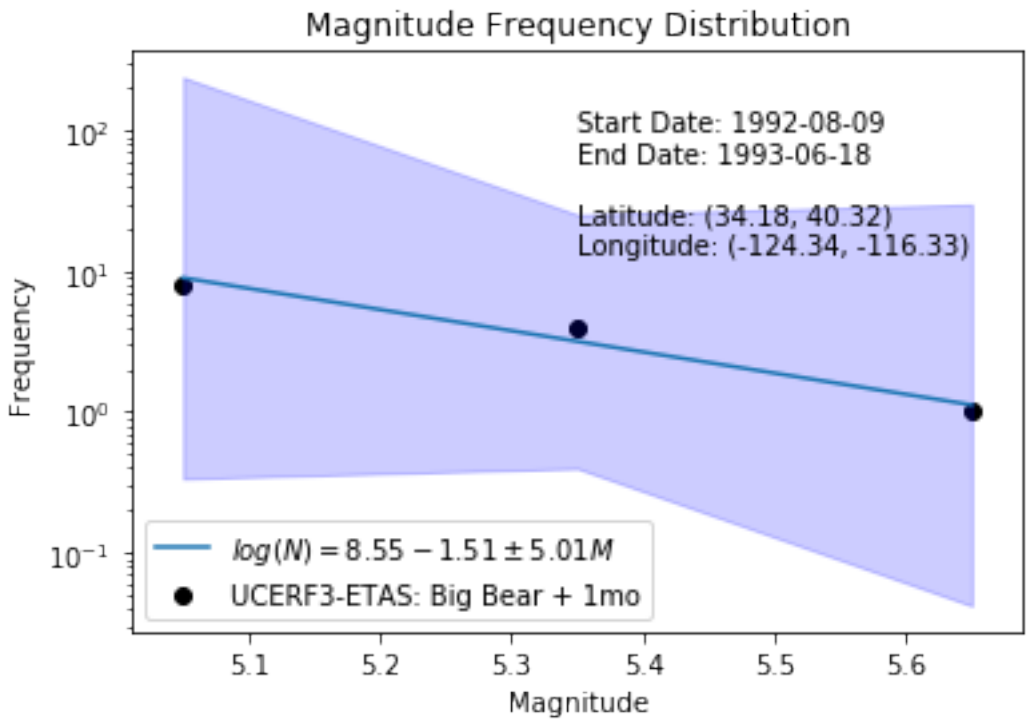
```
Plotting magnitude versus time.
```



6.7 Magnitude Frequency Distributions -- UCERF3-ETAS

```
In [30]: ax = plot_mfd(bigbear_p30.filt_catalogs[0])
```

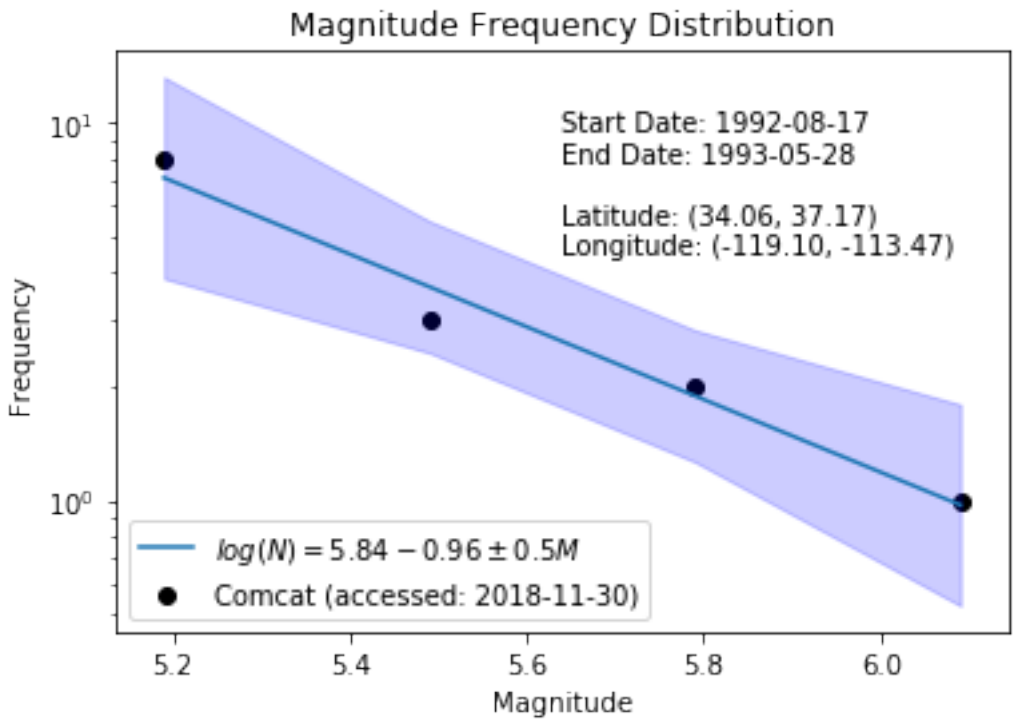
```
Computing MFD for catalog UCERF3-ETAS: Big Bear + 1mo.
```



6.8 Magnitude Frequency Distribution -- Comcat

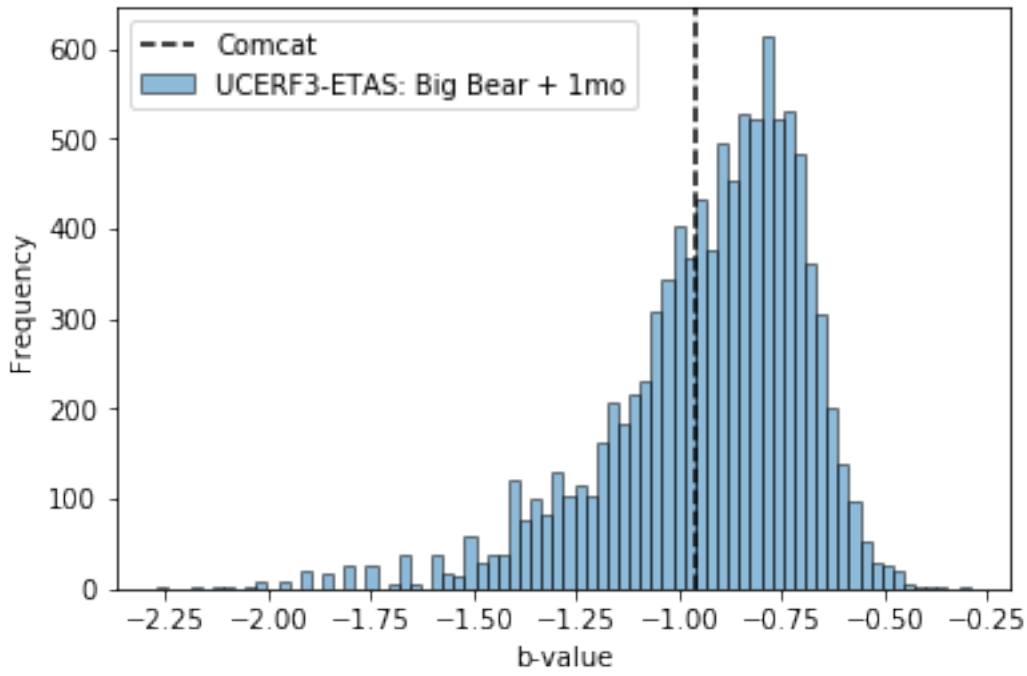
```
In [31]: ax = plot_mfd(comcat)
```

```
Computing MFD for catalog Comcat.
```



6.9 Distributions of *b*-values

```
In [32]: b_values = list(map(lambda x: x.get_mfd().loc[0,'b'], bigbear_p30.filt_catalogs))
         comcat.mfd = comcat.get_mfd()
         ax = plot_histogram(b_values,
                             comcat.mfd.loc[0,'b'],
                             plot_args={'sim_label': bigbear_p30.name,
                                        'obs_label': comcat.name,
                                        'xlabel': 'b-value'})
```



7 UCERF3-No Faults: Landers

1. Cumulative event counts
2. Histogram of event counts
3. N-test visualization
4. Events versus time for single catalog
5. MFD for single catalog

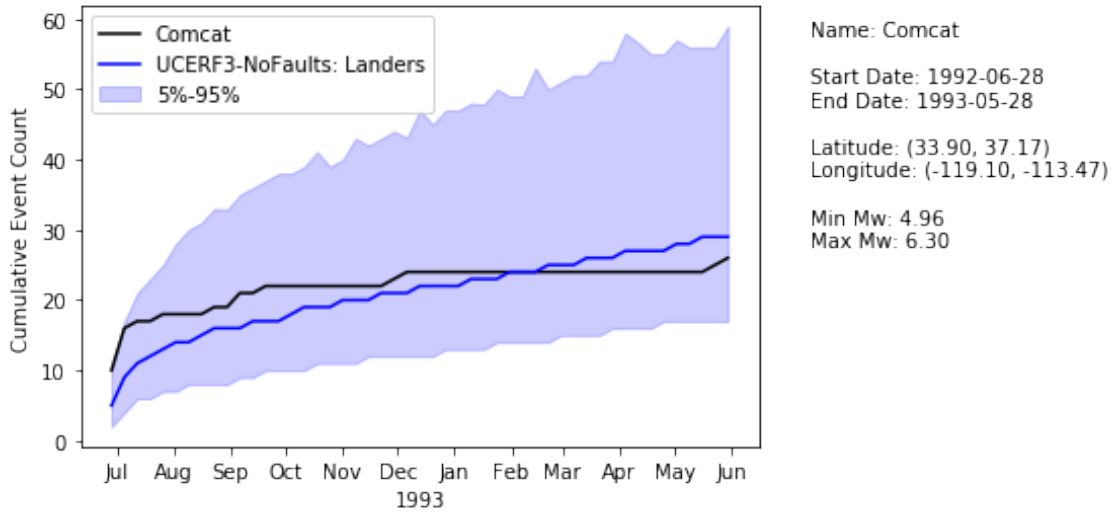
7.1 Load Comcat catalog for UCERF3-No Faults: Landers

```
In [33]: comcat = comcat_loader(nofaults.start_time, nofaults.min_mw, verbose = True)

Fetched Comcat catalog in 2.2441751956939697 seconds.

Downloaded Comcat Catalog with following parameters
Start Date: 1992-06-28 12:00:59.904000+00:00
End Date: 1993-05-28 04:47:20.064000+00:00
Min Latitude: 33.90 and Max Latitude: 37.17
Min Longitude: -119.10 and Max Longitude: -113.47
Min Magnitude: 4.96 and Max Magnitude: 6.30
```

7.2 Cumulative Event Counts

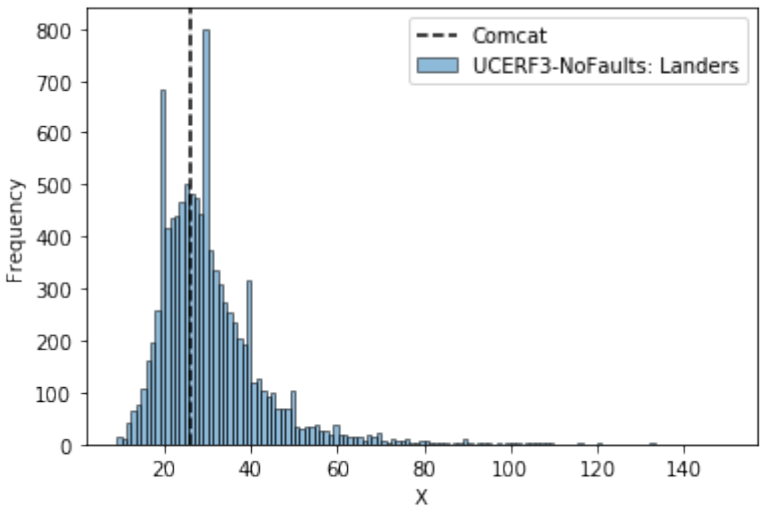
```
In [34]: ax = plot_cumulative_events_versus_time(nofaults.filt_catalogs,
                                                 comcat,
                                                 plot_args = {'sim_label': nofaults.name,
                                                              'obs_label': comcat.name,
                                                              'legend_loc': 'upper left'})
```

```
Plotting cumulative event counts.
Converted 305011 ruptures from 10000 catalogs into a DataFrame in 55.09207510948181 seconds.
```



7.3 Histogram of Event Counts

```
In [42]: event_counts = [x.get_number_of_events() for x in nofaults.filt_catalogs]
         comcat_count = comcat.get_number_of_events()
         ax = plot_histogram(event_counts,
                             comcat_count,
                             catalog=comcat,
                             plot_args={'obs_label': comcat.name,
                                        'sim_label': nofaults.name})
```



Name: Comcat

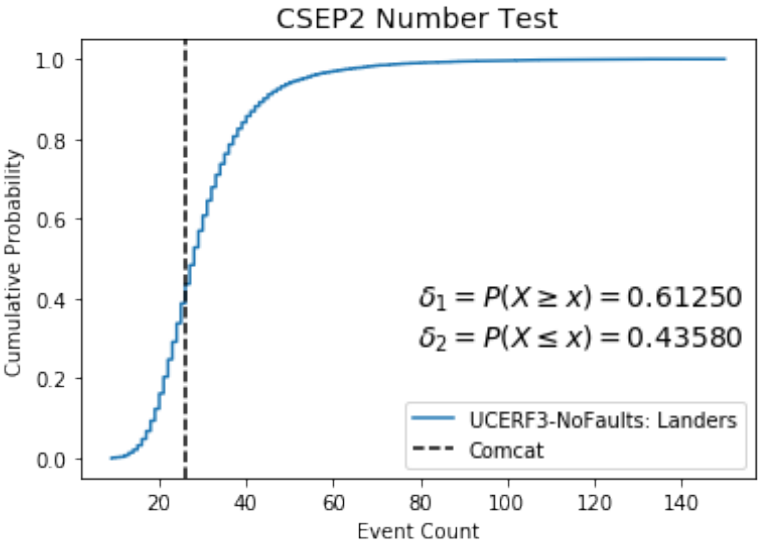
Start Date: 1992-06-28
End Date: 1993-05-28

Latitude: (33.90, 37.17)
Longitude: (-119.10, -113.47)

Min Mw: 4.96
Max Mw: 6.30

7.4 N-Test Results

```
In [36]: result = number_test(nofaults.filt_catalogs, comcat, plot=True)
```



Name: Comcat

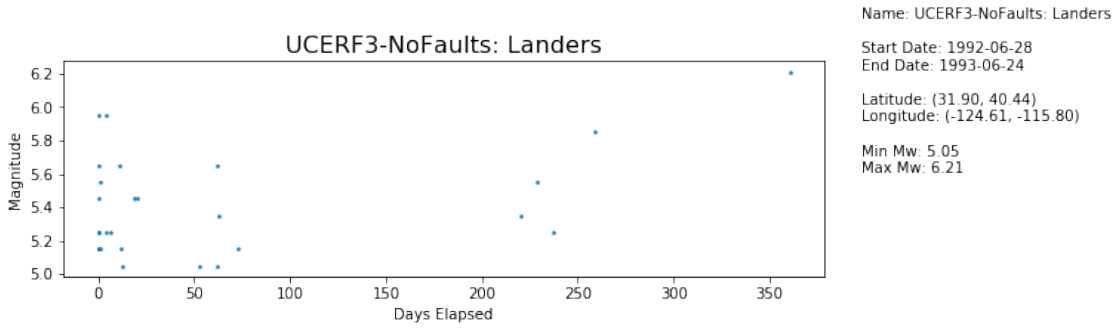
Start Date: 1992-06-28
End Date: 1993-05-28

Latitude: (33.90, 37.17)
Longitude: (-119.10, -113.47)

Min Mw: 4.96
Max Mw: 6.30

7.5 Magnitude versus time: UCERF3-NoFaults

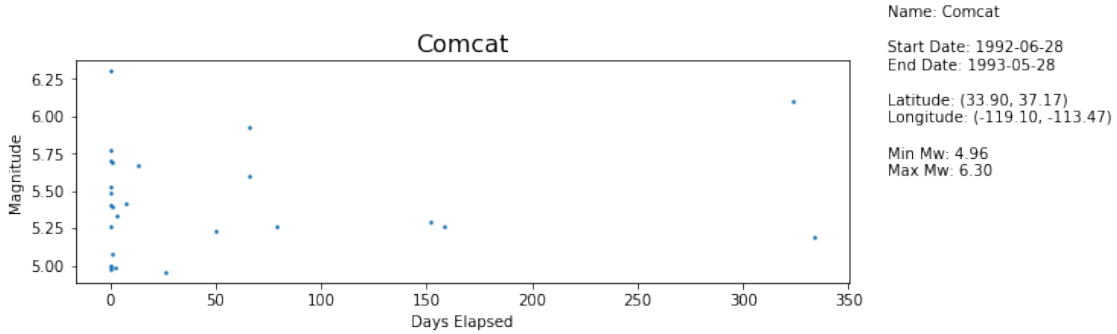
```
In [37]: ax = plot_magnitude_versus_time(nofaults.filt_catalogs[0])

Plotting magnitude versus time.
```



7.6 Magnitude versus time: Comcat

```
In [38]: ax = plot_magnitude_versus_time(comcat)
```

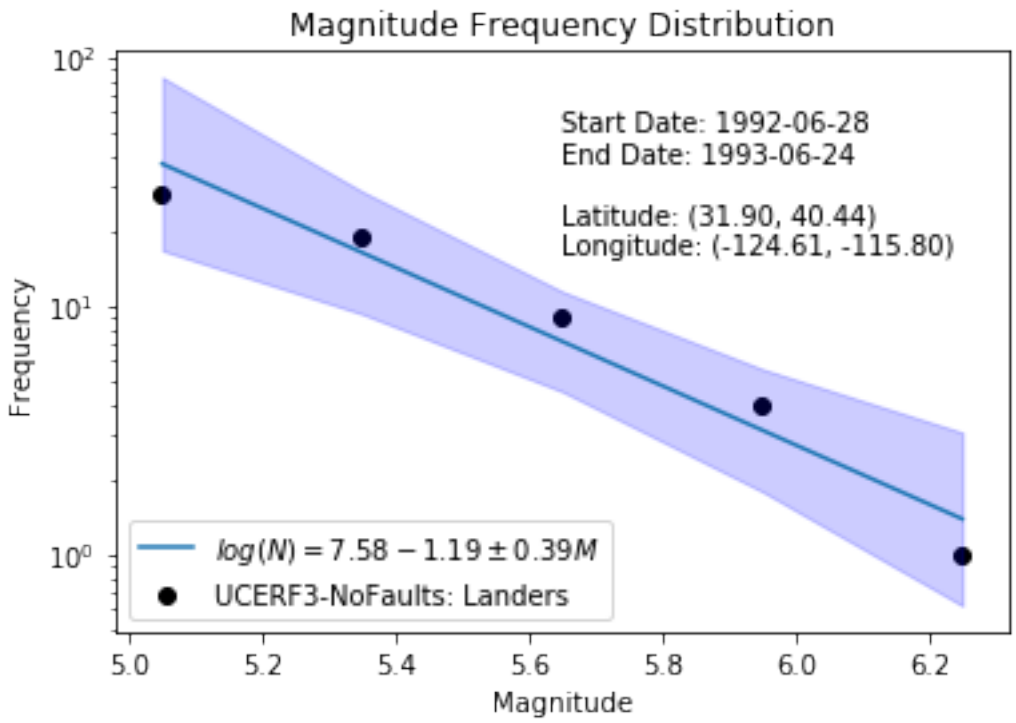
```
Plotting magnitude versus time.
```



7.7 Magnitude Frequency Distributions: UCERF3-NoFaults

```
In [39]: ax = plot_mfd(nofaults.filt_catalogs[0])
```

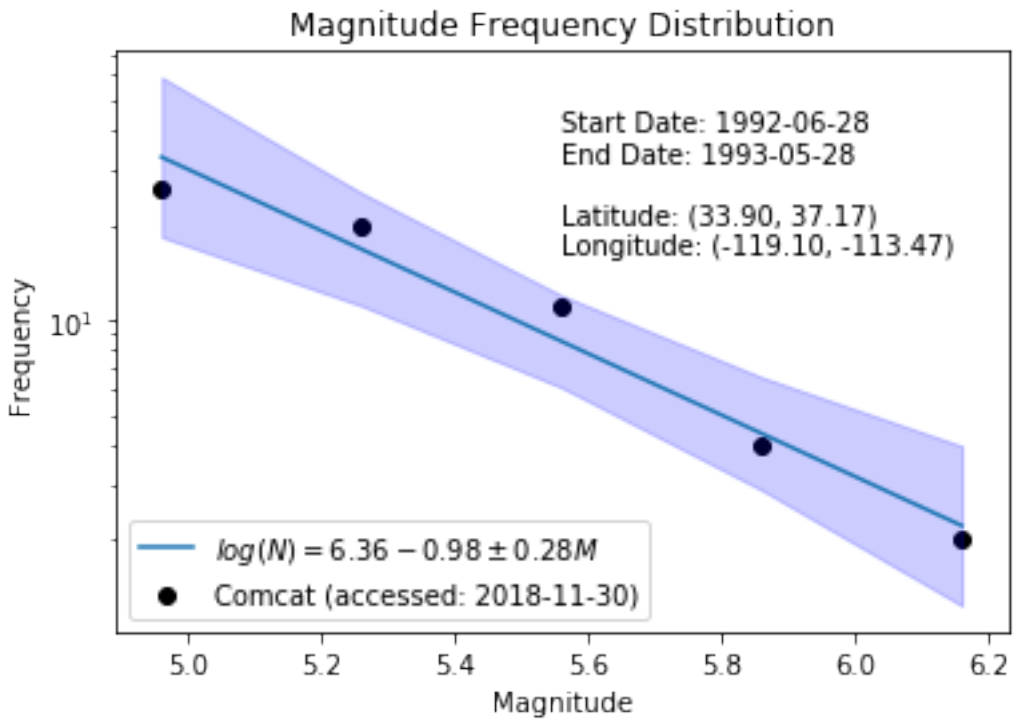
```
Computing MFD for catalog UCERF3-NoFaults: Landers.
```



7.8 Magnitude Frequency Distribution: Comcat

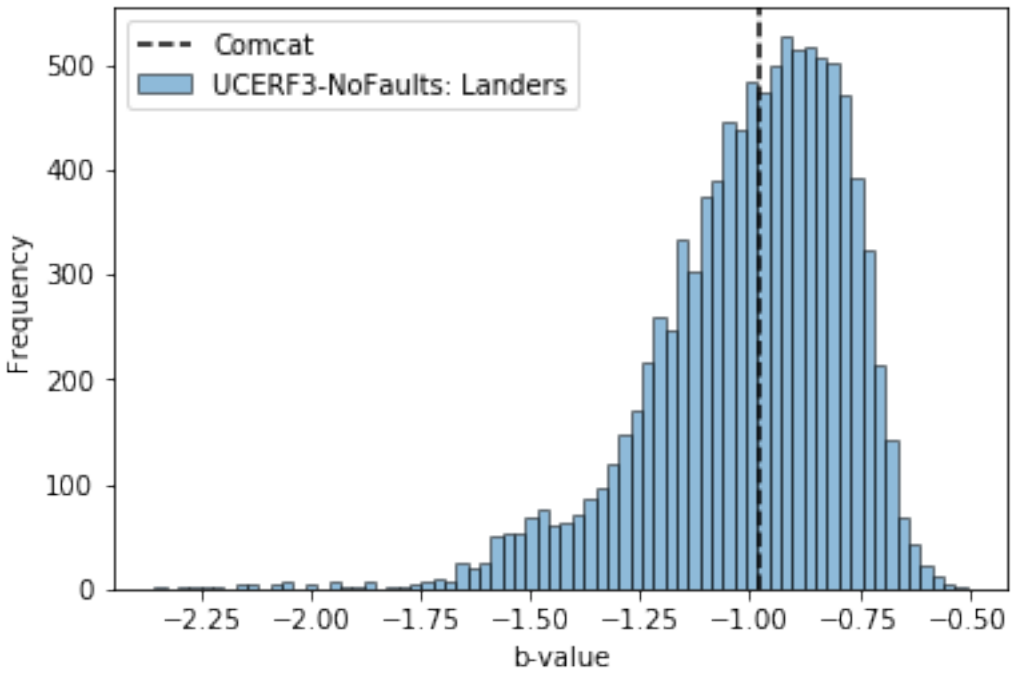
```
In [40]: ax = plot_mfd(comcat)
```

```
Computing MFD for catalog Comcat.
```



7.9 Distributions of *b*-values

```
In [41]: b_values = list(map(lambda x: x.get_mfd().loc[0,'b'], nofaults.filt_catalogs))
         comcat.mfd = comcat.get_mfd()
         ax = plot_histogram(b_values,
                             comcat.mfd.loc[0,'b'],
                             plot_args={'sim_label': nofaults.name,
                                        'obs_label': comcat.name,
                                        'xlabel': 'b-value'})
```


Comcat
UCERF3-NoFaults: Landers
Frequency
500
400
300
200
100
0
−2.25
−2.00
−1.75
−1.50
−1.25
−1.00
−0.75
−0.50
b-value