

```

pylab.rcParams['figure.figsize'] = (20, 15)
from generating_figures import india_basemap
import pickle
import pandas as pd
pd.set_option('display.max_rows', None)

pickle_files_loc = '/home/anis/Desktop/GitHub/Pesmos_Original/DataProcessing/'
station_data_from_file = pickle.load( open( pickle_files_loc+"station_data_from_file.pickle"
pesmos_stations_final_pd = pickle.load( open( pickle_files_loc+"pesmos_stations_final_pd.pi
pesmos_stations = pickle.load( open( pickle_files_loc+"pesmos_stations.pickle", "rb" ) )
pesmos_event_pd = pickle.load( open( pickle_files_loc+"pesmos_event_pd.pickle", "rb" ) )
EventsWithMagnitude = pickle.load( open( pickle_files_loc+"EventsWithMagnitude.pickle", "rb"
EventsWithMoreThanThreeRecords = pickle.load( open( pickle_files_loc+"EventsWithMoreThanThre

```

Introduction

PESMOS is a project initiated by Earthquake Engineering Department of Indian Institute of Technology Roorkee to study the ground motion characteristics of Himalayan earthquakes using strong motion accelerographs. The project was funded by Department of Science and Technology (DST), Government of India. The strong motion accelerograph network covers various region of Indian seismic zones V, IV and some thickly populated cities of seismic zone III. Out of 298 installed accelerograms 193 station have recorded various earthquake events as shown in Figure 1.

```

station_color = {'A':'r', 'B':'g', 'C':'b', 'D':'y'}
m = india_basemap('./')
for station in pesmos_stations:
    m.scatter([pesmos_stations[station]['Longitude']], [pesmos_stations[station]['Latitude']],
              s=25, latlon=True, marker='D', color= station_color[pesmos_stations[station]['Site
m.scatter([0],[0], s=25, latlon=True, marker='D', color='r', label='Site Class A Vs30 between 7
m.scatter([0],[0], s=25, latlon=True, marker='D', color='g', label='Site Class B Vs30 between 3
m.scatter([0],[0], s=25, latlon=True, marker='D', color='b', label='Site Class C Vs30 between 2
title('Figure 1 :: Strong Motion Station of PESMOS')
legend(scatterpoints=1)

```

```
<matplotlib.legend.Legend at 0x7f6c9b71e790>
```

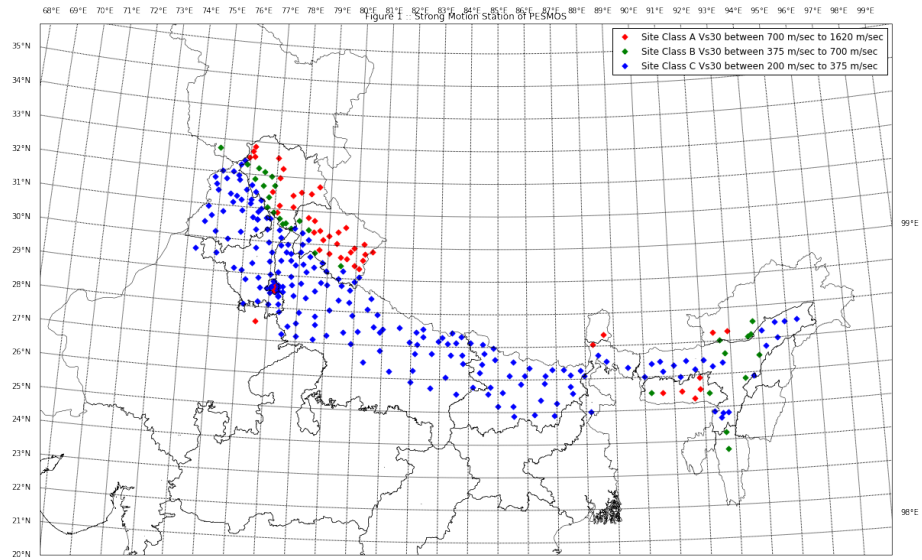


Figure 1: png

Accelarograph Stations

Indian Institute of Technology Roorkee install approximately 293 strong motion accelarograph in and around the Himalayas. The sites where these accelarograph stations located are in various classes of sites. These sites are classified into Class A, Class B and Class C as shown in Figure 1. The accelarograph used was AC-63 GeoSIG triaxial force-balanced accelerometers and GSR-18 GeoSIG 18-bit digitizers with external GPS. The recording for all instruments is in trigger mode at a sampling frequency of 200 sps. The triggering threshold was initially set at 0.005 g for all the instruments. List of accelarograph stations are shown in Table 1. As one can observe from the table, only 135 station have functioned or recorded events out of 293 recording stations.

```
print "Table 1 : List of PESMOS Stations"
```

```
display(pesmos_stations_final_pd[['Station ID','Name','Location','Site Class','Site Geology']])
```

Table 1 : List of PESMOS Stations

```
<tr style="text-align: right;">
  <th></th>
  <th>Station ID</th>
  <th>Name</th>
  <th>Location</th>
  <th>Site Class</th>
  <th>Site Geology</th>
```

<th>Record Available?</th>
</tr>
<tr>
<th>No</th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
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<td>PDELH0004</td>
<td>Dhaula Kuan</td>
<td>Lat: 28.590,Lon: 77.170</td>
<td>C</td>
<td>Alluvium</td>
<td>Yes</td>
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<tr>
<th>2</th>
<td>PDELH0005</td>
<td>Raja Garden</td>
<td>Lat: 28.660,Lon: 77.120</td>
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<td>Alluvium</td>
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<th>3</th>
<td>PDELH0006</td>
<td>Indraprastha University</td>
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<td>Yes</td>
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<td>PDELH0007</td>
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<td>Lat: 28.490,Lon: 77.200</td>
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<td>Alluvium</td>

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<td>PIITR0061</td>	
<td>Paonta Sahib</td>	
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<td>B</td>	
<td>sandstones</td>	
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  <th>13</th>
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<tr>
  <th>14</th>
  <td>PIITR0010</td>
  <td>Rudraprayag</td>
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15	PIITR0011	Tehri	Lat: 30.370, Lon: 78.430	A	phyllites	Yes
16	PIITR0157	Maharaj Ganj	Lat: 27.140, Lon: 83.540	C	Alluvium	No
17	PIITR0156	Lucknow	Lat: 26.850, Lon: 80.930	C	Alluvium	No
18	PIITR0155	Lakhimpur	Lat: 27.950, Lon: 80.790	C	Alluvium	No
19	PIITR0154	KushuNagar	Lat: 26.750, Lon: 83.760	C	Alluvium	No

<th>20</th>	<td>PIITR0153</td>	<td>Kanpur</td>	<td>Lat: 26.480,Lon: 80.350</td>	<td>C</td>	<td>Alluvium</td>	<td>No</td>		
</tr>	<tr>	<th>21</th>	<td>PIITR0152</td>	<td>Kannauj</td>	<td>Lat: 27.030,Lon: 79.920</td>	<td>C</td>	<td>Alluvium</td>	<td>No</td>
</tr>	<tr>	<th>22</th>	<td>PIITR0151</td>	<td>Jaunpur</td>	<td>Lat: 25.730,Lon: 82.690</td>	<td>C</td>	<td>Alluvium</td>	<td>No</td>
</tr>	<tr>	<th>23</th>	<td>PIITR0150</td>	<td>Hathras</td>	<td>Lat: 27.580,Lon: 77.980</td>	<td>C</td>	<td>Alluvium</td>	<td>No</td>
</tr>	<tr>	<th>24</th>	<td>PIITR0221</td>	<td>Purnia</td>	<td>Lat: 25.770,Lon: 87.470</td>	<td>C</td>	<td>Alluvium</td>	<td>No</td>
</tr>	<tr>	<th>25</th>						

	<td>PIITR0220</td>
	<td>Patna</td>
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<tr>	
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	<td>Samastipur</td>
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	<td>Saharsa</td>
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	<td>Saupaul</td>
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	<td>Pathankot</td>
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	<td>Khanna</td>
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<td>Dhar Kalan</td>	
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	<td>Alluvium</td>
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<td>University of Delhi</td>	
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<th>63</th>	<td>PIITR0238</td>	<td>Gangtok</td>	<td>Lat: 27.350,Lon: 88.630</td>	<td>A</td>	<td>gneiss/schist</td>	<td>Yes</td>
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<th>64</th>	<td>PIITR0239</td>	<td>Barpeta</td>	<td>Lat: 26.330,Lon: 91.010</td>	<td>C</td>	<td>Alluvium</td>	<td>Yes</td>
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<th>65</th>	<td>PIITR0232</td>	<td>Raxaul</td>	<td>Lat: 26.980,Lon: 84.840</td>	<td>C</td>	<td>Alluvium</td>	<td>Yes</td>
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<th>69</th>	<td>PIITR0236</td>	<td>Malda</td>	<td>Lat: 25.000,Lon: 88.150</td>	<td>C</td>	<td>Alluvium</td>	<td>Yes</td>
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<th>70</th>	<td>PIITR0237</td>	<td>Siliguri</td>	<td>Lat: 26.710,Lon: 88.430</td>	<td>C</td>	<td>soils (slope washed)</td>	<td>Yes</td>
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</tr>	<tr>	<th>109</th>	<td>PIITR0197</td>	<td>Sambhal</td>	<td>Lat: 28.590,Lon: 78.580</td>	<td>C</td>	<td>Alluvium</td>
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<th>114</th>	<td>PIITR0085</td>	<td>Taran Taran</td>	<td>Lat: 31.450,Lon: 74.930</td>	<td>C</td>	<td>Alluvium</td>	<td>Yes</td>
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		<th>171</th>	
		<td>PIITR0193</td>	
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		<td>Nautanwa</td>	
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		<td>Nakur (Gangoh)</td>	

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	<th>184</th>
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	<td>Firozpur</td>
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	<th>185</th>
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	<th>186</th>
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	<td>Gurdaspur</td>
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	<th>187</th>
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	<th>188</th>
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199	PIITR0276	Yupia	Lat: 27.150, Lon: 93.720	B	sandstones/shale	No
200	PIITR0277	Zero	Lat: 27.540, Lon: 93.810	B	quartzite/schist/gneiss	No
201	PIITR0274	Itanagar	Lat: 27.090, Lon: 93.610	B	sandstones	No
202	PIITR0064	Saluni	Lat: 32.700, Lon: 76.060	A	granitoids	Yes
203	PIITR0272	Bhalukpong	Lat: 27.020, Lon: 92.640	B	sandstones	No

<th>204</th>	<td>PIITR0273</td>	<td>Bomdila</td>	<td>Lat: 27.260,Lon: 92.420</td>	<td>A</td>	<td>gneiss/schist</td>	<td>No</td>
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<th>205</th>	<td>PIITR0270</td>	<td>Aizawl</td>	<td>Lat: 23.720,Lon: 92.730</td>	<td>B</td>	<td>sandstones</td>	<td>No</td>
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<th>206</th>	<td>PIITR0271</td>	<td>Kolasib</td>	<td>Lat: 24.230,Lon: 92.680</td>	<td>B</td>	<td>sandstones</td>	<td>No</td>
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<th>207</th>	<td>PIITR0184</td>	<td>Garh Mukteshwar</td>	<td>Lat: 28.790,Lon: 78.090</td>	<td>C</td>	<td>Alluvium</td>	<td>No</td>
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<th>208</th>	<td>PIITR0185</td>	<td>Gola Gokarnath</td>	<td>Lat: 28.090,Lon: 80.460</td>	<td>C</td>	<td>Alluvium</td>	<td>No</td>
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<th>209</th>						

	<td>PIITR0186</td>
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	<td>Kasauli</td>
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	<td>sandstones/shales</td>
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	<td>Chhata(kosi)</td>
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	<td>Deoband</td>
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	<td>Rupnagar</td>
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	<td>Ridge Observatory, IMD (NDI)</td>
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	<td>Yes</td>
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	<td>Sidharth Nagar</td>
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	<td>Anoop Sahar</td>
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  <td>Baraut</td>
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  <td>Biswan</td>
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  <td>Pithoragarh</td>
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<th>260</th>	<td>IGIPE, Vikas Puri</td>
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<th>261</th>	<td>PDELH0014</td>
<td>Maharaja Agrasen College, Mayur Vihar</td>	
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<th>263</th>	<td>PIITR0255</td>
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<td>Bhim Rao Ambedkar College, Delhi</td>	
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<td>Mangaldai</td>	
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<td>Chandausi</td>	
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	<td>Alluvium</td>		<td>No</td>
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<th>276</th>	<td>PIITR0164</td>	<td>Pratap Garh</td>	<td>Lat: 25.920,Lon: 81.990</td>
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<th>277</th>	<td>PIITR0049</td>	<td>Dadahu</td>	<td>Lat: 30.600,Lon: 77.430</td>
	<td>B</td>	<td>sandstones/shales</td>	<td>No</td>

<th>278</th>	<td>PIITR0168</td>	<td>Saharanpur</td>	<td>Lat: 29.950,Lon: 77.550</td>
	<td>C</td>	<td>Alluvium</td>	<td>No</td>

<th>279</th>	<td>PIITR0169</td>	<td>Shahjahanpur</td>	<td>Lat: 27.890,Lon: 79.920</td>
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<th>280</th>	<td>PIITR0138</td>	<td>Basti</td>	<td>Lat: 26.790,Lon: 82.720</td>
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<th>291</th>	<td>PDELH0018</td>	<td>NPTI, Badarpur</td>	<td>Lat: 28.510,Lon: 77.300</td>	<td>C</td>	<td>Alluvium</td>	<td>Yes</td>
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<th>293</th>	<td>PIITR0165</td>	<td>Pilibhit</td>	<td>Lat: 28.650,Lon: 79.820</td>	<td>C</td>	<td>Alluvium</td>	<td>No</td>
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Seismic Events Recorded

The PESMOS stations located as shown in Figure 1 recorded 253 events. List of events recorded by PESMOS stations and their details are given in Table 2. Out of 253 events only 170 records have magnitudes assigned to it. The 73 events have more than three records.

```

print "Table 2 : Events Recorded by Pesmos Stations"
pesmos_event_pd

```

Table 2 : Events Recorded by Pesmos Stations

```

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<th></th>
<th>Date</th>
<th>Event ID</th>
<th>Event Name</th>
<th>Location</th>

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<th>Magnitude in Accl. File</th>	<th>Recorded Stations</th>	<th>Time Provided in Accl. File</th>
</td>	</td>	</td>
<th>231</th>	<td>2005-12-14</td>	<td>PESMOS0232</td>
<td>20051214-Chamoli</td>	<td>Lat: 30.90,Lon: 79.30</td>	<td>5.2</td>
<td>PIITR0027,PIITR0008,PIITR0004,PIITR0013,PIITR0...</td>	<td>2005-12-14 07:09:48</td>	
</td>	</td>	</td>
<th>219</th>	<td>2006-03-31</td>	<td>PESMOS0220</td>
<td>20060331-Jhajjar</td>	<td>Lat: 28.70,Lon: 76.80</td>	<td>3.4</td>
<td>PIITR0115</td>	<td>2006-03-31 11:25:39</td>	
</td>	</td>	</td>
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<td>20060507-Jhajjar</td>	<td>Lat: 28.70,Lon: 76.60</td>	<td>4.1</td>
<td>PIITR0115</td>	<td>2006-05-07 16:01:00</td>	
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<td>20061129-Alwar Earthquake</td>	<td>Lat: 27.60,Lon: 76.70</td>	<td>3.9</td>
<td>PIITR0124</td>	<td>2006-11-29 05:41:14</td>	
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<th>105</th>	<td>2006-12-10</td>	<td>PESMOS0106</td>	<td>20061210-Mandi Earthquake</td>	<td>Lat: 31.50,Lon: 76.70</td>	<td>3.5</td>	<td>PIITR0042</td>	<td>2006-12-10 08:19:29</td>
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<th>85</th>	<td>2007-06-09</td>	<td>PESMOS0086</td>	<td>20070609-Bhagwanpur Earthquake</td>	<td>Lat: 0.00,Lon: 0.00</td>	<td>0.0</td>	<td>PIITR0027</td>	<td>None</td>
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<th>33</th>	<td>2007-06-22</td>	<td>PESMOS0034</td>	<td>20070622-Andaman</td>	<td>Lat: 0.00,Lon: 0.00</td>	<td>0.0</td>	<td>PIITR0129</td>	<td>None</td>
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<th>162</th>	<td>2007-07-22</td>	<td>PESMOS0163</td>	<td>20070722-Uttarkashi</td>	<td>Lat: 31.20,Lon: 78.20</td>	<td>5.0</td>	<td>PIITR0027,PIITR0056</td>	<td>2007-07-22 23:02:12</td>
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<th>244</th>	<td>2007-09-14</td>	<td>PESMOS0245</td>	<td>20070914-Chamba</td>	<td>Lat: 0.00,Lon: 0.00</td>	<td>0.0</td>		
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<td>2014-04-01 17:45:09</td>	

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<td>20140530-khokhrajhar</td>	
<td>Lat: 26.50,Lon: 90.40</td>	
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<td>2014-05-30 06:37:50</td>	

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<td>PESMOS0067</td>	
<td>20140617-Kangra</td>	
<td>Lat: 32.20,Lon: 76.10</td>	
<td>4.1</td>	
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<td>2014-06-17 17:31:08</td>	

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	<td>PESMOS0246</td>
	<td>20140821-Distt. Kangra</td>
	<td>Lat: 32.30,Lon: 76.50</td>
	<td>5.0</td>
	<td>PIITR0037,PIITR0038</td>
	<td>2014-08-21 08:11:17</td>
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	<th>150</th>
	<td>2014-09-12</td>
	<td>PESMOS0151</td>
	<td>20140912-Goalpara</td>
	<td>Lat: 26.10,Lon: 90.20</td>
	<td>4.2</td>
	<td>PIITR0239</td>
	<td>2014-09-12 07:56:44</td>
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	<th>221</th>
	<td>2015-11-29</td>
	<td>PESMOS0222</td>
	<td>Chamoli_29112015</td>
	<td>Lat: 30.60,Lon: 79.60</td>
	<td>4.0</td>
	<td>PIITR0022,PIITR0010,PIITR0003,PIITR0019</td>
	<td>2015-11-29 02:47:38</td>
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	<th>217</th>
	<td>2016-09-25</td>
	<td>PESMOS0218</td>
	<td>rudp_25sept2016</td>
	<td>Lat: 30.50,Lon: 78.90</td>
	<td>3.7</td>
	<td>PIITR0020,PIITR0008,PIITR0019,PIITR0013,PIITR0...</td>
	<td>2016-09-25 21:41:36</td>
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	<td>2016-11-23</td>
	<td>PESMOS0177</td>
	<td>Dehradun_23112016</td>
	<td>Lat: 30.30,Lon: 78.00</td>
	<td>3.4</td>
	<td>PIITR0016,PIITR0011,PIITR0062,PIITR0010,PIITR0013</td>
	<td>2016-11-23 02:31:03</td>

```

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  <th>113</th>
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  <td>PESMOS0114</td>
  <td>Nepal_01122016</td>
  <td>Lat: 29.80,Lon: 80.60</td>
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  <td>Uttarkashi_13122016</td>
  <td>Lat: 30.30,Lon: 79.40</td>
  <td>3.2</td>
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  <td>PESMOS0215</td>
  <td>Dehradun_13122016</td>
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  <td>3.9</td>
  <td>PIITR0016,PIITR0014,PIITR0013,PIITR0010,PIITR0...</td>
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  <td>2016-12-19</td>
  <td>PESMOS0048</td>
  <td>Uttarkashi_19122016</td>
  <td>Lat: 30.90,Lon: 78.00</td>
  <td>3.4</td>
  <td>PIITR0014,PIITR0260,PIITR0003,PIITR0013</td>
  <td>2016-12-19 04:31:56</td>
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  <th>186</th>
  <td>2016-12-26</td>
  <td>PESMOS0187</td>
  <td>Dehradun_26122016</td>

```

```

<td>Lat: 30.80,Lon: 77.90</td>
<td>3.5</td>
<td>PIITR0014,PIITR0013</td>
<td>2016-12-26 08:45:48</td>
</tr>

```

Parsing PESMOS Records

The pesmos datas are freely available through website for download. Although it is required for the users to obtain a log in credention for downloading data. The log in credential could be obtained through registration. After registration web admistator will review your application and will send confirmation mail upon successful approval of registration. After log in to wesite, the users are required to go to Downloads tab for downloading data. The data are available in two section. First section, “View/Download Ground Motion Reconds” provides events from 2005 to 2014. Second section, “View/Download Earthquake Early Warning System Data (EEWS)” provides events from 2015 to 2017. For each event “.zip” file is available containing station records. For each station three direction data, NS, EW and Z-directional are available. A typical format of accelaration record file is shown below

```

Origin Time      31/03/2006 11:25:39
Lat.             28.7 N
Long.            76.8 E
Depth (Km)       22.0
Magnitude        3.4
Region           JHAJJAR-HARYANA
Above details taken from IMD

```

```

Station Code     ROH
Station Lat.     28.896 N
Station Long.    76.593 E
Station Height(m) 225.0
Site Class       C Vs30 between 200 m/sec to 375 m/sec *
Record Time      31.03.2006 11:25:26.529
Sampling Rate    200. Hz
Record Duration  29.995 Sec.
Direction        E-W (E positive)
Max. Acceleration 4.799 cm/sec**2

```

* For reference see Site Classification link of website

Base Line Corrected and Low Pass Filtered (Cut Off at 35 Hz) Time History
Acceleration data in cm/sec**2

```

0.228
0.017
-0.067
-0.050
-0.004
0.018
0.008
.
.
.

```

These files are parsed using a python script.

“python” Program by Anis Mohammed Vengasseri anis.mhd@gmail.com
<https://github.com/anismhd>

Started Date :: 20/01/2017

```

fname - Should be the file name without '.ns', '.ew' or '.vt' extension

if '.' in fname:
    print "fname - Should be the file name without '.ns', '.ew' or
'vt' extension" return None
NS = fname + ".ns"
EW = fname + ".ew"
VT = fname + ".vt"
f_NS = open(NS).readlines()
f_EW = open(EW).readlines()
f_VT = open(VT).readlines()
""" from datetime import datetime import numpy
as np import pandas as pd import re

def geodetic_string_processor(lat_str, lon_str):
    if ('N' in lat_str) or ('n' in lat_str):
        lat = float(lat_str[:-2].strip())
    elif ('S' in lat_str) or ('s' in lat_str):
        lat = -1.0*float(lat_str[:-2].strip())
    else:
        lat = float(lat_str.strip())
    if ('E' in lon_str) or ('e' in lon_str):
        lon = float(lon_str[:-2].strip())
    elif ('W' in lon_str) or ('w' in lon_str):
        lon = -1.0*float(lon_str[:-2].strip())
    else:
        lon = float(lon_str.strip())
    return lat, lon

def time_stripper(time_str):
    if int(re.split('[-|/|:]',time_str)[0]) == 0:
        return None
    else:
        if 'UTC' in time_str:
            date, time, utc = time_str.split()
        else:
            date, time = time_str.split()
        day, month, year = re.split('[-|/|:]',date)
        hour, minute, second = re.split('[-|/|:]',time)
        microsecond = (float(second)-np.floor(float(second)))*10**6
        second = int(np.floor(float(second)))
        return datetime(int(year),int(month),int(day),int(hour), int(minute), int(second),int(microsecond))

def pesmos_reader(fname):
    data = open(fname).readlines()
    event = {}
    event['Origin Time'] = time_stripper(data[0].strip('Origin Time').strip())
    # event['Latitude'] = data[1].strip('Lat.').strip()
    # event['Longitude'] = data[2].strip('Long.').strip()
    lat_str = data[1].strip('Lat.').strip()
    lon_str = data[2].strip('Long.').strip()
    event['Latitude'], event['Longitude'] = geode-

```

```

tic_string_processor(lat_str, lon_str) event['Depth'] = data[3].strip('Depth
(Km)').strip() event['Magnitude'] = data[4].strip('Magnitude').strip()
event['Region'] = data[5].strip('Region').strip() event['Source of Event
Data'] = data[6].strip() station = {} station['Code'] = data[8].strip('Station
Code').strip() lat_str = data[9].strip('Station Lat.').strip() lon_str =
data[10].strip('Station Long.').strip() station['Latitude'],station['Longitude']
= geodetic_string_processor(lat_str, lon_str) # station['Height'] =
float(data[11].strip('Station Height(m)').strip()) station['Site class'] =
data[12].strip('Site Class').strip() station['Record time'] = time_stripper(data[13].strip('Record
Time').strip()) station['Sampling rate'] = float(data[14].strip('Sampling
Rate').strip()[:-2]) station['Record_duration'] = float(data[15].strip('Record
Duration').strip()[:-4]) station['Data direction'] = data[16].strip('Direction').strip()
station['Data PGA'] = data[17].strip('Max. Acceleration').strip() station['Data
filtering info'] = data[21].strip() station['Data unit'] = data[22].strip('Acceleration
data in').strip() station['Data number'] = int(station['Sampling rate']*station['Record_duration'])
station['Data series'] = np.zeros(station['Data number']) for i in range(station['Data
number']): station['Data series'][i] = float(data[24+i].strip()) return event,
station ""

```

The events recorded by PESMOS station have few issues with respect to derived values. Especially magnitude and location of event. In this section, magnitude and locations reported by PESMOS are cross verified with respect to data from USGS.

Methodology

The pes

The events reported in USGS for the region of India after 2000 are downloaded using python scripts. The data downloaded from USGS siite are parsed to obtain information on location, magnitude, magnitude scale, date and time of event etc. The parsed information are stored into a python pandas dataframe. Then,